STUDIES ON THE BIOLOGY AND CULTURE OF *Pleuroxus similis* (CLADOCERA, CHYDORIDAE)

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ABSTRACT

THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF THE DEGREE OF

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ABSTRACT

Cladocerans represent a group of mostly small microscopic animals comprising an Order under the sub-class Branchiopoda Crustacea. These microcrustaceans constitute an important fraction of any aquatic biota as these organisms serve as an important link in aquatic food chain by means of energy transfer from one trophic level to another.

The cladocerans are well known as important fish food organisms and they form about 95% of the diet of both young and adult fishes.

Studies on cladocerans started as early as 1883 when Forbes pointed out their importance in the aquatic food chain. Following this a number of investigations were done in the subsequent years. However, most of the work done was on the Genus *Daphnia* (Daphnidae) in comparison to which the Family Chydoridae is much less worked upon, except those by Smirnov 1962-1967; Fryer 1968; Whiteside 1970, 1974; Goulden 1971; Keen 1973; Shan 1975; Frey 1973-1900.

In India, studies on chydorids has been fragmentary even till to-date except for a few occasional papers by Quadri and Yousuf 1977, and Murugan 1982 from western Himalayas and Northern India. There is no detailed work on the chydorids done in the North Eastern regions of India

Shillong (latitude 25°34'N longitude 91°36'E) a small town of North East India is situated on a plateau at an altitude of 1600m above sea level. Further, its location being within 50km from Cherrapunji and Mawsynram - the highest rainfall areas of the world - has a luxurient vegetation

with humid climate which allows an interesting scope for ecobiological studies. The present work is therefore an attempt to investigate in as much detail as possible the biology of the available cladoceran species in Shillong area with more emphasis being given to relate the field information to laboratory findings in order to obtain a more comprehensive understanding of the basic life history patterns of cladocerans with special reference to the chydorid sp. *Pleuroxus similis*.

The present study comprises the following parts viz.,

a) Work out the taxonomy of *Pleuroxus similis* and compare it with the description given by different authors elsewhere in the world thereby bringing out their taxonomic relationships and in terms of their zoogeographic distribution.

b) Study the biology of *Pleuroxus similis* under different laboratory conditions.

c) Construct a seasonal distribution map of *Pleuroxus similis* in the system studied.

d) Study certain culture aspects of *Pleuroxus similis* in different nutrient media under laboratory conditions.

e) Report a preliminary investigation on the karyotype of *Pleuroxus similis*.

In part 'a', the taxonomy of *Pleuroxus similis* was worked out and the description was compared with the original description given by Vavra for the species in 1900 from Valdivia in South America and also with the description given by other authors like Sars 1901 from Argentina, Smirnov, 1971 from USSR - Northern Caucasus, Lake Issykkul, Tashkent Area, Smirnov and Timms, 1983 from nothern New South Wales in Australia. This also gave some indications about the world wide distributional pattern of the species *Pleuroxus similis* that was not hitherto known clearly. Ephippial females and males of this species were reported for the first time during the present study and in this context the gamogenetic strategy of *Pleuroxus similis* was compared with those of other chydorids of Europe and America.

In part 'b' the life cycle patterns of *Pleuroxus similis* reared individually was studied under laboratory conditions using three different culture media viz; chicken manure, rice bran and filtered pond water used as control. Studies were made on life span, instar duration egg production and growth rates for both parthenogenetic females and males, and the resultsare compared and discussed with those of other chydorid species studied by other authors. The life history strategy adopted by *Pleuroxus similis* with regard to other littoral and planktonic cladoceran species are also discussed.

In part 'c' the seasonal distributional pattern and population dynamics of *Pleuroxus similis* was studied in Ward's lake an artificial impoundment in the centre of Shillong town. Studies were made at fortnightly intervals for a total priod of 25 months. The percentage composition of the various categories of *Pleuroxus similis* viz; juveniles, adult with egg, adult without eggs, ephippial females and males, were worked out and was divided into different size classes. The occurrence of peak population density during spring and autumn were discussed in the light of occurrence of gamogenetic females in the population and the distributional pattern was compared with those of other chydorid species from Europe and America. A few of the major physicochemical parameters vegetational association, as well as biological properties including different groups of phytoplankton zooplankton and associated organisms have also been studied for the entire period of 25 months and their effect on the population density of *Pleuroxus similis* has been discussed. The population dynamics viz; mortality, natality, finite birth rate and coefficient of population growth were worked out and their effect on the population density of *Pleuroxus similis* has been discussed.

Part 'd' deals with studies on laboratory cultures of *Pleuroxus similis* For this part, studies were done on three aspects:

The first aspect includes the studies on life history parameters of *Pleuroxus similis* reared in different culture media viz; chicken manure, rice bran and filtered pond water, with three different inoculum densities of 3, 5 and 8 animals. The different life history parameters studied were the first reproduction time(A), total longevity (w), reproductive life span of the animal, net reproductive rate (R_0) total offspring production(S) and an average generation time (T_c). The survivorship curves and survivorship fecundity data for the three different media and three different inoculum densities were also worked out. The total population density under the above conditions were also estimated. The results obtained in the three culture media were compared and the most conducive culture medium for the culture of *Pleuroxus similis* was determined and is recommended for future experiments.

The second aspect deals with the effect of inoculum density on different population parameters in *Pleuroxus similis* using chicken manure as the culture medium. The population parameters studied were growth, survival, fecundity and population density under varied inoculum densities of 3,5 and 8 and 12 animals and the results obtained were compared and discussed with reference to availability of container space and food.

The third aspect deals with the population growth of *Pleuroxus similis* as a direct function of available space. For this study flasks of varied capacities of 15cm^3, 30cm^3, 60cm^3, 100cm^3, 250cm^3 and 500cm^3 were used and the mean population size of *Pleuroxus similis* were observed in each flask. It was noticed that the population density in general tended to rise with increasing flask capacities the maximum being in the flask capacity of 500cm^3. However, under space condition of 1.5cm^3/individual, there was no progeny production or in other words a minimum space of 3cm^3/ individual (flask capacity of 30cm^3) was required for growth and survival of *Pleuroxus similis*. This result was compared and discussed with those for other cladoceran species cultured under laboratory conditions.

Part 'e' deals with the karyological changes during the different phases of life history of *Pleuroxus similis*. Cladocerans are well known for their difficulties in karyological studies. In this study a preliminary report on the karyotype was obtained, and the chromosome number in parthenogenetic females of *Pleuroxus similis* were determined, and the result compared with those of *Daphnia* sp.

Finally, the various results obtained from the field population and the laboratory data are discussed together in detail and some fundamental knowledge regarding the biology and culture aspects of the animal *Pleuroxus similis* is presented.

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I certify that the Thesis entitled "**Studies on the Biology and Culture of Pleuroxus similis (Cladocera, Chydoridae)**" submitted by Miss Devjani Ghosh for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by her under my supervision. She has been duly registered and the Thesis presented is worthy of being considered for the award of Ph.D. Degree. This work has not been submitted for any degree of any other University.

Dated, Shillong
The 18th of December, 1990

R George Michael
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Forwarded

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The 18th December 1990

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INTRODUCTION

Limnology is the study which deals with various aspects of the structure and function of freshwater environments. The human race at the moment is confronted with the greatest crisis of finding adequate water resources for its multifarious use. While this may be a recent exigency of mankind, limnologists are concerned with the basic understanding of how plants and animals carry out their various life functions in relation to their environment. Waste products released in water are decomposed and degraded by bacteria to simple chemical compounds. These products from the main nutritional source for the phytoplankton which in turn form the food of the zooplankton. Thus, the phytoplankton are considered as the "producers", while the zooplankton are termed the "consumers". This basic knowledge may be of ultimate value, not only to understand the structural and functional dynamics underlying aquatic ecosystems, but also be of applied value in aquaculture programmes.

Most of the investigations today take into account the above view points depending upon the particular need of a region, state, or even a country. As such, a vast amount of limnological literature had accumulated over the years in different parts of the world (Smith 1924; Welch 1948, 1952; Pennak 1953; Edmondson 1959; Hynes 1960; Hutchinson 1957, 1967). Even in the Indian context several such general studies have been conducted on the ponds, lakes and streams, though most of them deal with freshwater biotopes of the plains of India (Arora 1931; Pruthi 1933; Sewell 1935; Ganapati 1941, 143, 1955, 1960; Das and Srivastava 1956, 1959; Singh 1960; Prasad 1961; Michael 1962, 1968, 1969, 1980; Hussainy 1967; Munawar 1970; Navaneethakrishnan and Michael 1971; Jana and Sarkar 1971; Jana 1973;

Nassar and Munshi 1974, 1975; Ragunathan and Srinivasan 1983; Sharma and Pant 1987; Bhati et al 1987). Comparable studies on Indian altitudinal lakes, ponds and streams are relatively few (Vasisht 1968; Sreenivasan 1968; Das et al 1969, 1970; Mathew 1977; Sharma and Pant 1981, 1985; Yousuf and Qadri 1981, 1983, 1984; Singh et al 1986; Prabhu et al 1987; Ramanibai et al 1987; Sharma 1987; Changoiwala et al 1987 and Ravichandran and Ramanibai 1988). Among these works, investigations on the cold water systems of Eastern Himalayan ranges are relatively lacking. It is all the more important because of the strategic location of these mountain ranges as a 'corridor' for faunal incursion as envisaged in the Satpura Hypothesis (Hora 1951). While this theory was primarily concerned with fish distribution, studies on other aquatic fauna may equally be of interest from a zoogeographic view point.

Though there are some natural lakes in the North Eastern Region, their number is very few. There are however a number of man-made artificial impoundments such as reservoirs primarily managed by the Government or private agencies for purpose of irrigation or fish culture. A detailed study of systems with special reference to their biota will be of great interest both from academic and applied points of view. It is for this purpose that the present investigations have been undertaken on such systems with special reference to cladocerans which are known to be one of the dominant groups of zooplanktonic communities.

Cladocerans represent a primitive group of microcrustacea. They are a group of small, mostly microscopic animals comprising an Order under the sub-class Branchiopoda of lower crustacea and are commonly termed as "waterfleas".

They are almost exclusively inhabitants of freshwaters except for the three marine genera *Podon*, *Evadne* and *Penilia*. They are mostly filter feeders, though there are some of predatory habit. These micro-crustaceans constitute an important fraction of any aquatic biota and thus studies on them have been given much importance. It is seen that these organisms serve as an important link in the aquatic food chain (Welch 1951; Alikunhi 1952; Pennak 1953; Michael 1963). Along with Copepoda they constitute the chief agency for converting the small algae of freshwaters into a form available to the carnivorous aquatic animals (Birge 1945).

As cladocerans are well known to form the food of fishes, both adult and fry, proper understanding of their basic life cycle parameters are of primary importance. Many workers have made a comparative study of field and laboratory life histories of cladocera (Green 1956; Bhajan and Hynes 1972; Bottrell 1975; Vijverberg 1976). In India too, studies in this direction were initiated in the early sixties (Michael 1962) followed by several studies elsewhere in the subsequent years.

Investigations on bioenergetic and trophic aspects of energy transfer through cladocerans as primary consumers have also gained importance (Kersting and Leeuw 1976; Goulden et al 1982; Chow Fraser et al 1985; Kndechel and Blair 1986; Sarnelle 1986; Hensen 1989; Mourelatos et al 1989). Prey-predator relationship and associated morphological changes in Cladocera has been another aspect, which is gaining importance (Hrbacek, 1959; Zaret and Kerfoot 1975; Lynch 1980; Haney 1985; Taylor and Gerking 1985; Gophen 1985; Irvine et al 1989).

Nutrient enrichment in aquatic ecosystems, through cladocerans is yet another aspect that is receiving much attention in recent years (Porter 1976; Levins 1977; Goulden et al 1982; Chow Fraser 1986; Elstad 1986).

For many years, even upto the recent time the cladoceran genus *Daphnia*, attracted scientists as an ideal laboratory organism for the understanding of different biological problems (Banta 1914; Anderson 1932; Richman 1958; Korinek 1970; Meijering 1975; Kring and O'Brien 1976; Lampert 1977; Hebert 1978; Dodson 1981; Venkataraman 1981; Tessier and Goulden 1982; Demott 1983; Murugan 1983; Okamato 1984; Infante and Litt 1985; Geoffrey 1985; Sarviro 1985; Korpelainen 1986; Bengtsson 1986, Olsen et al 1986; Foran 1986; Barker 1986; Schwartz et al 1985; Hebert et al 1987; Stevens et al 1987; Crosetti and Margaritora 1987; Gabriel et al 1987; Stevens et al 1987; Sharma and Pant 1987; Khan et al 1987; Bernardi 1987; Peters 1987; Hrbáček 1987; Haney 1987; Fernando 1987; Lampert 1987; Zaffagnini 1987; Threlkeld 1987; Stross 1987; Hebert 1987; Bohrer and Lampert 1988; Ward and Geissler 1988; Scholtz et al 1988; Hovenkamp 1989; Ketola and Vuorinen 1989).

As compared to other cladoceran families, the family Chydoridae is much least worked upon (Smirnov 1962, 1964, 1966, 1967; Fryer 1968; Shan 1969; Whiteside 1970, 1974; Goulden 1971; Keen 1973; Shan 1975; Whiteside et al 1978; Frey 1982; Williams 1982, 1983; Robertson 1988). In India very few investigations have been done in chydorids (Qadri and Yousuf 1977, 1981; Murugan and Job 1982; Rane 1984).

Thus keeping the above lacunae in mind and also the fact that these cladocerans are consumed by both young and adult fishes, the present investigations were taken up:

(a) To work out the taxonomy of *Pleuroxus similis* and compare it with the description given by different authors elsewhere in the world, thereby bringing out their relationships in terms of zoogeographic distribution.

(b) To study the biology of *Pleuroxus similis* under laboratory conditions.

(c) To construct a seasonal distribution map of *Pleuroxus similis* in the lake.

(d) To study certain culture aspects of *Pleuroxus similis* in different nutrient media under laboratory conditions.

(e) To report a preliminary investigation on the karyotype of *Pleuroxus similis*.

Since this study is the first of its kind from this region, it is hoped that the results obtained will not only contribute to the ecobiological understanding of these microcrustaceans, but also be of use in the pisciculture practices of these hill areas.

REVIEW OF LITERATURE

A review of earlier literature on cladoceran research shows that the information regarding the various aspects on the biology, ecology, taxonomy and distribution of different cladoceran species dates back to over one and a half century. It was Forbes (1883) who first emphasised the importance of cladocera in the aquatic food chain.

A number of works have been done on the taxonomy and distribution of cladocera (Birge 1891, 1893, 1897, 1918) contributed a great deal to the North American cladoceran fauna. Sars (1898) documented the faunistic records of Cladocera, Copepoda and Ostracoda from New Siberian Island.

Gurney (1927) reported cladoceran species from the dried mud after culturing in the laboratory. Ueno (1932-33) documented twenty two and eighteen cladoceran species from China and Japan respectively. A key for the species of Cladocera was presented by Johnson (1952) while dealing with the British fauna. Harding (1957) described two *Alona* species. A review of the two cladoceran genera, *Latonopsis* and *pseudosida* has been given by Thomas (1961). Green (1962) investigated cladoceran fauna of the river Sokoto, Uganda and reported fifty species and described the new species *Alona holdeni*. Goulden and Frey (1963) pointed out the significance of lateral head pores in *Bosmina*. Korde (1965) recorded eighteen species and three taxonomic forms of cladocera from the microbenthos samples of Volga river. Ueno (1966) contributed to the cladoceran fauna of Nepal and the surrounding Himalayan foothills. Dickinson (1967) identified cladoceran species from fossil remains from Nevada, USA. Frey (1967) emphasised the importance of cladoceran fossil remains for the understanding of their evolution. De Costa (1968) reported species diversity of chydorid cladoceran community from fortyfive lakes in the Mississippi valley in the USA. Korinek (1971) made a comparative study of head pores in the genus *Bosmina*. Hebert (1974) while dealing with *Daphnia*, showed that *Daphnia magna* consisted of a limited number of ecologically differentiated clones. Ferrara (1975) made observations on the taxonomy and distribution of *Daphina* species from Sardina. Kubersky (1978) discussed the worldwide distribution of *Alonopsis* and described a new species. Dodson (1981) studied the morphological variation of *Daphnia pulex* and related species from North America. Berner (1985) studied the morphological differentiation among species in the *Ceriodaphnia cornuta* complex. Schwartz et al (1985) studied the morphological separation of *Daphnia pulex* and *Daphnia obtusa* in North America. Hebert et al (1986) studied the systematics of *Daphnia pulex* complex and described a new species from North America. Kokkinn et al (1987) described ephippial morphology as a useful taxonomic descriptor in the Cladocera. Hebert (1987) studied the genotypic characteristics of cladocerans. Berner (1987) pointed out the significance of head and carapace pores in *Ceriodaphnia*. Frey (1988) differentiated *Alona weinecki* from *Alona rectangula* from a sub-antarctic island.

Some of the studies on the life-cycle parameters of different cladoceran species have been referred here. Brown (1926) studied the influence of temperature on duration of instars and pointed out the occurrence and developmental rate in nature and also later suggested a mathematical model (Brown 1927). Anderson (1932) reported more than five preadult instars in *Daphnia magna*. He also pointed out the relative growth and variation in this species. Buikema (1968) showed that longer wavelengths of light increased survival of the youngs of *Daphnia pulex*. Korinek (1970) studied the embryonic and postembryonic development in *Daphnia* in relation to food and temperature. Lei and Clifford (1974) studied the detailed biology of both male and female of *Daphnia schodleri.* Bottrell (1975) studied the life cycle parameters of eight cladoceran species. Steele and Steele (1975) observed that postembryonic development of cladocera to be inversely proportional to egg size. Munro and White (1975) discussed egg development and growth of *Daphnia longispina* in the light of temperature, history of animals, habitat and genetic differences. Kerfoot (1975) studied the egg-size cycle of *Bosmina longirostris.* Zhdanova (1976) studied the effect of algal food on the growth, fertility and life span of *Bosmina longirostris.* Lynch (1980) studied the evolution of cladoceran life histories. Sarviro (1985) investigated the role of temperature on development and specific growth rate of sexually immature females of *Daphnia longispina.* Korpelainen (1986) studied the intraspecific variation in life span and fecundity under controlled conditions in *Daphnia magna.* She also studied the effects of temperature and photoperiod on life history parameters of *Daphnia magna.* Scholtz et al (1988) studied the effects of turbidity on the life history parameters of *Daphnia pulex* and *Daphnia barbata.* Ketola and Vuorinen (1989) studied the effect of the presence of midge larvae (*Chaoborus* sp.) on the life history parameter of *Daphnia pulex* and *Daphnia magna.*

The problem of food and feeding and its impact on cladoceran life cycles have been studied by several workers. Wood and Banta (1933) pointed out the importance of food in the formation of ephippium in cladocerans. Parker (1961) reported the ability of *Daphnia* to utilize inorganic phosphorus from cell free medium while Marshall (1962) demonstrated the effect of gamma radiation on feeding and growth of *Daphnia*. McMohan and Rigler (1965) demonstrated that feeding rate in *Daphnia magna* is proportional to the concentration of food upto a critical level, after which there is no change in the rate. Ivanova (1966) calculated filtration rates in relation to body weight. Lavina (1966) reported that cladocerans consume more food than necessary for their metabolism which also increases proportionately with food concentration. Smyly (1967) pointed out the suitability of *Scenedesmus* to *Chlamydomonas* as food for *Simocephalus*. Burns (1968) established relationship between size of food particles and carapace length in cladocera to predict preference of particle size by different species. Weglenska (1971) pointed out the limiting significance of food in cladoceran life cycle. Kibby (1971) observed that *Daphnia rosea* showed different filtering rates when reared in varied temperature. Tezuka (1972) calculated the feeding rate of *Daphnia* on planktonic bacteria. Chirkova and Romanenko (1973) studied the consumption of organic matter of mud by *Ilyocryptus sordidus*. Semenova (1974) while marking out the food composition of *Bosmina coregoni* also reported that 18°-20°C was the best temperature for its growth. Lampert (1975) while determining the food selection of *Daphina pulex* found that only small *Daphnia* (L=1.5mm) filtered bacteria, while the larger animals ingested bacteria and algae without differentiation. Vijverberg (1976) observed that low concentration of food affected the life cycle of *Daphnia hyalina*. Lampert (1977) studied the carbon balance of *Daphnia pulex* as related to environmental conditions, using labelled Carbon for the measurement of Carbon assimilation. Lampert (1978) reported that fecundity in *Daphnia* is dependent on particular level of food concentration. Redfield (1980) observed that *Daphnia* is able to respond to improved food supply which increased the number of eggs/brood. De Bernardi et al (1980) reported better growth of *Daphnia* species when fed on *Microcystis* in comparison to *Scenedesmus*. Tessier et al (1982) estimated food limitation in cladoceran populations in terms of energy stored for reproduction as triglyceride droplets. Sadchikov (1983) showed that the cladocera of mesotrophic lake feed on phytoplankton and bacterioplankton. Okamoto (1984) demonstrated the size selective feeding of *Daphnia longispina hyalina* on a natural phytoplankton assemblage with the fractionising method. Infante et al (1985) indicated the difference between two species of *Daphnia* in the use of ten species of algae in Lake Washington. Haney (1985)**showed** the relationship of body length and filtering rate of some *Daphnia* species. Chow et al (1985) mentioned the factors regulating *in situ* filtering rates of cladocera. Sarnelle (1986) assessed the quality of phytoplanktonic food available in the field to *Daphnia* and *Bosmina*. Kudechel et al (1986) constructed a body-length based model for the prediction of cladoceran community filtering rates. Chow (1986) found out the effect of collection and acclimation period on grazing rate of *Daphnia* species. Horn (1986) investigated the food selectivity of *Daphnia hyalina*. Olsen et al (1986) showed the nature of the Carbon compounds released by *Daphnia*. Bohrer and Lampert (1988) studied the effect of food concentration assimilation and respiration of *Daphnia magna* Straus. Hensen (1989) studied the various factors determining the nutritional status and production of *Daphnia* in a humic lake. Mourelatos (1989) studied the diel pattern of *in situ* species-specific zooplankton clearence rate in a shallow pond. Schoenberg (1989) studied the effect of algal concentration.bacterial size and water chemistry on the ingestion of natural bacteria by cladocerns. Ahlgren et al (1990) studied the lipid composition and food quality of some freshwater phytoplankton for cladocerans.

Culturing of cladoceran species had been tried by many workers in the early part of the twentieth century. The first record being that of

Banta (1921) who improvised a culture medium for the cladocera which is still in use. Luginome and Baba (1963) improvised a standard culture medium and suggested the importance of the influence of food, temperature and population density for maximum yield in mass culture. The use of dry mud as culture medium for culturing *Daphnia* was first reported by Quoilin (1965). d'Agostino and Provasoli (1970) suggested a vitamin rich mineral medium for the culturing of cladocera. Provasoli et al (1970) further emphasized the importance of vitamins and fats for the restoration of fertility in *Daphnia*. Masters (1970) suggested a method of producing a large number of *Daphnia*. Arnold (1971) advocated the suitability of green algae over blue-greens for cladoceran culture due to the toxic effect of the latter. Metteilung (1975) cultured cladocerans with modified techniques and studied the effect of food and temperature. A culture method for *Chydorus* and *Bosmina* was suggested by Martin and Novotny (1975). Laurprel (1975) suggested a system for the cultivation of *Daphnia* under controlled conditions. Heisig (1979) cultured *Daphnia pulex* in ponds and indicated the effect of fertilization, aeration and harvest on the population development of the species. De. Pauw et al (1981) cultivated *Daphnia magna* on rice bran. Vijverberg (1989) suggested the culture techniques for studies on the growth development and reproduction of cladocerans under laboratory and *in situ* condition.

Sex and reproduction in Cladocera has been studied with enough emphasis since long time when Banta (1914) reported sex to be regulated by environmental factors which was reemphasised by Hebert and Ward (1972). Banta and Ward (1928) furnished genetic evidence of *Daphnia* malebeing diploid. Klugh (1927) was able to induce gamogenesis in several species of cladocerans by increasing the electrolyte content of the medium. Banta and Brown (1929-1930) Brown and Banta (1932), Banta (1937) and Banta and Wood (1938) performed a series of experiments in laboratory cultures and suggested sex in cladocera to be controlled by factors like crowding of females, excretory metabolites, critical light period, rate of material development, drugs, temperature, population density and maternal influence. Mortimer (1935) while working on *Daphnia magna* concluded that both somatic and spermatogonial cells showed 20 chromosomes, while the parthonogenetic eggs contained n=10. Banta and Wood (1939) studied the physiology, genetics and evolution of some cladocera. Hoshi (1951) presented a cytological report of the development and maturation of the parthenogenetic and sexual eggs of *Daphnia pulex*. Stross (1965) induced sexual reproduction in *Daphnia pulex* and was able to germinate sexual eggs through the regulation of temperature and photoperiod. Shan (1968) induced interbreeding between two stocks of a chydorid cladoceran. Davidson (1969) activated ephippia of *Daphnia* by regulating wavelengths and pointed out the need of dark reactions before light treatment. Shan (1970) could enhance the time for hatching of resting eggs by proper control of photoperiod. Makrushin (1970-71) reported the presence of protoephippial glands in the brood pouch of cladocera. Shan (1974) advocated the significance of photoperiod and light intensity in the regulation of male production in cladocera. Young (1978) reported about the sexual swarms in *Daphnia magna*, which is a cyclic parthenogen. Frey (1982) studied the contrasting strategies of gamogenesis in Northern and Southern populations of cladocerans. Sprules et al (1984) studied the phenotypic associations in *Bosminidae*. Barker et al(1986) studied the secondary sex ratio of the cyclic parthenogen *Daphnia magna* in the Canadian Arctic. Stevens et al (1987) investigated the conditions required to initiate the development of resting eggs of thirty six clones of *Daphnia*. Zaffagnini (1987) studied reproduction in *Daphnia* in detail. Ward and Geissler (1988) studied the reproductive mode in a population of *Daphnia pulex* and *Daphnia magna*.

Quite a number of studies have been done on the population parameters of various cladoceran species, some of which are mentioned here. Johnson (1956) detailed out the cladoceran population of Lake Toba from Sumatra. Parker (1960-61) observed that the daphnid species *Simocephalus exspinosus* seemed to obstruct feeding of *Cyclops*. Hall (1964) investigated the dynamics of natural population of *Daphnia galeata mendotae* and analysed frequency of moulting, duration of egg development, growth rate and life span. Elbourn (1966) reported two peaks in Spring and Autumn in a field population of *Daphnia obtusa*. Kowalczyk (1969) reported that crustaceans in peat bogs are influenced by the age of the bogs, water table, type of banks, pH and possible connection with river. Babitsky (1970) investigated the detailed biology and productivity of *Eurycercus lamellatus*. Brandl and Fernando (1971) attributed reproductive activities to be the cause of microaggregations while studying the population of *Ceriodaphnia affinis*. Asch and Kingsbury (1972) observed three distinct peaks in the Copepod and Cladoceran species of Red Rock reservior in Iowa, USA. Clark (1974) investigated the population dynamics of cladocerans in Lungish lake, Ontario. Kwick and Carter (1975) and Duncan (1975) studied production and population dynamics of different cladoceran species. Davis (1975) studied seasonal changes in cladoceran population in Newfoundland. de Bernardi and Cola (1976) used a compartmental method for the estimation of cladoceran production. Allan (1977) held the view that seasonal successions in Cladocera can be predicted as different species have different rates of response to temperature. Lynch (1978) pointed out the re-exploitative interactions between cladoceran species. Ghilarov (1980) investigated the population dynamics of epilimnetic cladoceran species. Demott (1983) studied the seasonal succession in a natural *Daphnia* assemblage. Rodriguez (1984) described the annual cycle of cladocerans from the Malaga harbor in Spain. Francez (1985) studied the composition and fluctuation of cladoceran communities in two peat bogs of the Massif Central (France). Haveno (1985) indicated the effect of acidification enclosures on the biomass, population size and structure of *Bosmina longirostris*. Amoros (1986) described the population of cladocera as indicators of the hydrological functioning of stagnant waterways. Bengtsson (1986) studied the life histories and interspecific competition between three *Daphnia* species in rockpools. Elstad (1986) studied the population dynamics of *Daphnia middendorffiana*, and the nutrient fluxes in an aquatic microcosm. Foran (1986) studied the relationship between temperature, competition and the potential for colonization of a subtropical pond by *Daphnia magna*. Crosetti (1987) studied the distribution and life cycles of cladocerans in temporary pools from Central Italy. Gabriel et al (1987) estimated the birth and death rates of a natural cladoceran population. Saunders and Lewis (1988) studied the dynamics and control mechanisms in tropical zooplankton communities. Vanni (1988) studied the freshwater zooplankton community structures. Difonzo and Campbell (1988) studied the spatial partitioning of microhabitats in littoral cladoceran communities. Pujin and Ratajac (1988) studied the structure and dynamics of zooplankton in Mrtva Tisa Yugoslavia. Twombly and Lewis (1989) described the factors regulating cladoceran dynamics in Venezuelan flood plains.

George (1989) studied the dispersion patterns of crustaceans in terms of patchiness in enclosed and unenclosed areas of water. Hanazato and Yasuno (1989) studied the zooplankton community structure driven by vertebrate and invertebrate predators. Hovenkamp (1989) studied the Instar-dependent mortality rate of coexisting *Daphnia* species in Lake Vechten, The Netherlands. Urabe (1989) studied the relative importance of temporal and spatial heterogenity in the zooplankton community in an artificial reservoir.

Studies on the Indian Cladocerans in general and the detailed ecology and biology at species level in particular are rather scanty as pointed out earlier. Nevertheless, a detailed review of all the major Indian Works has been attempted here.

The first study on Indian Cladoceran fauna was that by Baird (1859,1860) which dealt with the cladoceran fauna of Nagpur in Central India. Gurney (1907) gave a systematic account of the cladoceran fauna of Bengal and part of Bihar and described two new species of *Macrothrix*. Arora (1931) contributed to the cladoceran fauna of Lahore, now in Pakistan. Sewell (1935) added to the faunal records of Indian cladocera and also traced their seasonal changes. Brehm (1936) reported on the Yale North India Expedition as an important contribution to Indian cladoceran fauna. He later on (1950) described more freshwater cladocera of India. Biswas (1964) recorded *Latona tiwarii* as a new species from Rajasthan and dealt with its distribution. Again, Biswas (1966) described *Chydorus brehmi* sp. nov. from Jaipur, India. Biswas (1971) identified forty five species of cladocera from Rajasthan and dealt with their distribution. Nayar (1971) recorded seventeen species of cladocera from different parts of Rajasthan, India and added nine new records. Patil (1976) contributed to the cladoceran fauna of North-Eastern India and added seven new records for this region. Nassar (1977) recorded eleven species of cladocera from Bhagalpur, Bihar of which nine were new records. Sharma (1978) contributed to the freshwater cladocerans from West Bengal in which he reports thirty six species and subspecies spread over six families. Of the species and sub-species present, twenty four represent new records from West Bengal, seventeen comprise new records from N.E. India, while nine of them are new records from the Indian subcontinent. Yousuf et al (1981) contributed to the ecology of *Diaphanosoma brachyurum* in lake Manasbal, Kashmir. Ragunathan et al (1983) studied the cladocera from the Plankton community in Ennore Estuary, Madras, Yousuf et al (1983) studied the crustacean communities of freshwaters of Kashmir. Again Yousuf et al (1984) reported the Summer and Winter cladoceran communities of the Anchar Lake, Kashmir. Rane (1984) reported two new species of *Bosminopsis* and *Grimaldina brazzai* from India. Sharma (1985) studied the species composition of zooplankton in two Kumaon Himalayan lakes from Utter Pradesh, India. Sharma (1987) studied the ecological affinity of *Daphnia* population in their natural environment. Sharma et al in the same year studied the seasonality, population dynamics and production of *Daphnia longispina* in the sub-tropical lake at Bhimtal, U.P., India. Ravichandran et al (1988) studied the plankton and related parameters of Buckingham Canal at Madras.

Michael (1962) attempted for the first time in India to analyse the seasonal events in natural population of *Ceriodaphnia cornuta* and worked out their life cycle under laboratory conditions. Navaneethakrishnan and Michael (1971) studied the life cycle of *Daphnia carinata* and found faster rate in egg production than that of the temperate species *Daphnia pulex* and attributed this difference to differences in temperature regimes. Murugan and Sivaramakrishnan (1973) studied the biology of *Simocephalus acutirostris* and found resemblance with the temperate daphnid species *Daphnia pulex* in the life cycle pattern. Embryonic development resembled that of *Daphnia magna*. Murugan (1975) investigated the detailed life cycle and embryonic development of *Moina micrura* under laboratory conditions. Murugan and Sivaramakrishnan (1976) investigated the life cycle of *Scapholeberis kingi* and reported two preadult and seventeen adult instars with a life span of 493.6 hrs. The total number of eggs produced were 239.40. Murugan and Venketaraman (1977) traced the detailed morphological changes in the embryonic development of *Daphnia carinata*. Murugan and Ramaseshan (1978) observed that production of sexual eggs in *Scapholeberis kingi* is due to depletion of food supply and sexual egg producing mothers may or may not go through any parthenogenetic generation during the rest of the life cycle. They also recorded pseudosexual eggs to be more in the field than in laboratory. Venkataraman and Job (1980) stuided the effect of temperature on the development, growth and egg production in *Daphnia carinata*. Venkataraman (1981) studied the life history and seasonal variation in egg production of *Daphnia carinata* both in the field and laboratory. Jana and Pal (1983) contributed to the studies on population growth in *Daphnia carinata* as a direct function of available space. They have also studied some life history parameters and production of *Daphnia carinata* grown in different culture media. They also contributed to the population growth in *Diaphanosoma excisum* grown in different culture media, and also as a direct function of avialable space. Jana and Pal (1985) studied the effects of inoculum density on growth, reproductive potential and population size in

Moina micrura. Jana and Pal (1985) studied the relative growth and egg production in *Daphnia carinata* under different culturing media. Jana and Pal (1985) studied the life history parameters of *Moina micrura* grown in different culture media. Khan et al (1987) stuided the effect of fertilization for mass cultivation of *Ceriodaphnia cornuta.*

The first study on Chydoridae was done by Jurine (1820), who worked on the life history of chydoridae that was later summarised by Baird (1850) for *Chydorus sphaericus* and *Alona quadrangularis.* Weismann (1876-79) described in detail the life histories of several daphnids, which parallel the general pattern in chydorids. He mentioned specifically some observations in *Eurycercus lamellatus, Chydorus sphaerious* and few other species. Vavra (1900) for the first time described *Pleuroxus similis.* Smirnov (1962) made some field observations on *Eurycercus lamellatus* and also contributed to their nutritional aspects. Smirnov (1964) made field observation on *Pleuroxus aduncus* and also stuided their growth parameters. Frey (1965) differentiated *Alona rostrata* from two related species. Smirnov (1966) studied the morphology and taxonomy of *Pleuroxus.* Frey (1967) contributed to the phylogenetic relationship in the family Chydoridae. Smirnov (1967) contributed to age related morphological changes of males of chydoridae. Whiteside (1967) studied the species diversity in Chydorid communities. Fryer (1968) studied the evolution and adaptive radiation in the chydoridae and contributed to the comparative functional morphology and ecology of the organisms. Shan (1969)studied the life cycle of the Chydorid *Pleuroxus denticulatus* and held the view that probably all chydorids have similar life cycle patterns. Whiteside (1970) contributed to the modern ecology and core studies of Danish Chydorid cladocera. Goulden (1971) worked on the distribution of chydorid cladocera and pointed out the importance of environment on their abundance. Frey (1973) compared the morphology and biology of three species of *Eurycercus*, and also described the species *Eurycerous macrocanthus*. Keen (1973) made a probabilistic approach to the dynamics of natural population of chydoridae. Whiteside (1974) contributed to the ecology, seasonal pattern and abundance of population of chydorids in Elk lake of Minnesota, USA. Shan (1975) studied the reproduction in a laboratory stock of *Pleuroxus* under the influence of photoperiod and light intensity. Frey (1976) redescribed *Chydorus pigroides* and allocated it to *Pleuroxus*. Frey (1977) contributed to the variability and taxonomy of *Pleuroxus denticulatus*. Whiteside et al (1978) contributed to the seasonal abundance and pattern of chydorid cladocera in mud and vegetation habitat. William (1978) studied the factors regulating chydorid population in lake Itasca, USA. Again, Williams (1982) studied the temporal and spatial patterns of abundance of the chydoridae in lake Itasca, Minnesota, USA. Williams (1983) also studied the summer mortality factors for a natural population of chydoridae. Frey (1988) separated *Pleuroxus laevis* from two other resembling species in North America. Frey (1990) studied the radiation of *Pleuroxus* in Australia and New Zealand (paper presented in the II Symposium on Cladocera held in Czechoslovakia).

Among the Indian workers, Qadri and Yousuf (1977) reported *Pleuroxus similis* from Kashmir. The same authors described the seasonal variations in the population of twelve species of cladocera belonging to the Family Chydoridae in the lake Manasbal, Kashmir (Qadri and Yousuf, 1981). Murugan (1982) made laboratory studies on the life cycle of *Leydigia acanthocercoides*. Rane (1984) reported the occurrence of *Pleuroxus similis* and *Kurzia latissima* in India.

MATERIALS AND METHODS

(a) Description of Study Site

Materials for the present study were collected mainly from Ward's Lake in Shillong (25°34'N Latitude; 91°36'E Longitude). This system is located behind the Shillong Club adjacent to the Shillong main road. This is an artificial lake, more or less semicircular in shape (Plate: 1). It has been constructed as early as 1894 by Sir William Ward. A dam has been erected on one side to store the inflowing water. Total area of the lake was 23800 sq m with a maximum depth of 6 m. The maximum length and breadth were 333.0 m and 75.0 m respectively. Three inlets constantly carry the water into the lake. The main inlet carries the sewage water from the surrounding habitation to an isolated part of the lake located on the southeastern corner. This portion is connected to the main lake through an inlet as a result of which this isolated part always maintains a constant water level as the surplus amount continuously flows into the main lake. The second inlet carries underground spring water from near the shore into the lake from the eastern side, while the third inlet joins from the northeastern side, and carries sewage water. The outlet is situated on the western side of the lake near the dam.

This permanent lake which is one of the largest lentic system in Shillong has been extensively and successfully used for fish culture by the Department of Fisheries, Government of Meghalaya. The most commonly cultured fish is the common carp (*Cyprinus carpio*) along with a few other Indian Cyprinid species.

Since it is a well known fact that most chydorids are littoral and hence associated with vegetation in the system, collections were confined

Plate I. Study site. Ward's Lake

a. A view of the lake.

b. Collection spot.

Plate I

only to those areas which had thick vegetation. Thus for the purpose of collections the vegetation areas were divided into 3 stations. Station I was located on the southeastern corner of the lake. Station II on the northeastern corner and Station III on the northwestern corner (Fig:1).

Throughout the study period no *Pleuroxus similis* was recorded from Stations II and III inspite of them having a thick vegetation consisting of *Ageratum conyzoides*, *Polygonum* sp. *Nymphaea* sp. and also *Rotala rotundifolia*. However, the maximum availability of *Pleuroxus similis* was recorded from Station I throughout the study period.

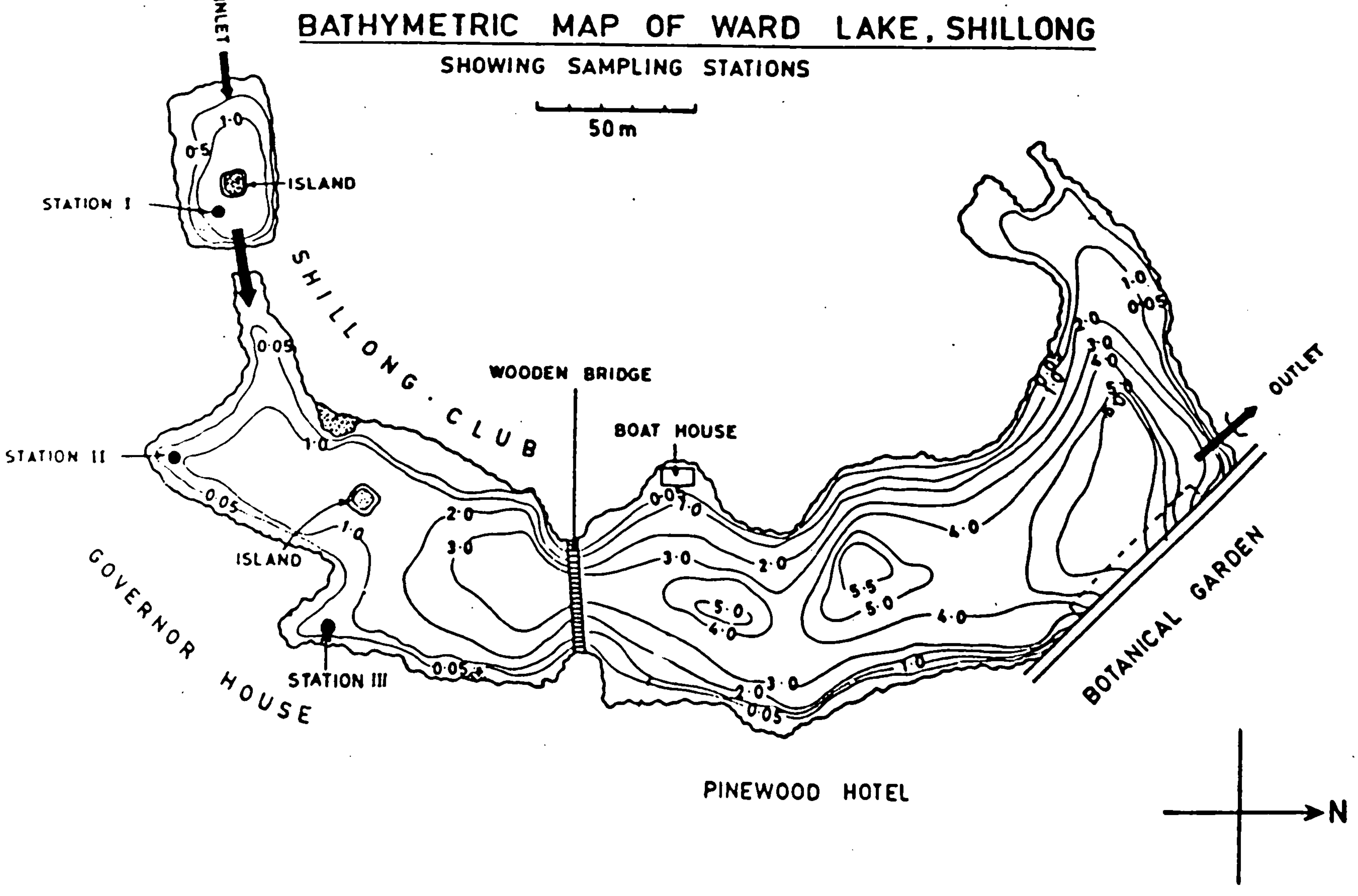
This particular station was located on the isolated portion resembling somewhat a rectangular shaped pond. This pond was 53 m in length and 35 m in breadth, with an average depth of 0.80 m. The total volume of water was about 1200 m^3. This pond receives the main inflow of water and as a result remains turbid with abundant vegetation. Among the various plants present, the dominant forms were *Polygonum* sp, *Utricularia*, *Hydrilla* sp, *Vallisneria* sp. and *Oxalis* sp.

(b) Collection and Preservation of Samples

For collection of plankton, a plankton net was used, which was fabricated out of No.25 XXX bolting silk. The net was towed through the littoral zone of the system, and at times when there was too much littoral vegetation, an iron handle was attached to the net which helped in the proper collection of samples. The net had a metal sieve at the mouth to prevent the entry of unwanted weeds and filamentous algae. The composite concentrated samples were then fixed in Formalin raising slowly to a final

Fig.1. Map of Ward's Lake, showing the location of the sampling stations.

Fig.1


BATHYMETRIC MAP OF WARD LAKE, SHILLONG
SHOWING SAMPLING STATIONS
50m
INLET
ISLAND
STATION I
SHILLONG CLUB
WOODEN BRIDGE
BOAT HOUSE
OUTLET
STATION II
ISLAND
STATION III
GOVERNOR HOUSE
PINEWOOD HOTEL
BOTANICAL GARDEN
N
0·5
1·0
0·05
2·0
3·0
4·0
5·0
5·5

concentration of about 5%. This process of slow addition of Formalin was found to prevent distortion of body shape in Cladocera. The organisms in the plankton samples were then sorted out under a binocular microscope, and each specimen identified.

(c) Morphological Studies

For detailed morphological studies, the exuviae of the animals were taken, different parts dissected with help of fine tungsten needles, mounted in polyvinyl lactophenol and camera lucida diagrams done. Specimens were also studied in temporary mounts of 15% glycerol, for their length and height measurements and also for drawing of intact animals.

For Scanning Electron Micrographs mostly intact specimens were used. These were fixed in 2.5% glutaraldehyde in 1 molar sodium cacodylate buffer for 2-4 hrs. This was followed by washing in buffer, post fixation in 1% Osmium tetroxide, dehydration in graded concentration of acetone and drying, as suggested by Wolley and Vossfrinck (1977). The specimens were then secured to brass studs by electroconductive point 'Dotite'. This was followed by coating the specimens with a thin layer of gold in a fine coat Ion sputter and scanned subsequently.

(d) Studies on the Life Cycle patterns of *Pleuroxus similis* reared individually in different culture media

Laboratory studies on the life span, instar duration, egg production and growth were conducted on individual parthenogenetic females, and the information gathered using several such replicates.

As mentioned earlier, clodoceran samples were collected from fresh water pond with the help of a plankton net, and the chydorid species *Pleuroxus similis* was picked out with the help of a dropper. Gravid females were isolated and reared in Petri dishes. Filtered pond water, chicken manure and rice bran were used as culture media. The preparation of chicken manure and rice bran media are given in detail under culture methods (vide *infra)* and detritus was also given to the animals as food. However, during rearing of an individual the medium was not changed, but 1 ml of fresh medium from the stock solution (chicken manure or rice bran) was added to the Petri dishes on alternate days. This provides the animal with sufficient nutrition for normal growth and reproduction.

Initially studies on life cycle were carried out by selcting 20 sets of 12 animals each viz., 240 neonatae (I instar). Out of which approximately 128 neonatae survived to complete the life cycle. Each individual was reared in a separate Petri dish. The experiments were carried out at room temperature ranging from 15°-20°C. The number and duration of instars, number of eggs per brood, increase in length and total life span were recorded.

The length measurement of both young and adult parthenogenetic females were made from the tip of head to the tip of the posterior end of carapace. The measurements were done by using an ocular micrometer under a compound microscope. Duration of instars and increase in length and the total life span of males were also measured in the same way as described above.

To study the effects of temperature and light on the growth, fecundity and life span of individual females, laboratory experiments were performed in the BOD incubator at a temperature of 30°C with continuous light regimes, and filtered pond water as the culture medium.

(e) Field studies on Population dynamics and Seasonal distribution of *Pleuroxus similis*

For the study on the seasonal distribution and population dynamics of *Pleuroxus similis*, samples were collected fortnightly for a continuous period of 25 months except for the months of June to September '87 due to unavoidable circumstances. A plankton net fabricated out of No 25 XXX bolting silk was used for collection. One litre of water was seived through this net, and the plankton thus obtained was fixed and preserved in 5% formalin. The chydorids were later identified and then counted in a Sedgewick Rafter cell. The results were calculated in terms of number of individuals per litre.

The population composition of *Pleuroxus similis* was grouped into following categories: (i) Juveniles (ii) Parthenogenetic females (iii) Females without eggs (iv) Ephippial Females (v) Males.

Both females and males were measured separately with the help of an eyepice oculometer and were placed in the following size groups:

Females:		Males:	
I.	0.20mm - 0.25mm	I.	0.27mm - 0.30mm
II.	0.26mm - 0.30mm	II.	0.31mm - 0.35mm
III.	0.31mm - 0.35mm	III.	0.36mm - 0.38mm
IV.	0.36mm - 0.40mm		
V.	0.41mm - 0.45mm		
VI.	0.46mm - 0.50mm		

The various population parameters were determined by following methods of George and Edwards (1974) and the following formulae were used for calculation:

$$\text{Mean Brood Size (E)} = \frac{\text{Total number of eggs}}{\text{Number of females with eggs}}$$

$$\text{Finite Birth Rate (B)} = \frac{E}{D} \times N_0$$

Where (D) the duration of development of eggs as determined in the laboratory.

N_0 is the initial population size. Instantaneous birth rate (b') = $\log_e (1+B)$

$$\text{Coefficient of population growth (r')} = \frac{\log_e N_t - \log_e N_0}{t}$$

where N_0 is the initial population and N_t the population after time 't'.

Mortality rate (d') = b' - r'.

Associated groups of phytoplankton and zooplankton were also sorted out and their numbers/litre calculated. Temperature and pH of the system were also recorded.

Statistical Analysis:

(a) Simple correlation between the population values and the different biotic and abiotic factors like associated phytoplankton zooplankton and insect larvae (predators), temperature and pH was undertaken and the 'r' value was determined by using the formula:

value was determined by using the formula:

$$r = \frac{\Sigma\, xy}{\sqrt{\Sigma x^2\ \Sigma y^2}}$$

(b) The coefficient of determination was derived for the population values against all the factors via a regression analysis programme and the coefficient of determination was arrived at as

$$R^2 = \frac{\text{regression SS}}{\text{Total SS}}$$

The values were expressed as a percentage.

(f) Studies on laboratory culture of *Pleuroxus similis*

Studies on laboratory cultures were done on three aspects:

(i) Life history parameters of *Pleuroxus similis* reared in different culture media with different inoculum densities

Life history parameters of *Pleuroxus similis* were derived from culture experiments with different media - chicken manure, rice bran, and filtered pond water which was used as control.

The culture media were prepared by adding the manure separately to tap water in glass jars of two-litre capacity. The amount of media used, and their organic contents are given below:

Medium used	Dosage used (gm/l)	Dry matter %	Crude protein %	Nitrogen %	Ash %	Organic Carbon %	Organic Matter %
1. Rice bran	9	91.36	5.30	0.848	19.17	12.08	20.83
2. Chicken manure	8	89.98	11.49	1.838	24.42	13.53	23.33

The media prepared were used to set up cultures. The cultures were set up in Petri dishes of 120 ml capacity. Each culture dish received three different inoculum densities of 3, 5 and 8 neonatae. Each set was duplicated and the mean of the results was calculated.

The culture dishes were kept in the laboratory under the temperature range of 17°-22°C with normal light conditions. Length, fecundity and progeny production for each animal was observed daily. Estimates of life history parameters:

'A' (first reproductive time)

'W' (Longevity)

'S' (total offspring born to a female)

were derived from the culture studies following procedures suggested by Allan (1976).

The net reproductive rate (R_0) was determined by:

$$R_0 = \Sigma\, l_x\, m_x$$

where l_x is the probability of surviving to age x.

x = is the number of offspring per female between ages x+1.

The average generation time (T_c) is given as:

$$T_c = \Sigma\, x.\, l_x m_x\, (\Sigma l_x m_x)^{-1}$$

Population count was done every week and the density determined as number of individuals/litre.

A two-way ANOVA was done to find the effect of different inoculum densities and different culture media on the various life history parameters, such as longevity, total offspring production, net reproductive rate and average generation time of *Pleu.roxus similis*.

(ii) Effect of Inoculum density on different population parameters in *Pleuroxus similis* using chicken manure as the medium

The effects of inoculum density on the different population parameters in *Pleuroxus similis*, were studied after having the basic information on the life history parameters described in the previous section. For this experiment, chicken manure was used to rear *Pleuroxus similis*, because it was found to be the most suitable culture medium as seen from the earlier observations on this cladoceran species. For this experiment, cultures were set up in flasks of 60cm^3 capacities and each flask was inoculated with 3, 5, 8 and 12 neonate respectively. The experiments were set up in duplicate and the mean was calculated. The temperature and light conditions were similar to that of the previous experiment. Observations were made to determine the growth, survival, fecundity and population density of *Pleuroxus similis* under different inoculum densities.

One way analysis of variance was done to find the effect of different inoculum densities on population density, and also on cumulative offspring production. Student's 't' test was applied for comparison of total egg production per female in different inoculum densities and also maximum population density at different inoculum densities of 3, 5, 8 and 12 animals. Weekly population dynamics for the above inoculum densities were also worked out, following methods used by Hall (1964) and George and Edwards (1974).

(iii) **Population growth of *Pleuroxus similis* as a direct function of available space**

The volume of the flasks used in this experiment ranged from $15cm^3$, $30cm^3$, $60cm^3$, $100cm^3$, $250cm^3$ to $500cm^3$, and the inoculum density in all the flask capacities remained fixed at 10 animals. The medium for this experiment was chicken manure. The dosage of manure and the preparation of the medium is same as mentioned earlier. The temperature and light conditions were also similar.

The flasks were filled with the prepared medium and inoculated with 10 neonate. Each set of experiment was carried out in duplicate and the mean taken. The animals were examined daily for determination of their population size, state of maturity and offspring production. Comparison of mean population size was done by mean of Duncan's Multiple Range test. One way ANOVA was also done for total population under different flask capacities.

(g) **Karyological studies**

Karyological changes during the different phases of life history of *Pleuroxus similis* was also attempted. For this purpose both neonates and adults of *Pleuroxus similis* were taken. The procedure followed for studying the chromosomes of the organisms was Smith's technique. In this procedure the animal is first placed in 1% sodium citrate solution for about 5-6 minutes. The specimen is then transferred to acetoalcohol (1 part glacial acetic acid: 3 part by volume absolute alcohol) and kept for 45 minutes.

A clean slide is taken and Mayer's albumen is spread on the slide and is heated over a spirit lamp. The animal (fixed) is then transferred to the slide dissected and squashed in 45% acetic acid and warmed. The slide is then placed in 50% alcohol overnight and then transferred to 30% alcohol and allowed to remain for 10 minutes. After this the slide is washed in tap water and then placed in 3% Fe-alum for 25-30 minutes. The preparation is again washed in water and stained in haematoxylin for 45 minutes. Once again the slide is washed with water, differentiated in picric acid. Finally, the slide is placed in running water for 25-30 minutes, dehydrated (upgraded), cleared in xylene and mounted in DPX medium.

TAXONOMIC AND DISTRIBUTIONAL STUDIES ON *Pleuroxus similis* (VAVRA, 1900).

Pleuroxus similis (Vavra, 1900)

Pleuroxus similis Vavra 1900, p.23-24, Fig.6; Sars, 1901, p.79-80 pl XI, Fig.7.7a-b, Manuilova, 1964, p.267, Fig. 128; Smirnov, 1971, p.230-231, Figs 218-219; Yousuf and Qadri, 1977, p.89; Qadri & Yousuf, 1978, p.859-860 Fig 2. Sharma, 1978 p.150; Mamaril Sr. and Fernando, 1980, p.140 Figs. 136-137; Michael and Bhattacharya 1980 p.127-130 Fig.39,a-e; 40 Rane 1984 p.713, Michael and Sharma 1988, p.127-130, Figs.39,a-e; 40.

Synonym: *Pleuroxus australis* Henry, 1922 p.45 pl.VII, Fig.3.

Pleuroxus similis var. *fuhrmanni* Stingelin, 1913 p.624-625. Figs. 24-25.

Materials Studied:

1. Parthenogenetic females from Zoological Museum, Oslo Norway. No.NRF 12391.
   Pleuroxus similis Vavra.
   Sted: Argentina lg G.O. Sars.
2. Parthenogenetic females from Australia nos N 58, N 100 C, N 110 e as permanent mounts of *Pleuroxus similis* Vavra. collected by B. V. Timms.

Distribution

Pleuroxus similis was first described by Vavra in 1900 from Chile (Valdivia) South America. In India it was first reported by Qadri and Yousuf (1977) from Beehama Spring in the State of Kashmir. In 1978 the same authors again reported the occurence of *Pleuroxus similis* in Lake Manasbal in Kashmir situated in the northern part of India (32°,01'-35°,00'N and 73°,48'-75°,30'E). Sharma (1978) reported the occurrence of *Pleuroxus similis* in West Bengal from the eastern part of the country. Following this, Michael and Bhattacharya (1980) reported *Pleuroxus similis* from Meghalaya, located in the northeastern part of the country. Rane (1984) reported the occurrence of *Pleuroxus similis* from Madhya Pradesh in Central India. Thus, it is observed that *Pleuroxus similis* is fairly well distributed in the northern, eastern and central part of India. However, there has been no reports about the occurrence of this species from the peninsular India.(Fig. 2).

Elsewhere in the world it has been reported from Chile, Australia, Sri Lanka, Northern Caucasus and Tashkent area in U.S.S.R. and also from Argentina.

None of the earlier reports on *Pleuroxus similis* show the presence of males, which has been recorded for the first time during the present study.

General description of the animal :

1) **Parthenogenetic female** (Plates II, VIII and IX)

Body with uniformly curved dorsal margin. Posteroventral corner of valves with 1-4 denticles, variation were noticed even on the two valves of the same animal. The anterior end of the valve has a series of 5-6 curved striae; rather obscure reticulations on the valve in the posterior-ventral and ventral region as also seen in ephippial female; surface of the valve marked with tiny pits (Visible under SEM only). Ventral margin with feathered

Fig.2. Map of India showing distribution of *Pleuroxus similis* Vavra.

MAP OF INDIA

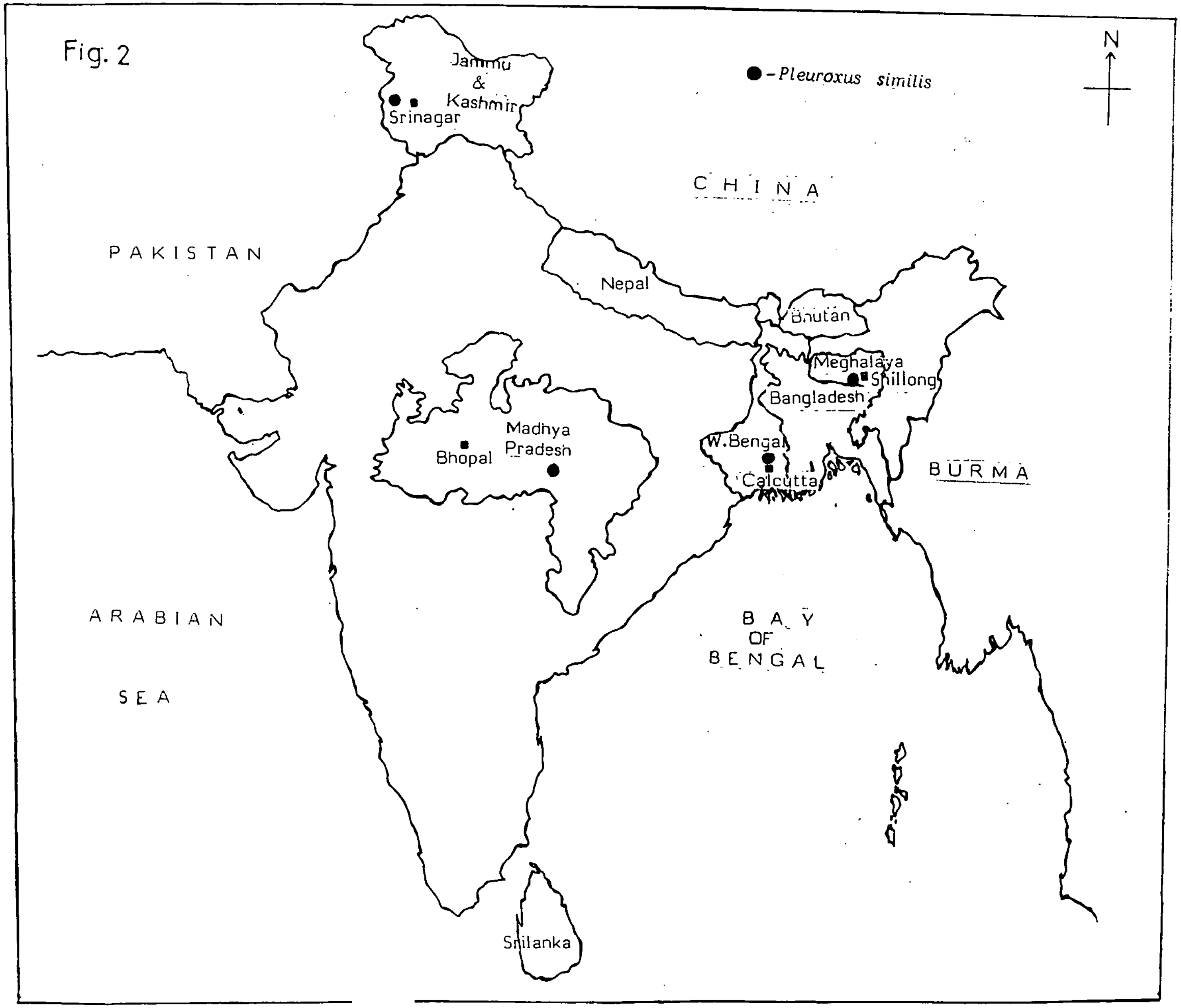


Fig. 2

Plate II *Pleuroxus similis*. Parthenogenetic females from Ward's Lake Shillong. Scale in mm.

- **1.a** Whole view of mature parthenogenetic female.
- **1.b** Shell showing the setules along the ventral and posteroventral margins, and also the denticles on the posteroventral corner of the valve.
- **1.c** Head shield showing the head pores.
- **1.d** Postabdomen and claw with anal denticles and abdominal setae.
- **1.e** Postabdomen with rows of weak cresents of fine spinules on lateral surface. Postabdominal claw with setules on the dorsal margin, and with 2 basal spines.
- **2.** Whole view of ephippial female of *Pleuroxus similis*.

PLATE-II

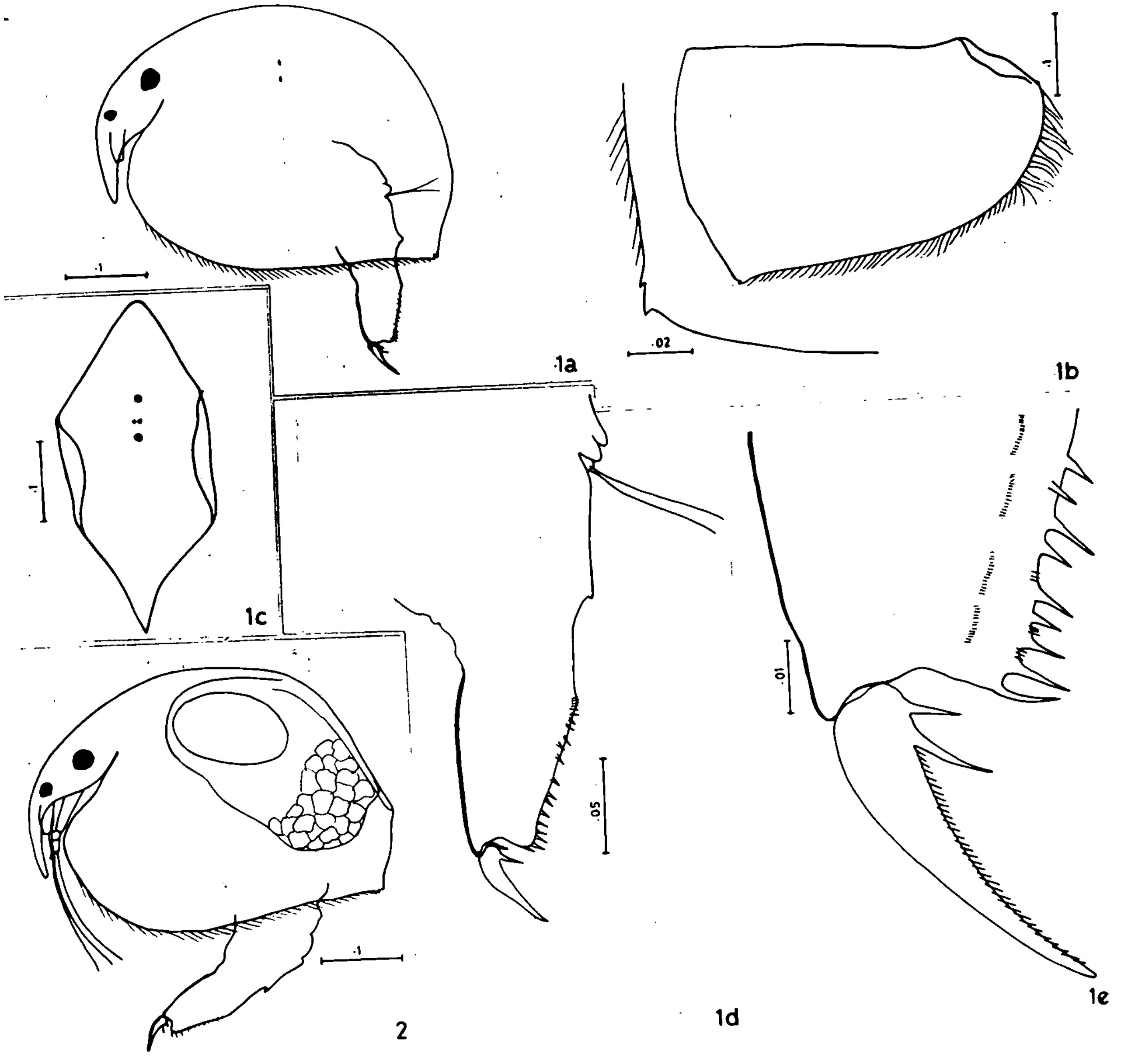
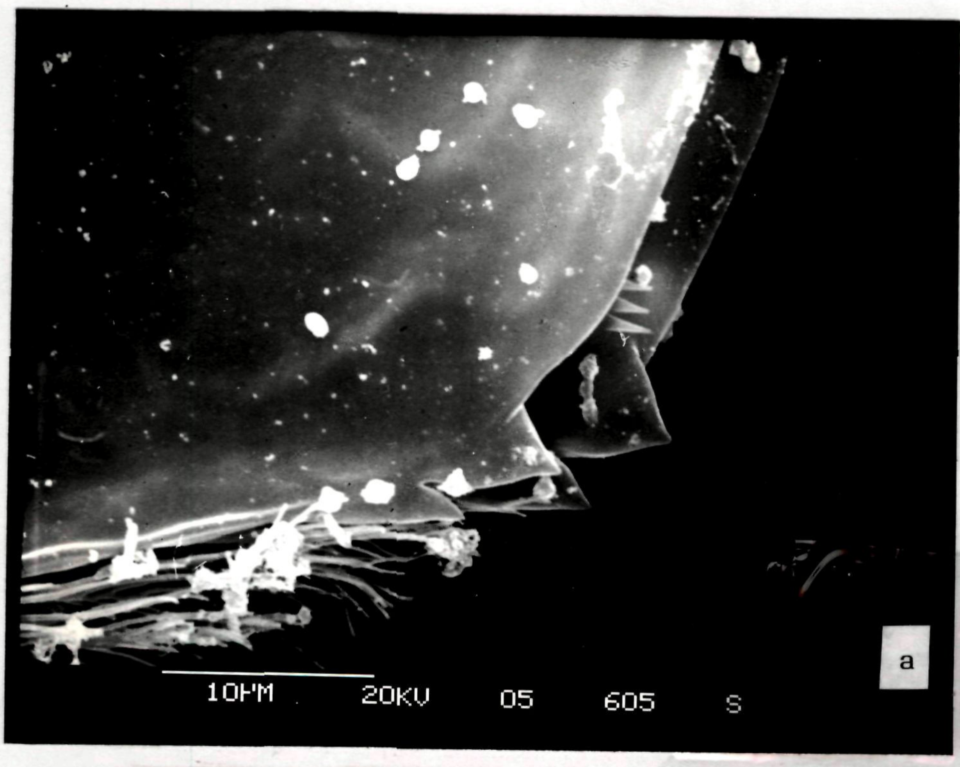


Plate VIII. *Pluroxus similis.* Parthenogenetic females.

a. Spinules on the inner side of the posteroventral corner of the shell.

b. Surface of the valve marked with tiny pits.

Plate VIII



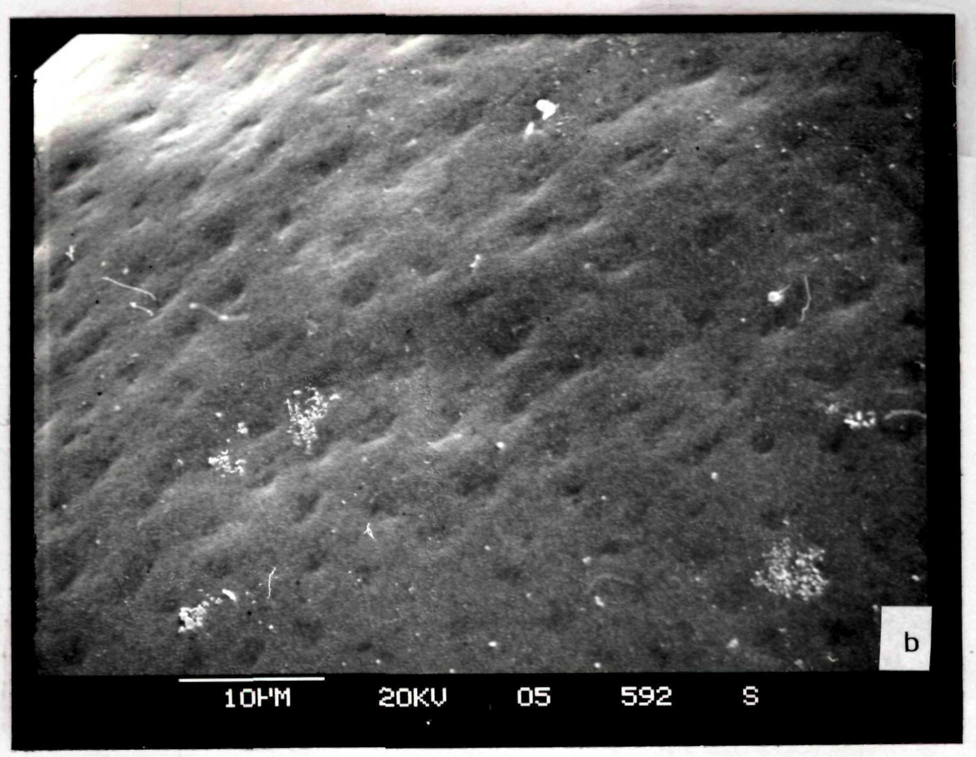
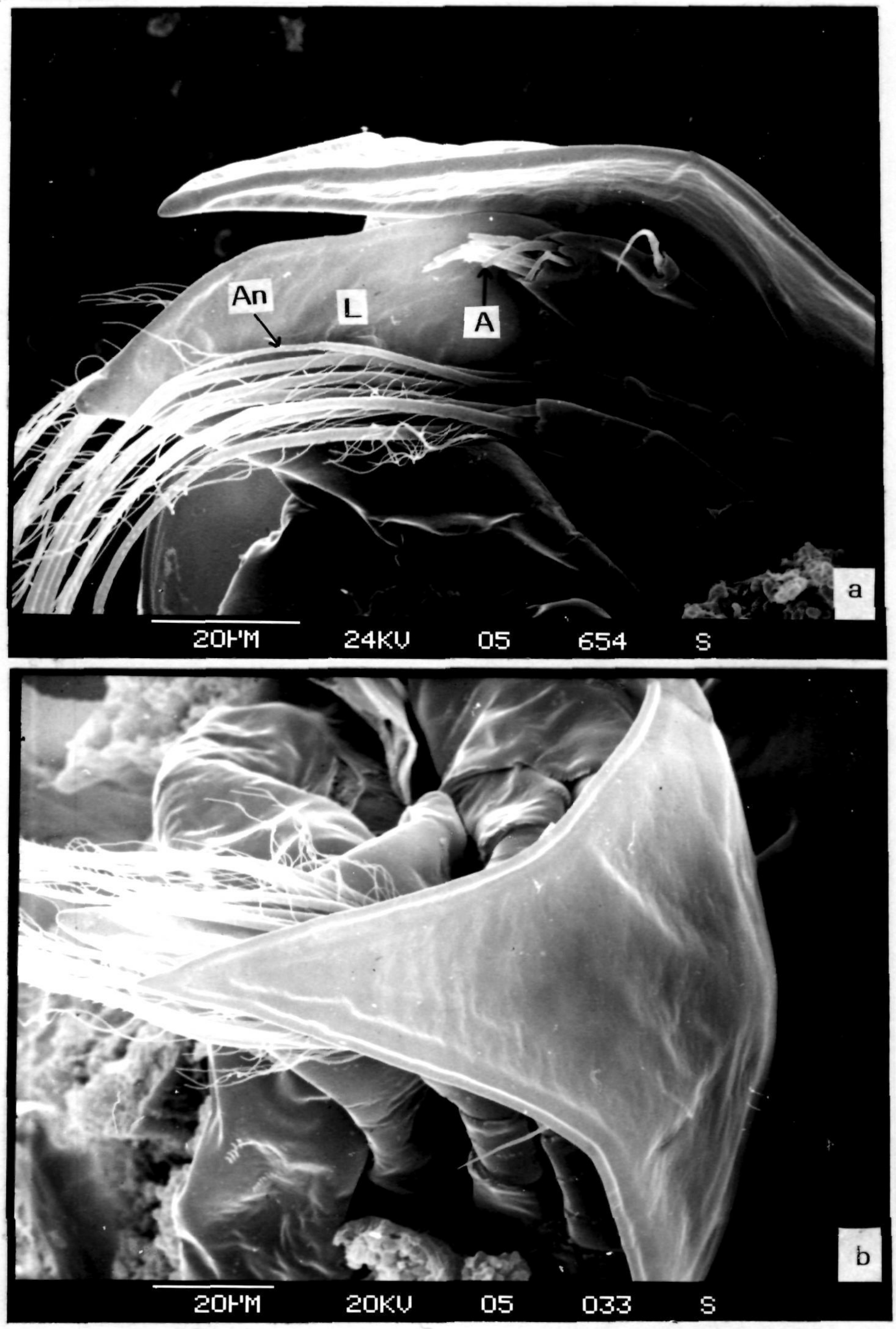


Plate IX. *Pleuroxus similis.* Parthenogenetic females.

- **a.** Rostrum from below. Showing the : A. antennular aesthetascs of variable length.
  L. Labrum and the An. Ȃntenal setae.

- **b.** Frontal view of rostrum of parthenogenetic females.

Plate IX



setae. Posterior ventral corner of the shell has 3 spinules on the inner side. Rostrum long and pointed downwards reaching level of ventral margin of valves. Posterodorsal angle not so prominent. Antennules terminating far from apex of rostrum. Distance of ocellus to eye half distance to apex of rostrum. Postabdomen elongated, tapering slightly towards the distal end, the preanal angle moderately prominent. Dorsal distal corner of post-abdomen situated slightly behind base of claws. Anal spines 9-14 increasing gradually in size distally. Abdominal setae barely reach anal groove when extended. Postabdominal claw almost straight with two basal spines.

a) Shape and shell:-

The dorsal margin of the body is uniformly curved. The posteroventral corner of the valve has 1-4 denticles with variations on the two valves of even the same animal. The posteroventrál corner of the shell has 3 spinules on the inner margin. The posterior margin of the valve is short and weakly convex. The ventral margin of the valve convex anteriorly, but almost straight posteriorly. Posterior dorsal angle not so prominent; posterior ventral angle weakly rounded, with 1-4 denticles arising submarginally. Ventral margin with feathered setae, which are marginal with broad bases. The anterior margin of the valve has 5-6 curved striae, parallel to the margin. Obscure reticulations on the valve in the posteroventral and ventral regions, visible only under SEM. Surface of the valve has a pitted appearance.

b) Head (Plate.X):

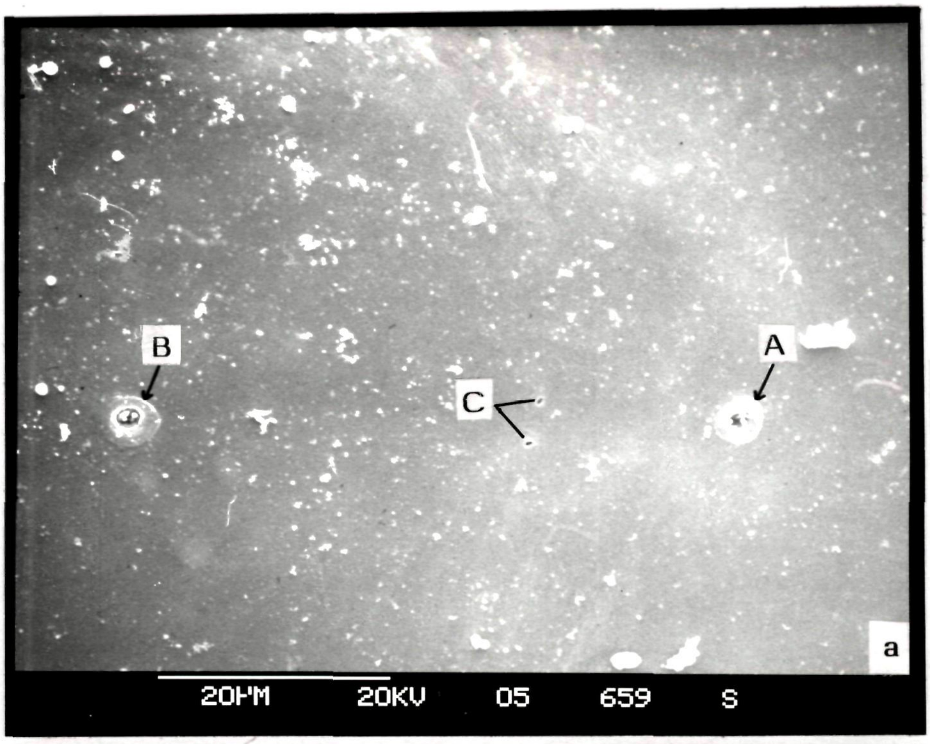
Elongate, broad at junction with shell tapering posteriorly to narrow rounding. Rostrum elongate and narrow, provided with thickenings on the

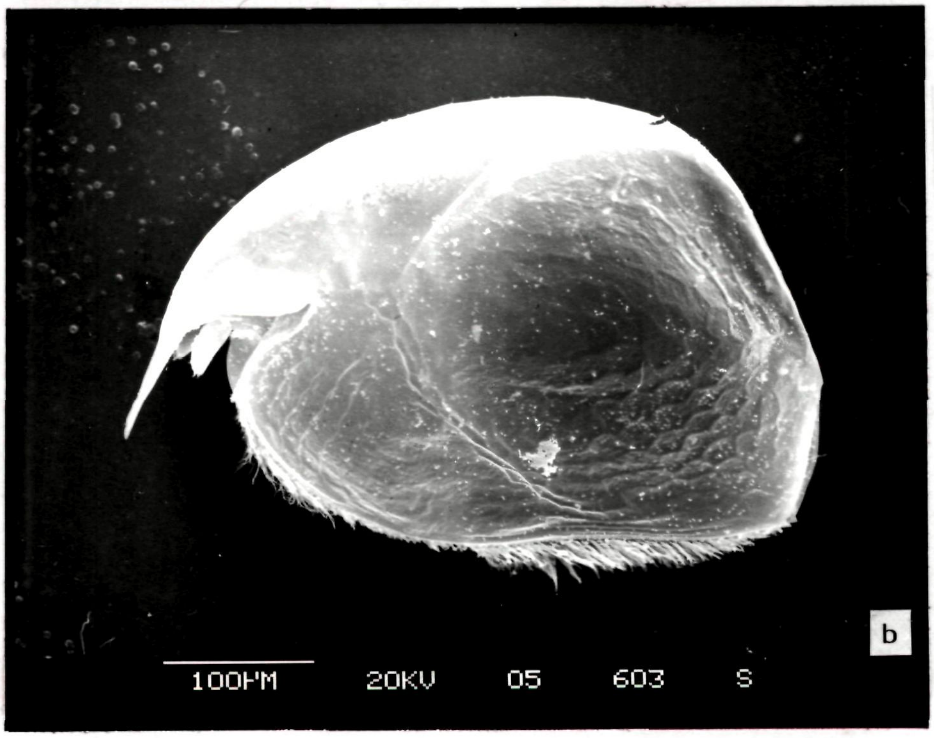
Plate X. *Pleuroxus similis*. Parthenogenetic females.

a. Head shield of parthenogenetic female : A. Anterior pore. B. Posterior pore. C. Median pores.

b. *Pleuroxus similis*. Ephippial female - side view.

Plate X





ventral side:In side view it islong and pointed downwards reaching the level of ventral margin of valve. Lateral margin of the rostrum almost rectangular. Median pores distinct and somewhat closer to anterior pore. Sculpturing evident on the ventral margin. Eye big and almost round, distance of ocellus to eye half distance to apex of rostrum.

c) Postabdomen (Plate.II):

Elongated, tapering slightly towards distal end. Preanal angle moderately prominent. Ventral margin convex and thickened and dorsal margin weakly concave provided with 9-14 anal spines increasing gradually in size distally. Lateral surface with rows of weak crescents of fine spinules. Abdominal setae almost as long as preanal portion.

d) Postabdominal claw (Plate.II):

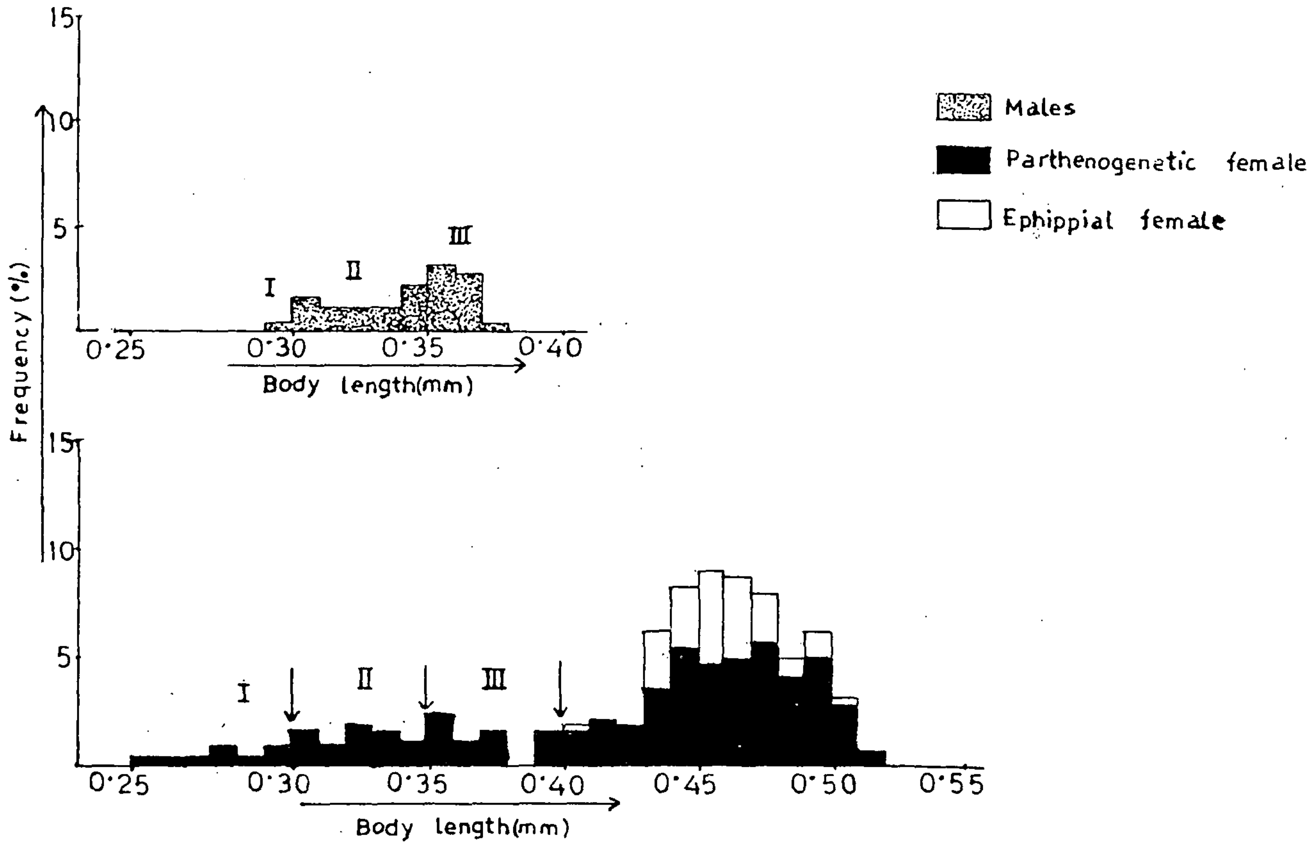
Ventral margin almost straight or weakly convex tapering towards the tip. The dorsal margin distinctly concave provided with setules. Presence of two basal spines, distal is larger than the proximal one.

e) Size Freuency (Fig.3):

In a population of 350 animals, the size ranged from 0.25mm to 0.52mm. The Ist instar size range was from 0.25mm to 0.30mm. The II nd instar size range was from 0.30mm-0.35mm and IIIrd instar size range was 0.35mm-0.40mm. Beyond this size upto 0.52mm, the animals were considered as adults, since most of them were egg-bearing. The size of smallest females with eggs was 0.41mm.

Fig.3 Size frequency analysis of a population of *Pleuroxus similis* collected on 27.2.88. (n=350)

Fig.3


Males
Parthenogenetic female
Ephippial female
Frequency (%)
15
10
5
I
II
III
0·25
0·30
0·35
0·40
Body length(mm)
15
10
5
I
II
III
0·25
0·30
0·35
0·40
0·45
0·50
0·55
Body length(mm)

2) **Ephippial female** (Plates. II, VI, VII and XI)

From side view the shape of the ephippial female is very similar to the parthenogenetic female, with a prominent bulge laterally for egg locule. But the frontal view shows that the dorsal margin of the shell is angled at junction with head and distinctly thickened. Head shield more elongate posteriorly than in parthenogenetic female; rather narrowly tapered posteriorly to fit against "Keel" of ephippial female; sharp lateral rectangular expansion into region of slough line. Slough line indicated by lines on shell. Surface of ephippial portions provided with reticulations. The dissected ephippium shows foamy mass in the form of fine holes (punctae).

3) **Male** (Plates. XII and XIII)

Males show changes typical of chydorids over the three instars though Ist instar males were present detailed morphological studies have been made only on II.nd and IIIrd instar males) in morphology of rostrum and trunk limb I. Rostrum becomes much shorter and broader. On trunk limb I the copulatory hook tapers distally. The postabdomen of mature male with both dorsal and ventral margins almost straight. The shape differs distinctly from the female postabdomen in being broader and stout. The preanal angle is not at all prominent and the anal groove lined with setules. The marginal denticles are replaced by short rows of long spines. Genital pores located far distally near the dorsal margin. Abdominal setae reaches the anal groove when extended. Postabdominal claws similar to those of the females.

a) Shape and Shell (Plate.III)

The IInd instar male appears more or less like the female, but

Plate III. *Pleuroxus similis.* Males.

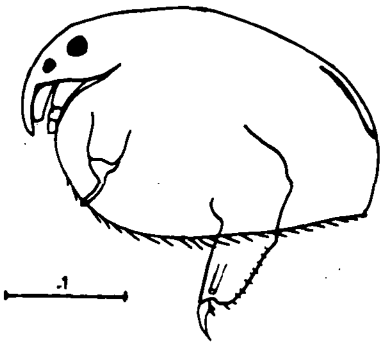
3.a Whole view of II instar male.

3.b Whole view of III instar male (mature).

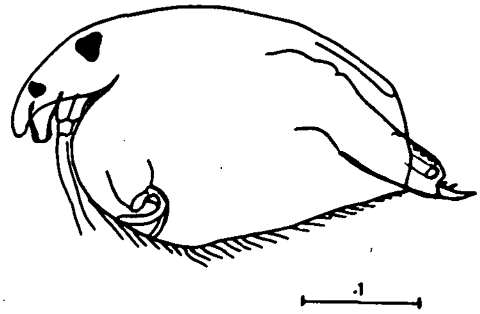
3.c Copulatory hook in trunk limb I of II instar male.

3.d Copulatory hook in trunk limb I of mature male.

PLATE-III



3a



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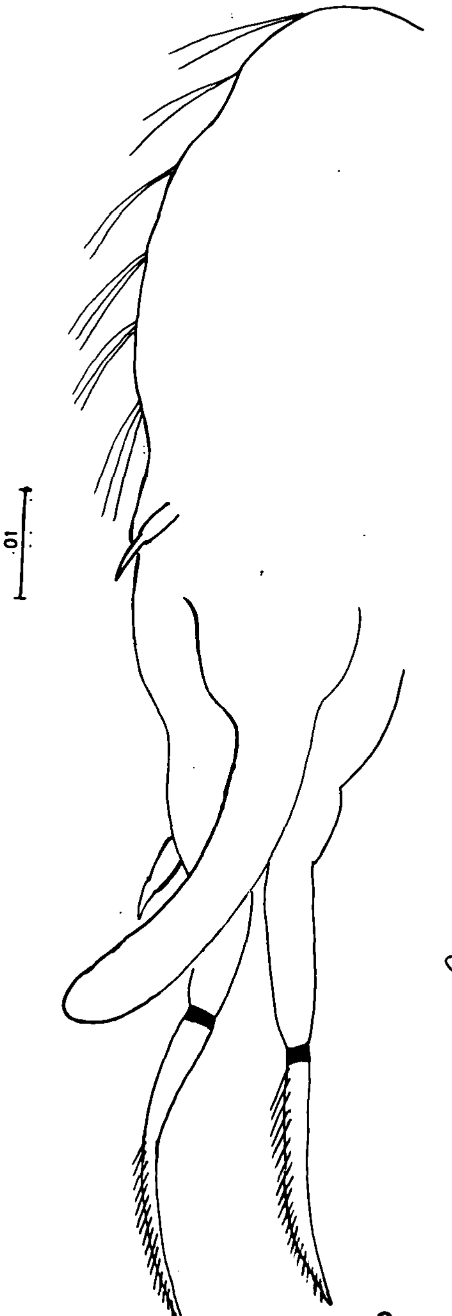

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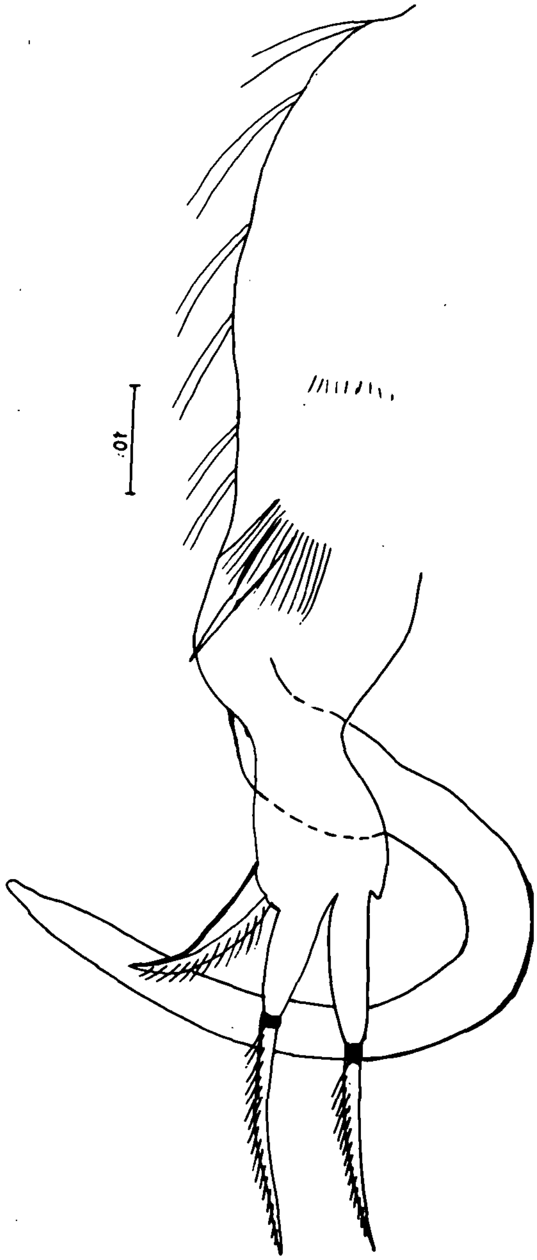

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Plate VI. *Pleuroxus similis*. Exuvium of Ephippial females.

a. Whole view showing the ephippial region.

b. Head shield showing the head pores :

1. anterior pore
2. posterior pore
3. Medium pores.

c. Shell showing the denticles on the posteroventral corner of the valve and the ventral margin with feathered setae.

Plate VI

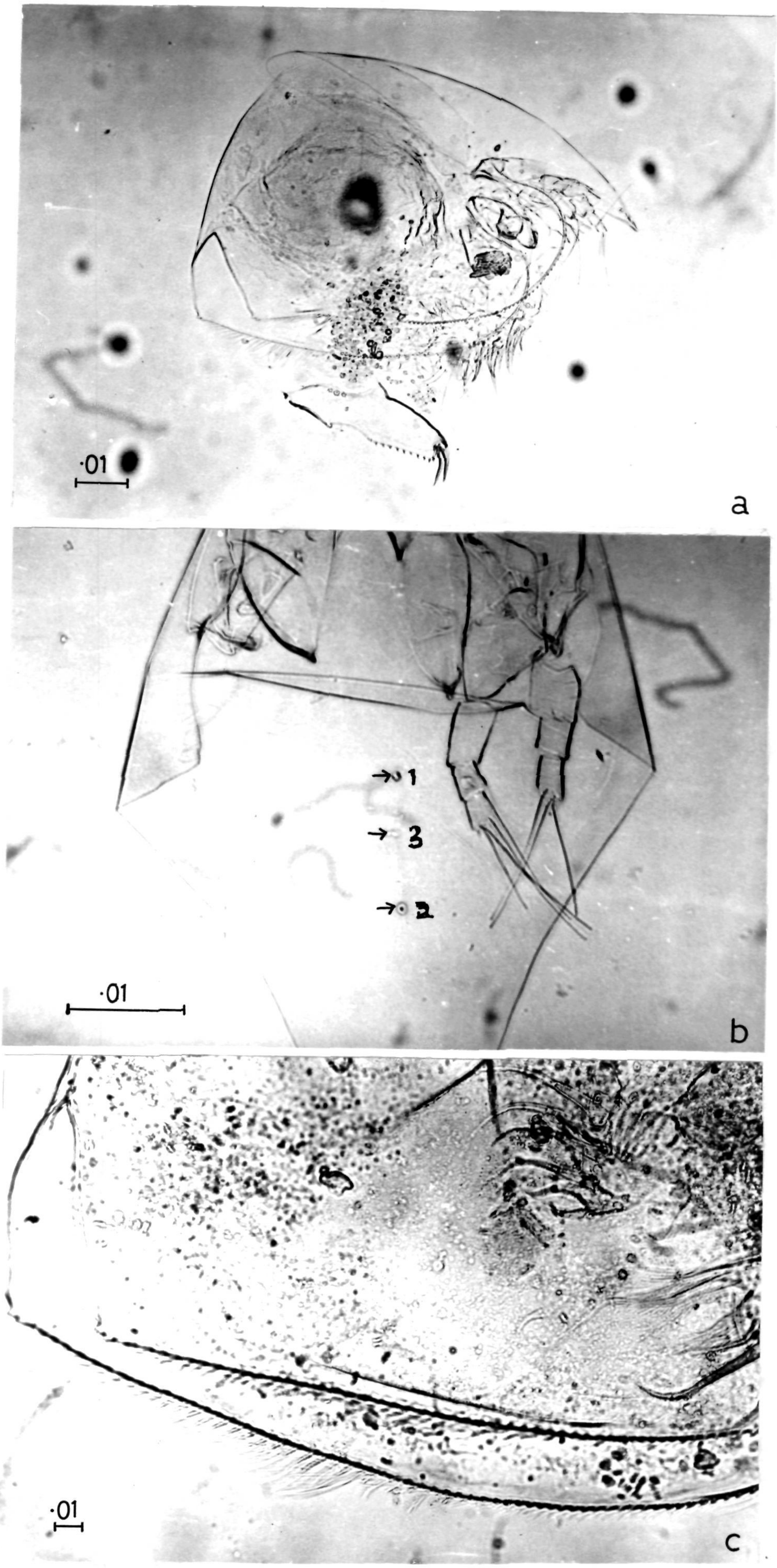


Plate VII. *Pleuroxus similis.* Ephippium.

a. The ephippium - enlarged.

b. Dissected view of the ephippium showing the foam-like material within.

c. Magnified view of the foam like material, within the ephippium.

Plate VII

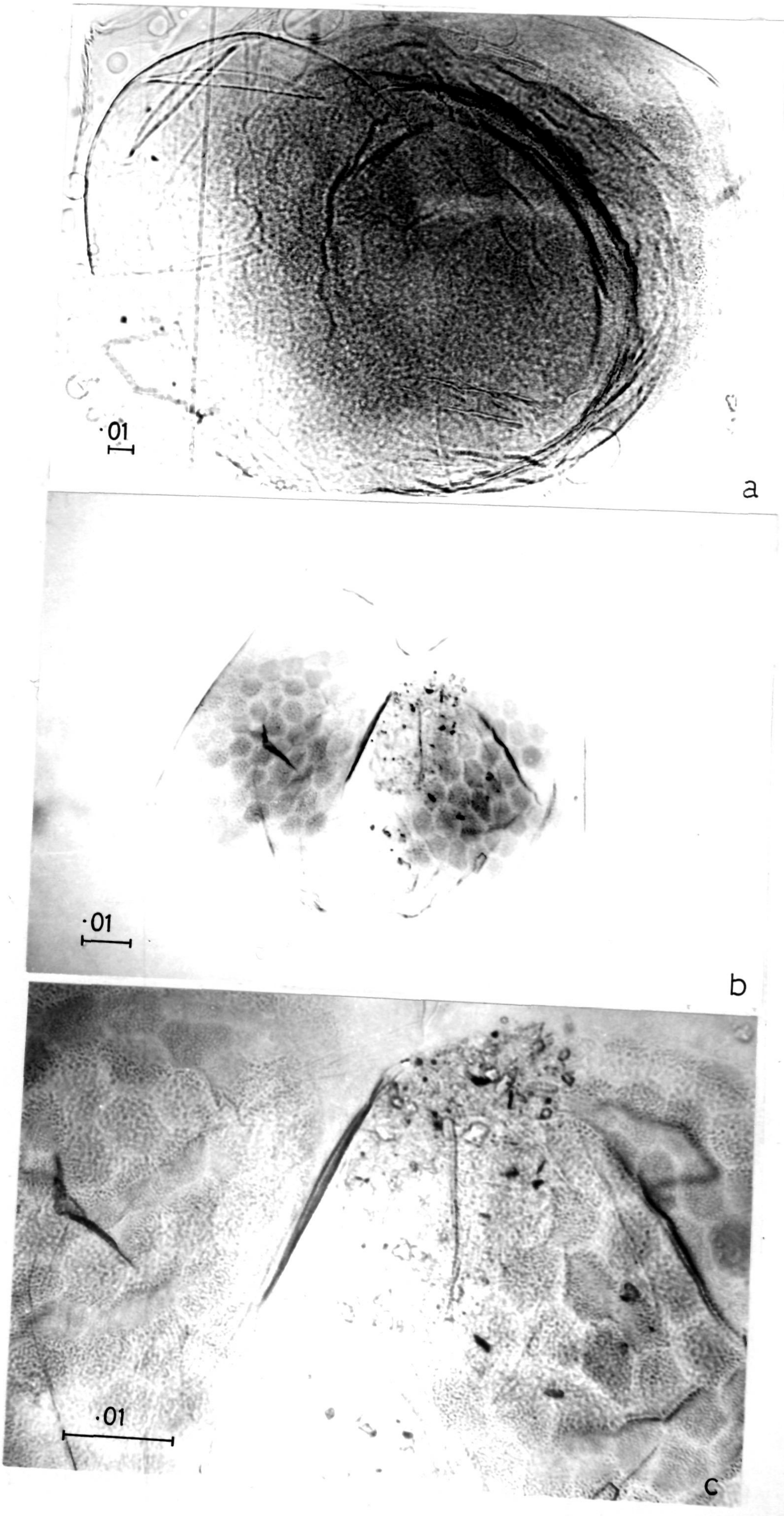


Plate XI. *Pleuroxus similis.* Ephippial female.

a. Dorsal view of the animal showing lateral compression of posterior margin of head shield and the valves.

b. Frontal view of the ephippial female showing the lateral bulge of the egg locule.

Plate XI

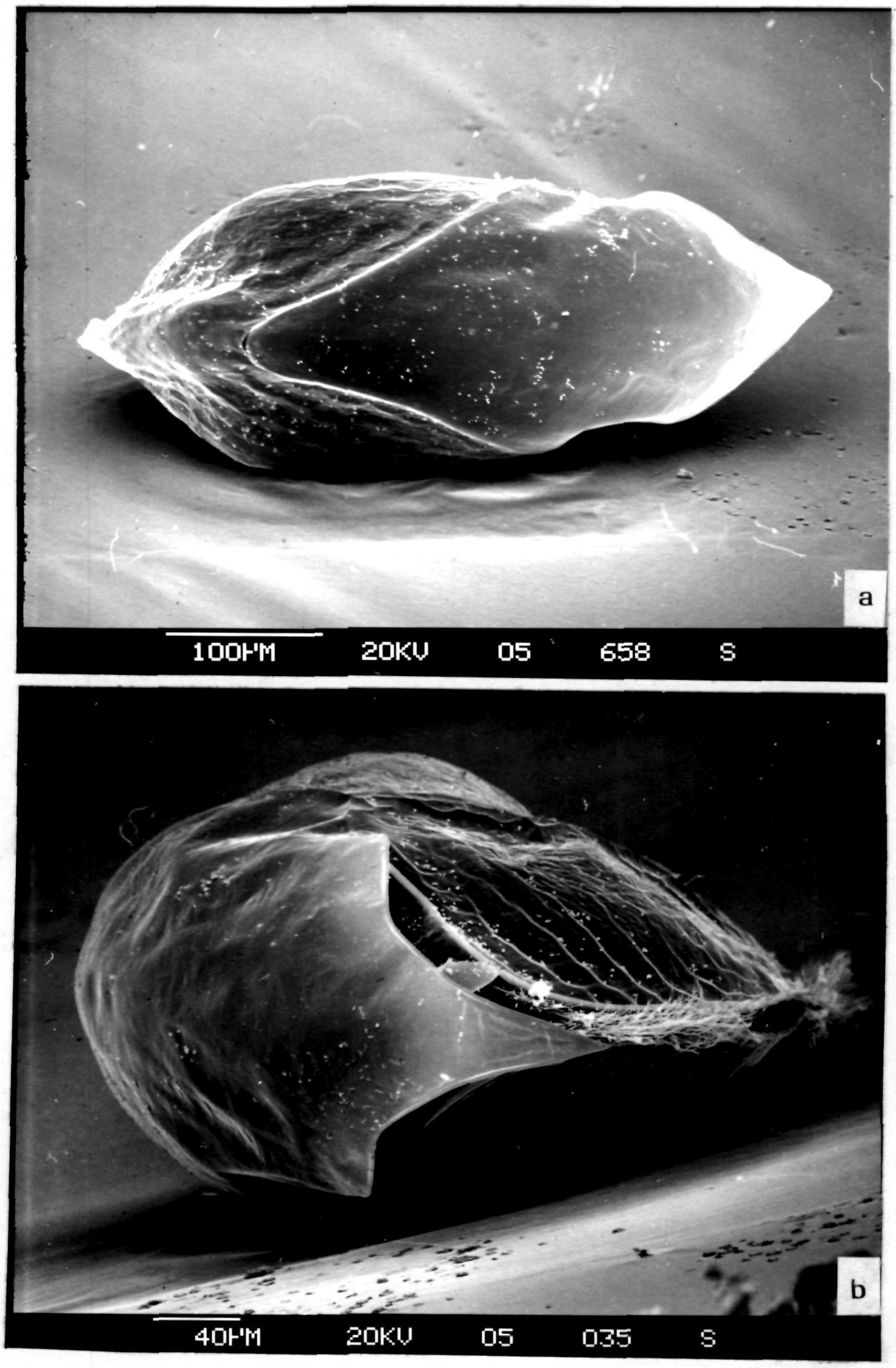


Plate XII. *Pleuroxus similis*. Males.

a. Mature male - side view.

b. Frontal view of mature male showing the short and rounded margin of the rostrum.

Plate XII

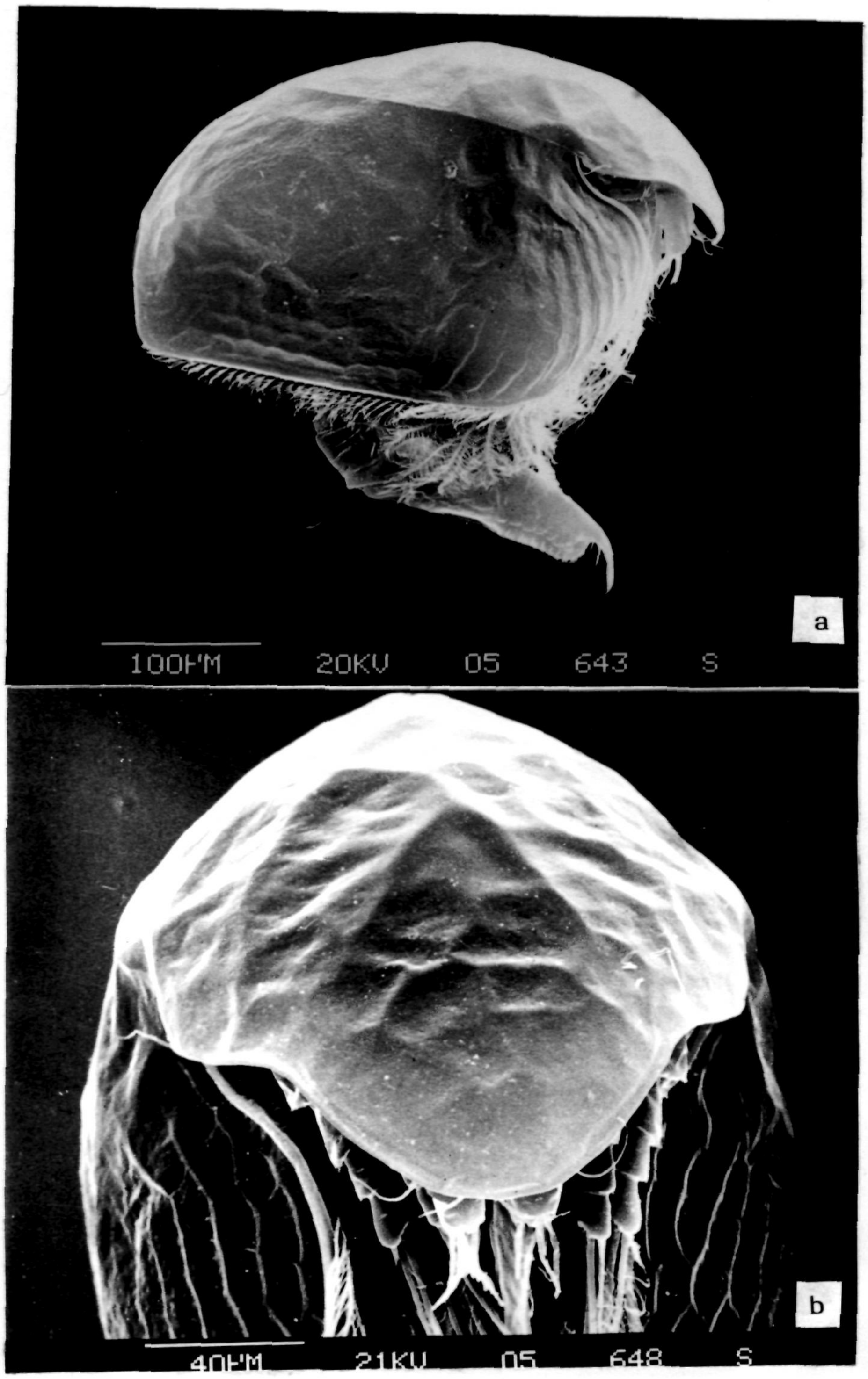
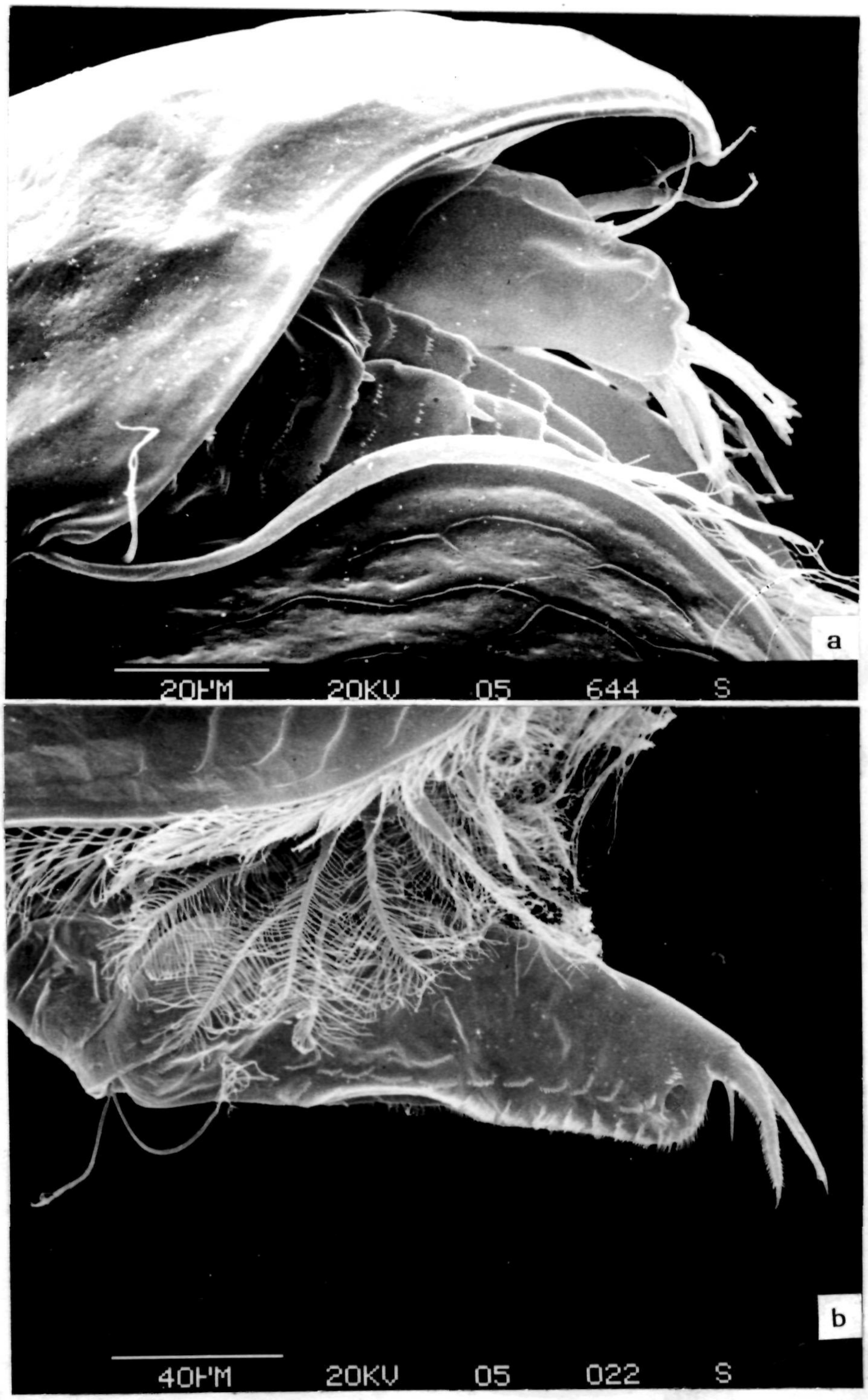


Plate XIII. *Pleuroxus similis.* Males.

a. Short and stout antennule showing aesthetacs and antenae.

b. Postabdomen with claws, genital pore, abdominal setae and the rounded preanal angle.

Plate XIII



the mature male is distinctly different in shape, the ventral margin of the shell is almost straight thus giving the body a slender shape towards the posterior end. The anterior part of the shell has 5 striae. The ventral portion of the shell shows reticulations. Marginal setae along the bulge longer than in female, very slender and with long hair-like lateral branches.

b) Trunk limb I (Plates.III and XV)

The copulatory hook in trunk limb I is more or less 'J' shaped in IInd instar male. The general morphology of male setae anlage is very much similar to those of the other chyorid males. In the instar male the copulatory hook is 'U' shaped with the tip tapered. The copulatory brush present in mature male.

c) Head and Rostrum (Plates. IV and XIII)

Less elongate as compared to the female. In the IInd instar male the head is more elongate as compared to that of mature male; broad at junction with shell tapering posteriorly. Rostrum of the IInd instar male narrower compared to mature male, with thickening on the ventral side. The rostrum of the mature male is short and broad, margin being distinctly convex. The lateral margin of the rostrum is almost rectangular. In side view it is short terminating at the level of antennule. The head pores situated posteriorly as compared to that of females. In IInd instar male distance of ocellus to eye half distance to apex of rostrum, but in mature males the distance of ocellus to eye more than the distance between the eye and tip of rostrum.

Plate IV *Pleuroxus similis.* Males.

3.e Head shield of II instar male.

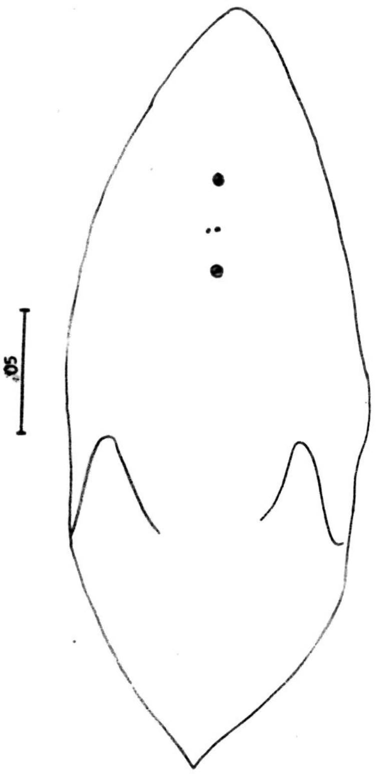
3.f Head shield of III instar male (mature).

3.g Postabdomen of II instar male showing the genital pore.

3.h Post abdomen of mature male showing the genital pore.

3.i Postabdominal claw of mature male with two basal spines.

PLATE-IV



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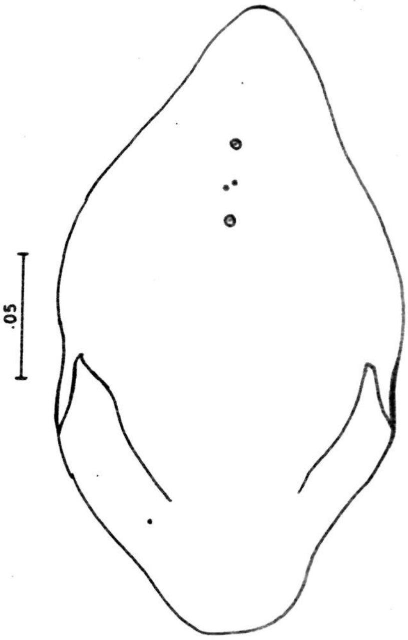

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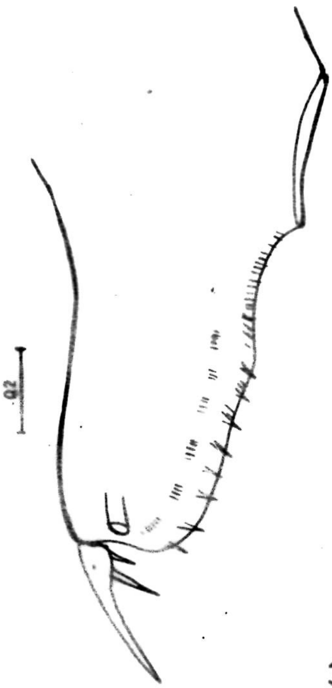

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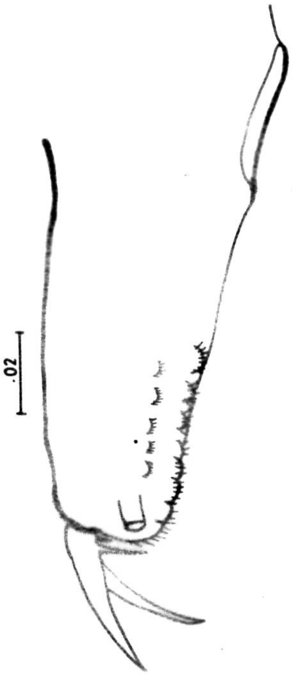

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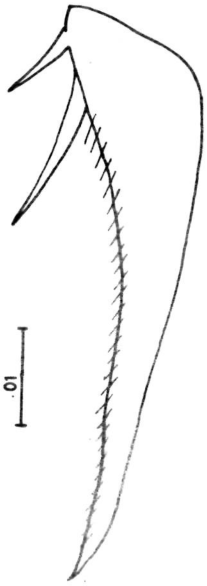

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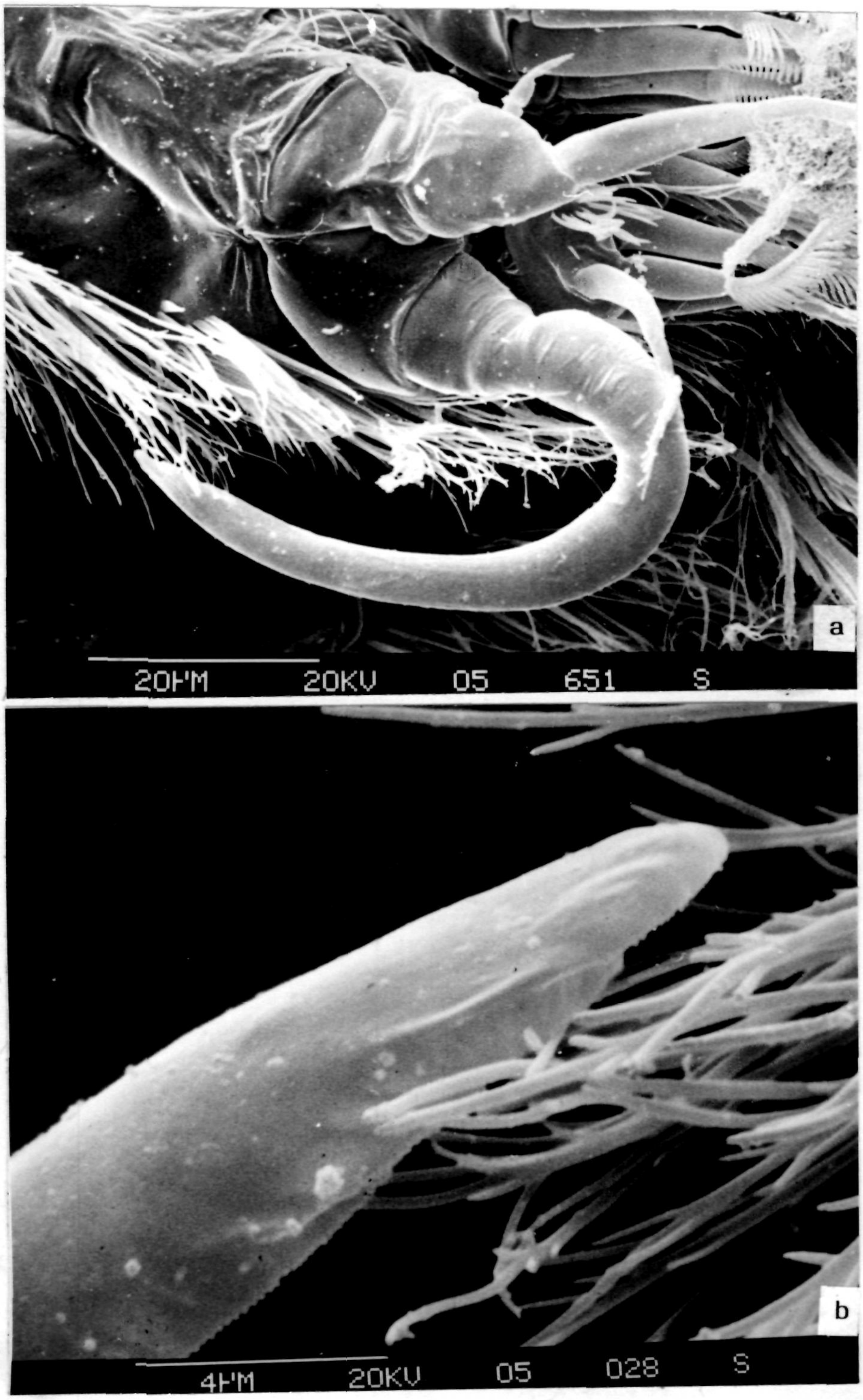
Plate XV. *Pleuroxus similis.* Copulatory hook of mature male.

a. Copulatory hook on trunk limb I.

b. Tip of copulatory hook and also the copulatory brush - enlarged.

Plate XV



d) Postabdomen (Plates. IV and XIV)

The postabdomen of the male is different from that of the female in being broader and more stout. The shape of the postabdomen also differs between the IInd and IIIrd instar males. In IInd instar males the postabdomen is broader as compared to that of mature males. The ventral margin in IInd instar is concave proximally whereas in mature males it is almost straight or even weakly convex. The position of the genital pore in the IInd instar male is more along the median plane as compared to that in mature males where it is situated on the distal dorsal margin of the postabdomen. The IInd instar male has the dorsal margin of the postabdomen armed with denticles (similar to those of females), but in mature males they are replaced by several rows of thin spines distally followed by several groups of spines, of which the proximal spine is always the longest. (Seen only in SEM). These group of spines appear as crescents under the light microscope.

In males the anal groove is armed with setules unlike those of females where it is unarmed. The preanal angle is not at all prominent and rather rounded in mature males. The abdominal setae long and reaches the anal groove when extended.

e) Postabdominal claw (Plate. IV)

The postabdominal claw is very similar to that of females.

f) Size (Fig.3)

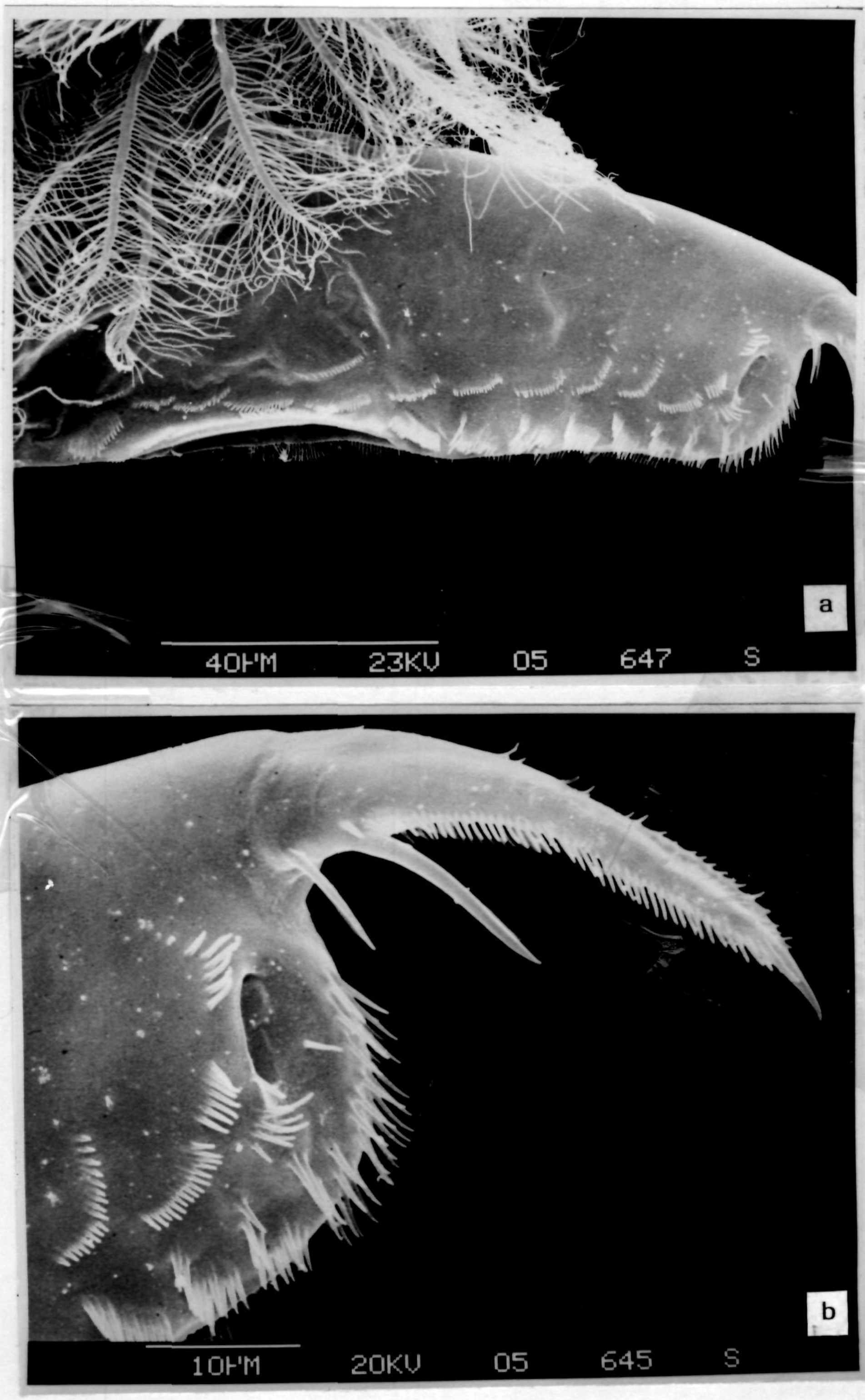
The size of Ist instar males ranged from 0.26-0.30mm (as was determined in the laboratory, though in the field the smallest male recorded

Plate XIV. *Pleuroxus similis*. Mature male postabdomen enlarged.

a. Postabdomen showing the anal groove armed with setules, and also showing the marginal setae along the ventral margin of the shell with long hair like lateral branches.

b. Tip of the postabdomen showing the genital opening, and also the postabdominal claw with two spines.

Plate XIV



was never below 0.30mm). The IInd instar size ranged from 0.30mm-0.35mm and the size range of III instar males was from 0.35mm-0.38mm.

Discussion

Pleuroxus similis as many other species of chydorids, is intercontinental in distribution rather than cosmopolitan. It has been reported to occur in south America (Chile, Argentina), Asia (USSR, India) and Australia (Northern N.S.W.). There is however no report of its occurrence in Europe and in North America.

When Vavra (1900) described the species for the first time from Chile in South America, he placed it in the *Pleuroxus hastatus* group or *Pleuroxus laevis* as it was known in Europe. But there were some significant differences between *Pleuroxus similis* and *Pleuroxus hastatus* in several characteristics such as ventral margin, size, number of antennal setae, shape of labrum, shape of postabdomen and the posteroventral angle of the valve. These differences were noticed by Vavra himself when he described *Pleuroxus similis* for the first time.

Morphological observations on the present species made during the present study agrees very closely with those made by Vavra (1900) and Sars (1901) on the South American population of *Pleuroxus similis* and it also agree with the description given by Smirnov (1971) on the USSR (northern Caucasus, Lake Issyk-Kul, Tashkent area) population. The description of *Pleuroxus similis* given by different authors are compiled and represented in Table:1.

Comparison made between the parthenogenetic females from

Table 1: Occurrence and description of *Pleuroxus similis* as given by different authors including the present study.

	Vavra, 1900	Sars, 1901	Smirnov, 1971	Smirnov and Timms, 1983	Present study
Occurrence	Chile, Valdivia	Argentina	USSR-Northern Caucasus, Lake Issyk-Kul', Tashkent Area.	Northern N.S.W. in Australia	Meghalaya in North Eastern India
Characters					
Mature Female (Parthenogenetic)					
1. Shape	The dorsal margin is highly arched. The ventral is slightly convex goes in a regular arch. The height not equal to length.	The dorsal margin arched, ventral angularly curved in front of the middle, posterior extremity gradually narrowed and truncated at the end.	Dorsal margin uniformly convex Posterior margin straight maximum height 3.4 times length of posterior margin.	-	Dorsal margin of the body is uniformly curved and the posterior margin is short and weakly convex.

Contd.2..

Table 1 contd..

	Vavra, 1900	Sars, 1901	Smirnov, 1971	Smirnov and Timms, 1983	Present study
2. Shell	No shell sculpturing. Posteroventral angle has two spines on the right valve and three spines on the left.	Surface of shell very faintly reticulate, anterior part ofthe valve however, sculptured with 10-12 rather distinct curved transverse striae. The lower edges finely ciliated. Inferoposteal corners each with 2 very small denticles.	Shell without sculpturing. Ventral margin of the shell with feathered setae posteroventral corner of the valve with 3-4 denticles.	-	Obscure reticulations on the valve in the posteroventral and ventral region. The anterior margin of the valve has 5-6 curved striae. Ventral margin with feathered setae, The posteroventral corner of the valve has 1-4 denticles with variations on the 2 valves in the same animal. The posteroventral corner of the shell has 3 spines on the inner margin.
3. Head	Low Rostrum pointed and lies close to the body. Antennules short and thick, hidden under the rostrum.	Comparatively small and procumbent. Rostral projection very long, acuminate and pointing obliquely behind. Antennulae short,scarcely, reaching to the middle of rostrum.Ocellus much smaller than eye, and almost 3 times nearer to it than to tip of rostrum.	Rostrum pointed reaching level of ventral margin of valve. Antennules ending far before apex of rostrum. Distance of ocellus to eye half its distance to apex of rostrum.	-	Elongate. Rostrum long and pointed downwards reaching level of ventral margin of valve. Antennules terminating far from the apex of rostrum; distance of ocellus to eye half distance to apex of rostrum.

Contd.

Table 1 contd..

	Vavra, 1900	Sars, 1901	Smirnov, 1971	Smirnov and Timms, 1983	Present study
4. Postabdomen	Seemingly long and equally broad, almost half is convex. Dorsal margin provided with 20 small spines equal in size.	Rather narrow and conspicuously tapering distally. Supra-anal projection well marked and defined below by a deep sinus, lower corner slightly produced and narrowly rounded; marginal denticles rather strong.	Slightly tapering. Dorsal distal corner of post abdomen situated slightly behind base of claws. Preanal corner blunt. 14-16 anal denticles.	Truncated slightly narrowing distally. And denticles are comparatively large, regularly diminishing proximally.	Elongated, tapering slightly towards distal end. Preanal angle moderately prominent. 9-14 anal spines increasing gradually in size distally.
5. Postabdominal claw	Presence of two basal spines	Moderate in size, each with 2 denticles at the base.	Presence of two basal spines	-	The dorsal margin of claw provided with setules. Presence of 2 basal spines, the distal is larger than proximal.
6. Size	0.55mm	0.48mm	0.50mm	0.50mm	0.41mm - 0.52mm
Ephippial Females	Not recorded	Not recorded	Not recorded	Not recorded	The shape is similar to parthenogenetic females, but provided with a prominent bulge laterally to accommodate. the egg locule. Surface of ephippium with reticulations. Head shield with strongly developed rectangular expansions at the commencement of the slough line.

Contd...

Table I contd..

	Vavra, 1900	Sars, 1901	Smirnov, 1971	Smirnov and Timms, 1983	Present study
IInd Instar Male	Not recorded	-	-	-	Recorded.
1. Shape	-	-	-	-	Similar to that of the young female.
2. Head	-	-	-	-	Less elongate as compared to that of females with thickening on the ventral side. Distance of ocellus to eye half distance to apex of rostrum.
3. Trunk limb I	-	-	-	-	The copulatory hook is more or less 'J' shaped.
4. Postabdomen	-	-	-	-	Broad, ventral margin concave. Position of genital pore along the median plane. Dorsal margin armed with denticles.
5. Size	-	-	-	-	0.30mm - 0.35mm.
Mature male					
1. Shape	-	-	-	-	Slender, with ventral margin of the body being almost straight; ventral portion of shell shows reticulations. Marginal setae longer than those of the females with long hair like lateral branches.

Contd...

Table 1 contd.

	Vavra, 1900	Sars, 1901	Smirnov, 1971	Smirnov and Timms, 1983	Present study
2. Head	Not recorded	-	-	-	Rostrum short and broad with convex margin, terminating at the level of antennule.Head pores situated posteriorly. The distance of ocellus to eye more than the distance between the eye and tip of rostrum.
3. Trunk limb I	-	-	-	-	The copulatory hook is 'U' shaped with the tip tapered. Copulatory brush present.
4. Post abdomen	-	-	-	-	Stout and broad. The position of the genital pore is along the distal dorsal margin of the postabdomen. Dorsal margin of the postabdomen armed with short rows of long spines. Anal groove armed with setules.
5. Size	-	-	-	-	0.35mm - 0.38mm.

Sars collection of south American population (Parthenogenetic female from Zoological Museum, Oslo No. NRF 12391 *Pleuroxus similis* Vavra. Sted: Argentina. lg G.O. Sars. Plate V) and the specimen presently studied, shows that females in both cases are similar in size, shape of postabdomen, shell sculpture, size of the eye and the ocellus, distance between the eye and the ocellus and ocellus to tip of the rostrum and also the length of the antennulae.

The Australian *Pleuroxus similis* as studied from the permanent mounts (Parthenogenetic females from Australia Nos. N 58, N100C N110e permanent mounts. Plate V) are smaller in size as compared to the females from south America and India. The preanal angle is much more pointed as compared to those of South American and Indian specimens.

Unfortunately, no specimens were available from USSR, so comparison had to be based only on description given bySmirnov (1971). However, no gamogenetic or male populations were ever recorded in any of the earlier studies and hence no description in the literature are available.

In the ephippial female, the portion of the shell in which the eggs are located bulges out to form a locule. The surface of the shell is provided with fine reticulations and is also structurally modified. The inner surface of the ephippial case is provided with foamlike mass, which protects the eggs from damage, as also reported in other chydorid species (Michael and Frey 1983, Michael and Frey 1984, Frey 1988).

Cladoceran males are different from the females morphologically. They are usually smaller in size as compared to that of the females. Rostrum is shorter and broader, the first trunk limb in the adult is invariably modified

Plate V. *Pleuroxus similis*. Parthenogenetic females from Argentina (NRF 12391)

4.a Whole view of mature parthenogenetic female.

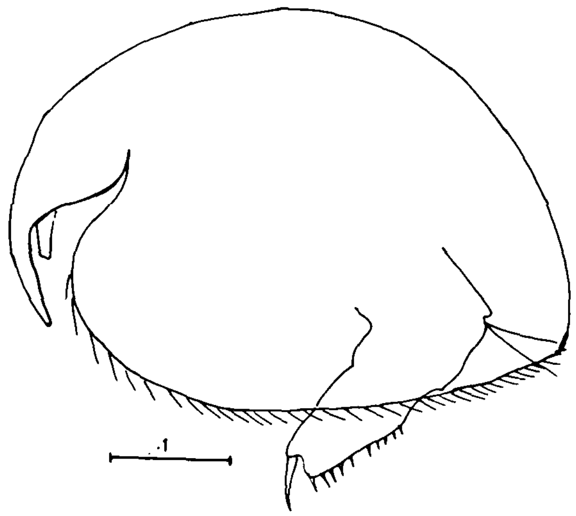
4.b Postabdomen and postabdominal claw.

Pleuroxus similis. Parthenogenetic females from Australia (N58, N100e, N110c)

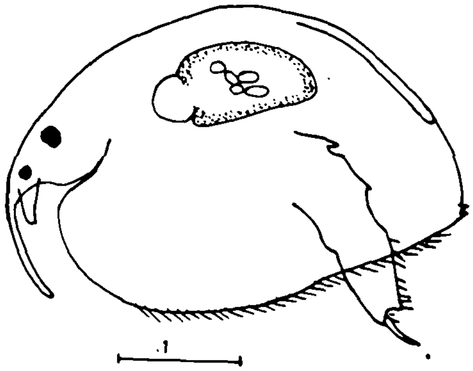
5.a Whole view of mature parthenogenetic female.

5.b Postabdomen and postabdominal claw.

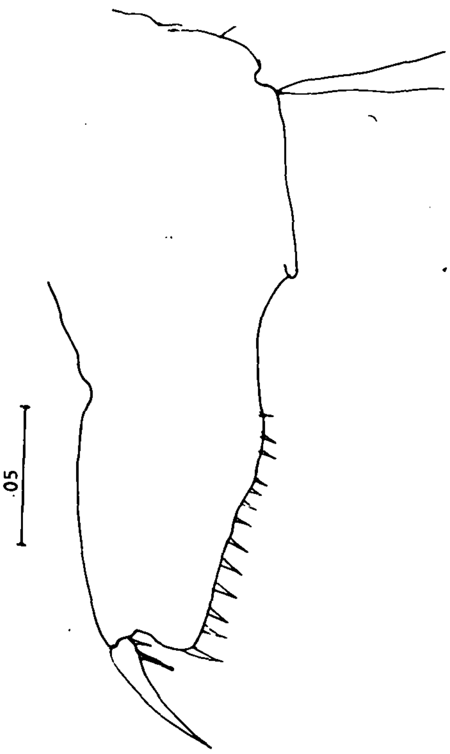
PLATE-V



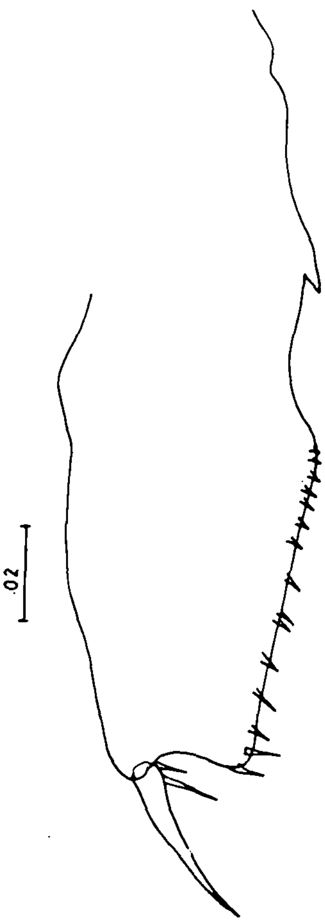
4a



5a



4b



5b

into a copulatory hook and the postabdomen changes from the female configuration to function in sperm transfer. In the present studies too, the male is different from that of the female in size, shape of the body, rostrum and the postabdomen. Thus, it may be concluded that the species which was thought to have constituted only of parthenogenetic population also has a gamogenetic phase in its life cycle which constitutes the gamogenetic population during certain periods of the year.

In this context it may be mentioned that *Pleuroxus similis* tends to become gamogenetic during early winter and spring viz., from Feb. to April. According to Frey (1982) the period of gamogenesis in Cladocerans depends upon the stressful environmental conditions like extreme cold or heat and accordingly the individuals adapt to these conditions by becoming gamogenetic either during autumn or during spring. Depending on this strategy of gamogenesis, the species may be termed as 'southern' species which are more adapted to warmer climates and hence enter into gamogenesis during autumn to overcome the intense cold, or they may be 'northern' species, which are more suitably adapted to colder climate and hence enter gamogenesis during spring to overcome the intense summer heat.

In Northern latitudes both in Europe and America where the winters are severe, gamogenesis among different groups of Cladocerans like *Camptocercus lilljeborgi, Leydigia leydigi, Chydorus piger, Alonopsis elongata, Pleuroxus trigonellus Acroperus harpae, Pleuroxus procurvus, Pleuroxus denticulatus Chydorus globosus* and *Monospilus dispar* occurs chiefly immediately prior to winter before the lakes freeze over during the winter and the cladoceran population is monocyclic with autumnal gamogenesis being very important. But with milder winter conditions southwards (Florida, USA, 25°N), the period of gamogenesis of these species shifts from those of autumnal one to a spring or vernal gamogenesis, suggesting a shift in the season of stress of these animals from winter to summer. Many of the northern species tend to die out in summer because of high temperature, and their place is taken by the 'southern' species like *Euryalona orientalis* and *Chydorus pubescens*, which became gamogenetic in autumn and reduced to very low numbers during winter. However, gamogenesis in south, whether in spring or autumn is not so well coordinated as autumnal gamogenesis in the north. It is usually noticed in the south that gamogenesis among 'northern' species peak in April to mid May and among 'southern' populations in October and November, for strictly vernal species gamogenesis tends to occur in March. But further south near the tropics (Peru, 12°2'N) different species undergo gamogenesis during different periods of the year like *Alona cambouei* in April, *Alona diaphana* in July and *Ilyocrytpus spinifer* in December, thus suggesting that gamogenesis occurs in the tropical population in a scattered and uncoordinated manner.

So when the gamogenetic strategy of *Pleuroxus similis* is compared with the earlier records on other chydorids from Europe and America, it is quite clear that this species is a 'northern' species or may even be a strictly 'vernal' species, since the peaks in gamogenesis are recorded during February and March, and it would be favourably adapted to the temperate regions rather than the sub-tropical regions (Shillong 25°5'N 91°9' E where the summer temperature of 26°C and above prove to be a stressful environmental condition for these organisms. Their common occurrence in lakes of

Kashmir further coroborates the above contention.

However, during the present course of study, a very small number of gamogenetic females were recorded in the month of October (during autumn). This could be attributed to the short photoperiod during this time of the year in this north-eastern part of India, and which is known to cause gamogenesis among cladocera. This has also been demonstrated by Shan (1975) in the northern species of *Pleuroxus denticulatus*.

RESULTS AND DISCUSSIONS

(a) Life Cycle patterns of *Pleuroxus similis* reared individually in different Culture media.

Results

The mean length of neonate cultured at 15°-20°C in the two different media (filtered pond water and chicken manure) measured0.31mm, while those cultured in rice bran had a mean length of 0.30mm. The neonate resembled the adult in all characters, and passed through two or three preadult instars and thirteen adult instars. Since majority of the neonate underwent three juvenile instars, the number is expressed as three in the Tables.

The mean length of the primiparous instar measures about 0.41mm except in chicken manure where it measured about 0.42mm. The maximum size of adults measured 0.48mm in filtered pond water which was attained at the eleventh instar (Table:2). In chicken manure the maximum size of the adult was 0.52mm reached at the thirteen instar (Table:3) and in rice bran the maximum size of 0.47mm was reached at the twelveth instar (Table:4). The mean life span of the animals in filtered pond water was 59.6±1.23 days. In chicken manure the mean life span was61.2±1.64 days, and rice bran life spanwas63.4±1.47 days. The preadult instars have a duration of 72 hours in all the three media, while in case of adult instars the time varied between 72-120 hours.

Growth curves for the two morphometric dimensions i.e. body length and carapace height in the three different media are represented in Figs. 4, 5 and 6. It is seen that the growth curves in the three different

Table 2: Mean length, carapace height, number of eggs/brood, and duration of instars of *Pleuroxus similis* at 15°-20°C cultured in filtered pond water. (n=50)

Instars	Length (mm)	S.D. ±	Carapace height(mm)	S.D. ±	No.of eggs per brood	S.D. ±	Duration of Instars(hrs)	S.D. ±
1	0.31	0.006	0.19	0.006	-	-	72	0.516
2	0.35	0.007	0.22	0.008	-	-	72	0.351
3	0.37	0.007	0.26	0.009	-	-	72	0.723
4	0.41	0.012	0.30	0.003	2	0.414	120	0.833
5	0.43	0.005	0.31	0.004	2	0.703	72	0.703
6	0.44	0.055	0.31	0.006	2	0.828	72	0.990
7	0.45	0.004	0.34	0.008	2	0.975	72	01.21
8	0.45	0.005	0.34	0.004	2	0.865	72	0.743
9	0.46	0.005	0.35	0.005	2	0.743	120	0.883
10	0.47	0.006	0.35	0.005	2	0.858	72	0.828
11	0.48	0.005	0.36	0.004	2	1.02	120	0.899
12	0.48	0.007	0.36	0.006	2	0.820	120	0.952
13	0.48	0.003	0.36	0.007	2	0.978	72	0.884
14	0.48	0.004	0.37	0.004	-	-	72	0.786
15	0.48	0.003	0.37	0.003	-	-	120	0.435
16	0.48	0.004	0.37	0.005	-	-	120	0.588

Table 3: Mean length, carapace height, number of eggs/brood, and duration of instars of *Pleuroxus similis* at 15°-20°C cultured in chicken manure. (n=50)

Instars	Length (mm)	S.D. ±	Carapace height(mm)	S.D. ±	No.of eggs per brood	S.D. ±	Duration of Instars(hrs)	S.D. ±
1.	0.31	0.004	0.19	0.008	-	-	72	0.411
2	0.34	0.008	0.21	0.006	-	-	72	0.519
3	0.37	0.007	0.25	0.008	-	-	72	0.689
4	0.42	0.005	0.30	0.005	2	0.551	120	0.788
5	0.44	0.008	0.30	0.006	2	0.857	72	0.581
6	0.45	0.006	0.32	0.008	2	0.987	120	0.980
7	0.45	0.008	0.32	0.004	2	1.501	72	0.756
8	0.45	0.005	0.33	0.008	2	0.956	72	0.645
9	0.47	0.007	0.33	0.008	2	0.856	72	0.558
10	0.47	0.006	0.33	0.008	2	1.207	72	0.875
11	0.48	0.009	0.34	0.007	2	0.995	120	0.587
12	0.50	0.006	0.35	0.003	2	0.766	72	0.758
13	0.52	0.009	0.36	0.008	2	0.665	120	0.788
14	0.52	0.006	0.36	0.007	2	0.788	120	0.438
15	0.52	0.004	0.36	0.005	-	-	120	0.339
16	0.52	0.002	0.36	0.004	-	-	120	0.356

Table 4: Mean length, carapace height, number of eggs/brood and duration of instars of *Pleuroxus similis* at 15°-20°C cultured in rice bran. (n=50).

Instars	Length (mm)	S.D. ±	Carapace height(mm)	S.D. ±	No.of eggs per brood	S.D. ±	Duration of Instars(hrs)	S.D. ±
1	0.30	0.005	0.19	0.006	-	-	72	0.418
2	0.34	0.008	0.21	0.004	-	-	72	0.552
3	0.37	0.004	0.26	0.004	-	-	72	0.358
4	0.41	0.014	0.30	0.003	2	0.314	120	0.885
5	0.42	0.005	0.31	0.006	2	0.588	72	0.567
6	0.44	0.0087	0.31	0.006	2	0.825	120	0.875
7	0.44	0.004	0.32	0.007	2	1.005	120	0.742
8	0.45	0.008	0.33	0.006	2	0.978	72	0.853
9	0.45	0.007	0.33	0.004	2	0.289	72	0.788
10	0.45	0.006	0.34	0.005	2	0.888	120	0.688
11	0.46	0.004	0.35	0.006	2	0.925	120	0.785
12	0.47	0.008	0.36	0.007	2	0.988	72	0.865
13	0.47	0.006	0.36	0.006	-	-	72	0.642
14	0.47	0.004	0.36	0.004	-	-	120	0.698
15	0.47	0.004	0.37	0.005	-	-	120	0.521
16	0.47	0.003	0.37	0.004	-	-	120	0.452

Fig.4. Growth curve for body length and carapace height for *Pleuroxus similis*.

Fig. 4

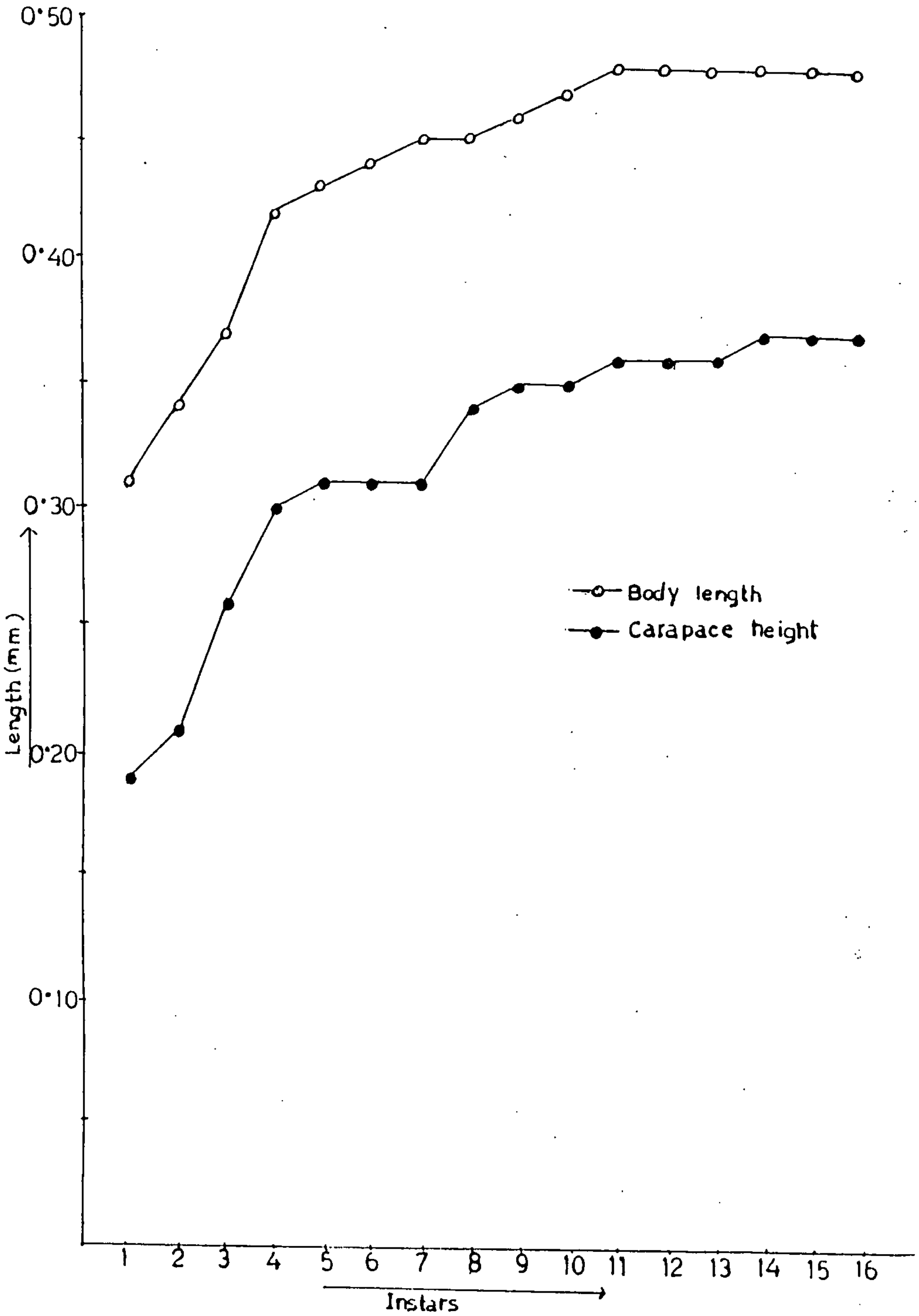

0·50
0·40
0·30
0·20
0·10
Length (mm)
Body length
Carapace height
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Instars

Fig.5. Relation between Instars and body length of *Pleuroxus similis* in:

Filtered pond water

Rice bran

Chicken manure

Fig. 5

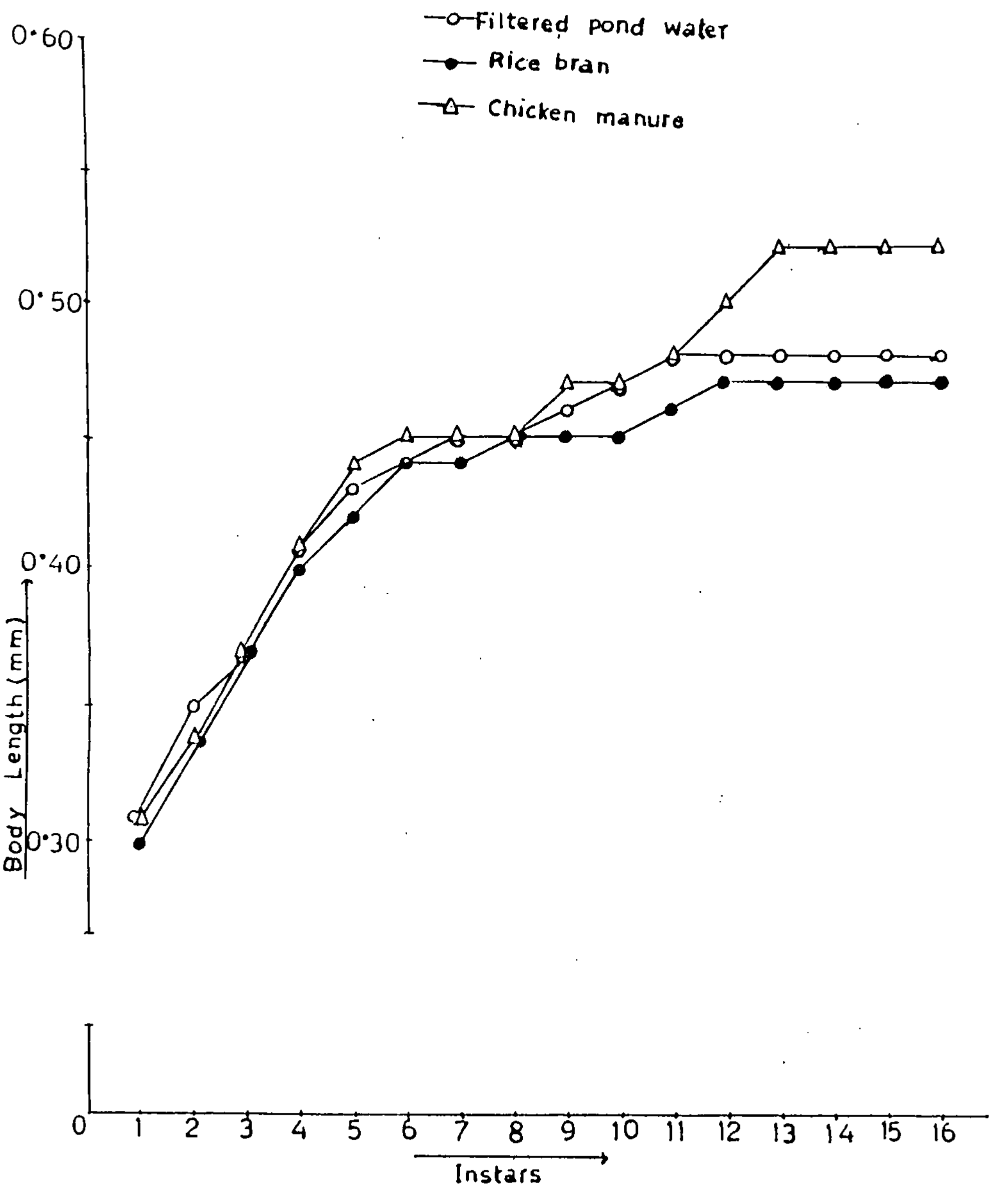

Filtered pond water
Rice bran
Chicken manure
0·60
0·50
0·40
0·30
Body Length (mm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Instars

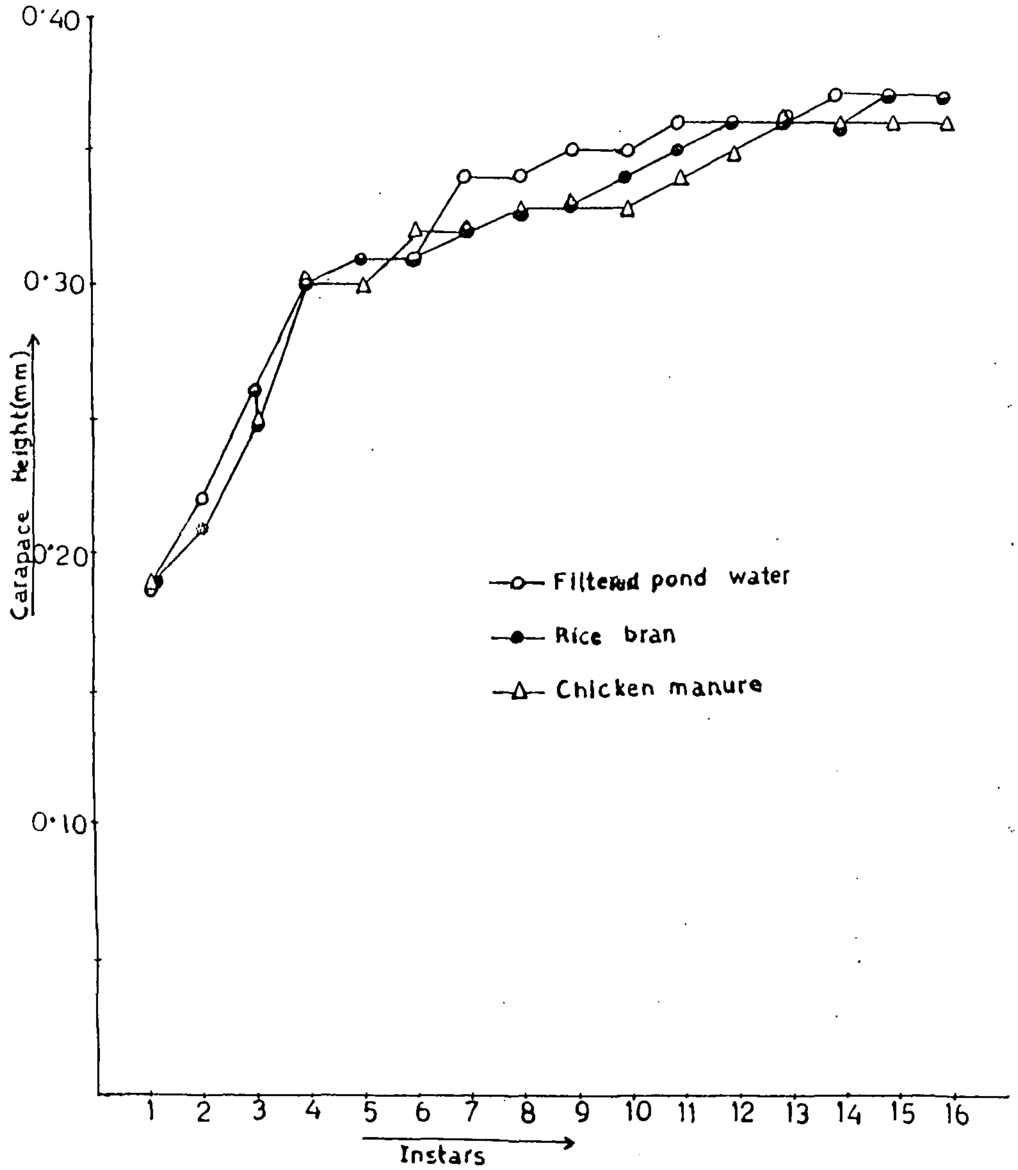
Fig.6. Relation between Instars and carapace height of *Pleuroxus similis* in:

Filtered pond water

Rice bran

Chicken manure

Fig. 6



0·40
0·30
0·20
0·10
Carapace Height (mm)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Instars
Filtered pond water
Rice bran
Chicken manure

media are not significantly different (Table:5). Growth rates of individual animals in the different culture media are represented in Fig.7.

Experiments carried out in the filtered pond water medium (i.e. 30°C) and with continuous illumination showed a marked differences in the time of instar duration. The duration of both preadult and adult instars were reduced to 48 hours, as compared to 72 and 120 hours at 15°-20°C. The mean size of the neonate measured about 0.30mm, the size of primiparous animal was about 0.41mm, while the size of the adult female was 0.47mm reached at the twelvth instar (Table:6). The mean life span of the animals was 31.00±1.77 days.

Growth curves at two different temperatures at 15°-20°C and at 30°C are represented in Fig.8.

The duration of instars at two different temperatures were also found to be significantly different, i.e. t=4.13 d.f. 30 ($p > .011$). It is seen that at higher temperature (30°C) the duration of instars becomes less compared to that at 15°-20°C as shown graphically in Fig.9.

Growth rates of individual animals in two different temperatures i.e. 15°-20°C and 30°C are represented in Fig.10. The growth rate at 30°C is more or less uniform, whereas at 15°-20°C, the growth rate seems to fluctuate. Initially from the first to third instar there is an increase in growth rate, when it suddenly decreases at the fourth instar only to increase at the fifth instar, to remain steady till the eighth instar and decreases again. Following this an increase in the tenth instar occurred which again decreases at the eleventh instar, to remain steady till the twelveth instar.

Table 5: Comparison of growth curves of *Pleuroxus similis* in three different culture medium using two way ANOVA.

Parameter	Sources of variance	d.f.	MSS	Variance Ratio
Growth curve of *P. similis*	Between medium	2	0.0025	$F_1 = 0.114$ **N.S.**
	Between instars	15	0.009	$F_2 = 0.41$ **N.S.**
	Error	30	0.022	

Fig.7. Growth rates of *Pleuroxus similis* in:

Filtered pond water

Rice bran

Chicken manure

Fig. 7

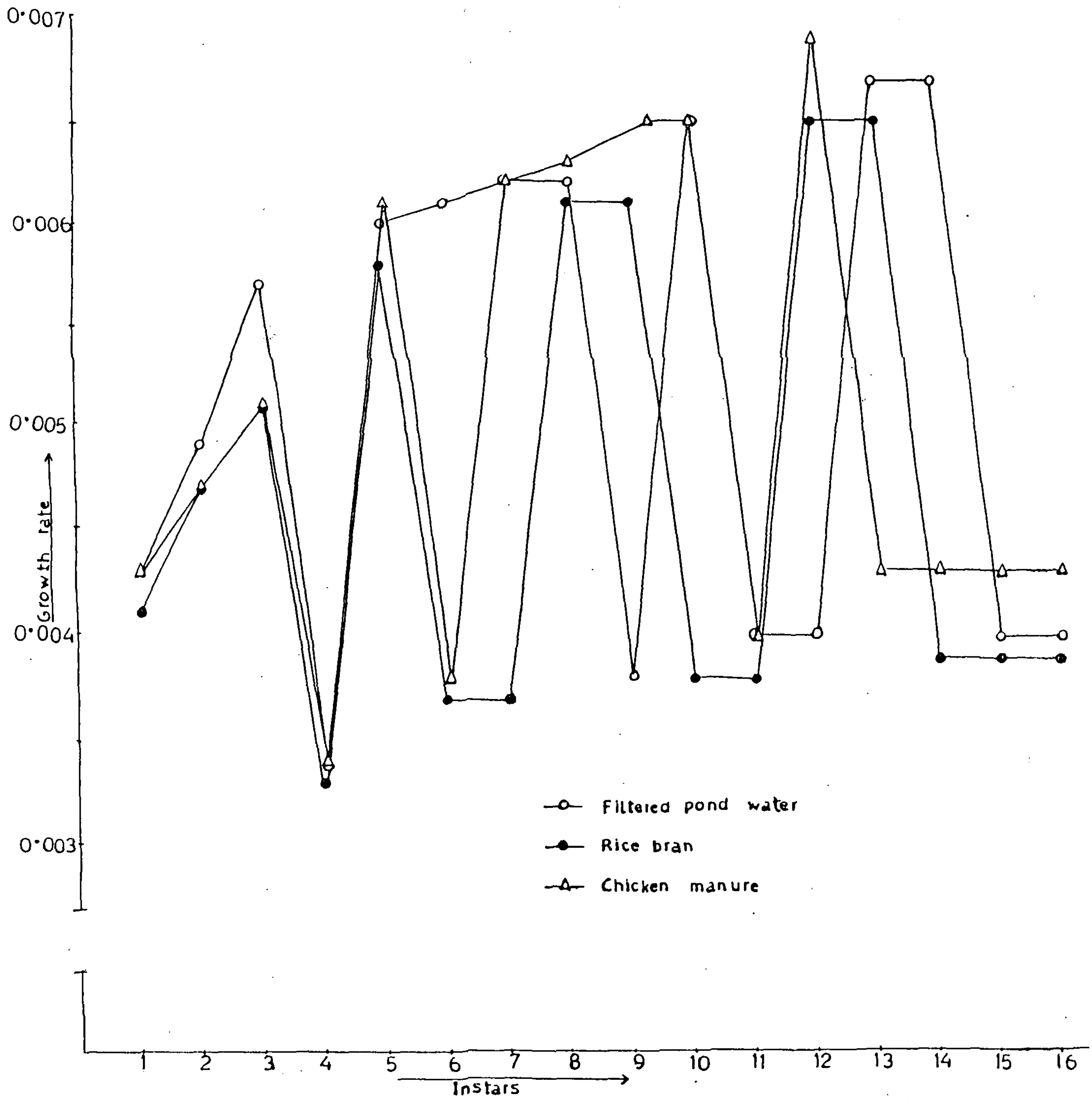

0·007
0·006
0·005
0·004
0·003
Growth rate
Filtered pond water
Rice bran
Chicken manure
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Instars

Table 6: Mean length, carapace height, number of eggs/brood and duration of instars of *Pleuroxus similis* at 30°C cultured in filtered pond water. (n=50)

Instars	Length (mm)	S.D. ±	Carapace height(mm)	S.D. ±	No.of eggs per brood	S.D. ±	Duration of Instars(hrs)	S.D. ±
1	0.30	0.006	0.19	0.004	-	-	48	0.703
2	0.35	0.007	0.21	0.005	-	-	48	0.755
3	0.38	0.004	0.24	0.005	-	-	48	0.855
4	0.41	0.006	0.30	0.004	2	0.732	48	0.641
5	0.43	0.008	0.31	0.006	2	0.888	48	0.852
6	0.44	0.005	0.31	0.004	2	0.985	48	0.856
7	0.45	0.004	0.31	0.003	2	0.654	48	0.752
8	0.45	0.004	0.33	0.006	2	1.020	48	0.975
9	0.45	0.004	0.34	0.005	2	0.710	48	0.651
10	0.46	0.006	0.34	0.006	2	0.512	48	0.448
11	0.46	0.004	0.36	0.005	2	0.751	48	0.859
12	0.47	0.005	0.36	0.004	2	0.855	48	0.985
13	0.47	0.005	0.36	0.006	2	0.978	48	0.652
14	0.47	0.004	0.37	0.005	2	1.005	48	0.822
15	0.47	0.006	0.37	0.004	-	-	48	0.589
16	0.47	0.006	0.37	0.006	-	-	48	0.586

Fig.8. Growth curves of *Pleuroxus similis* at:

15°-20°C

30° C

Fig. 8

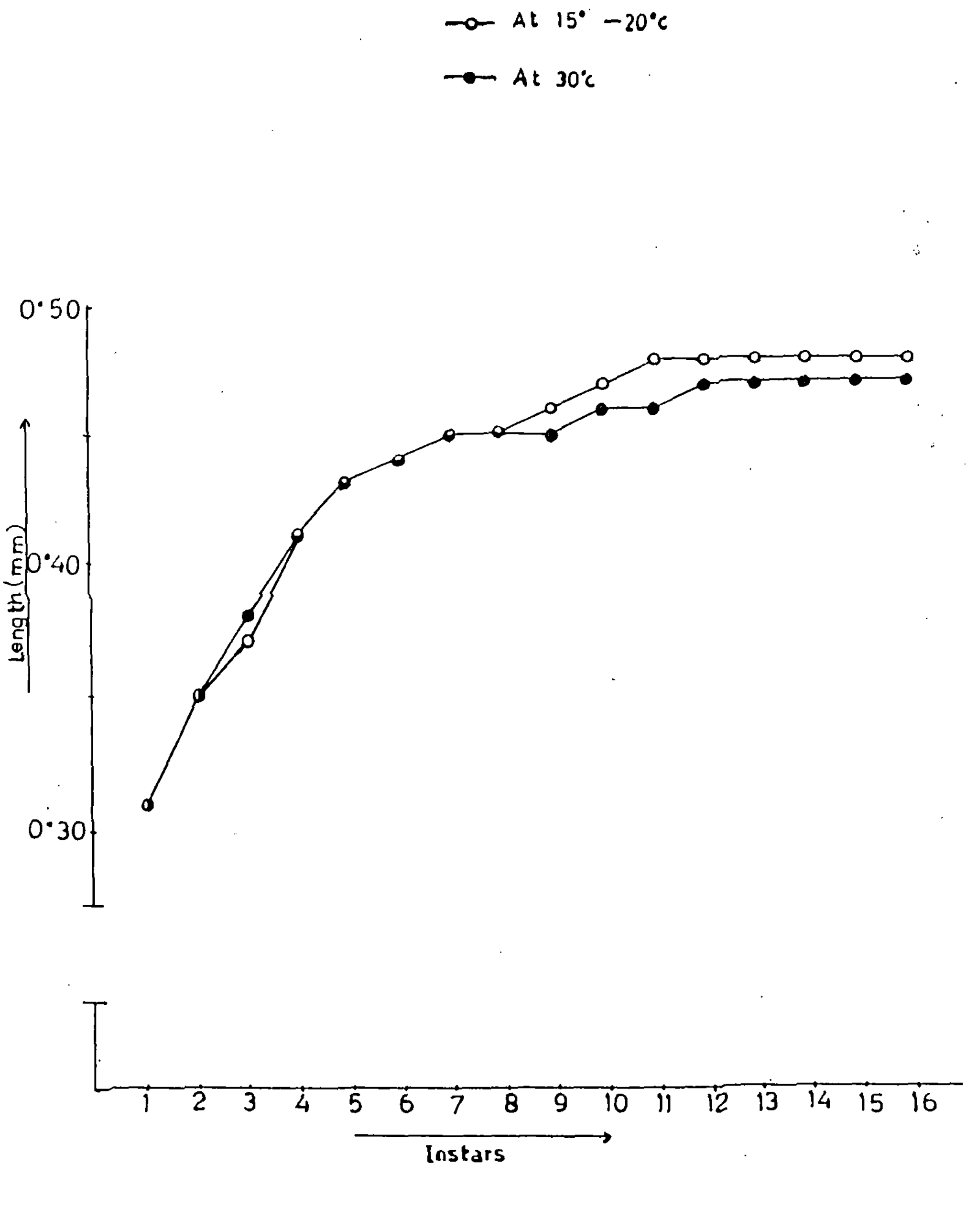
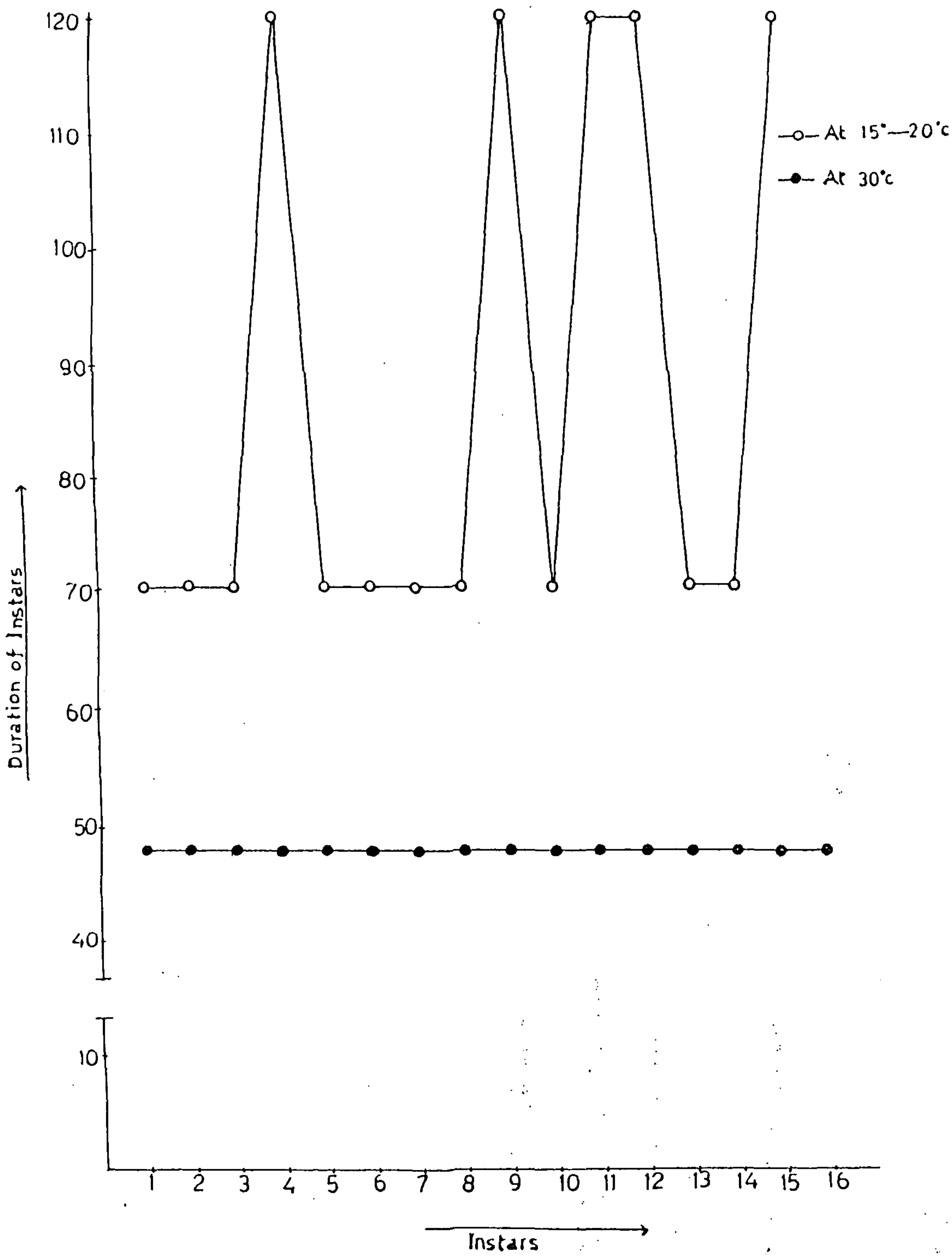

At 15° –20°c
At 30°c
0·50
0·40
0·30
Length (mm)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Instars

Fig.9. Duration of Instars in *Pleuroxus similis* at:

15°-20°C

30°C

Fig. 9



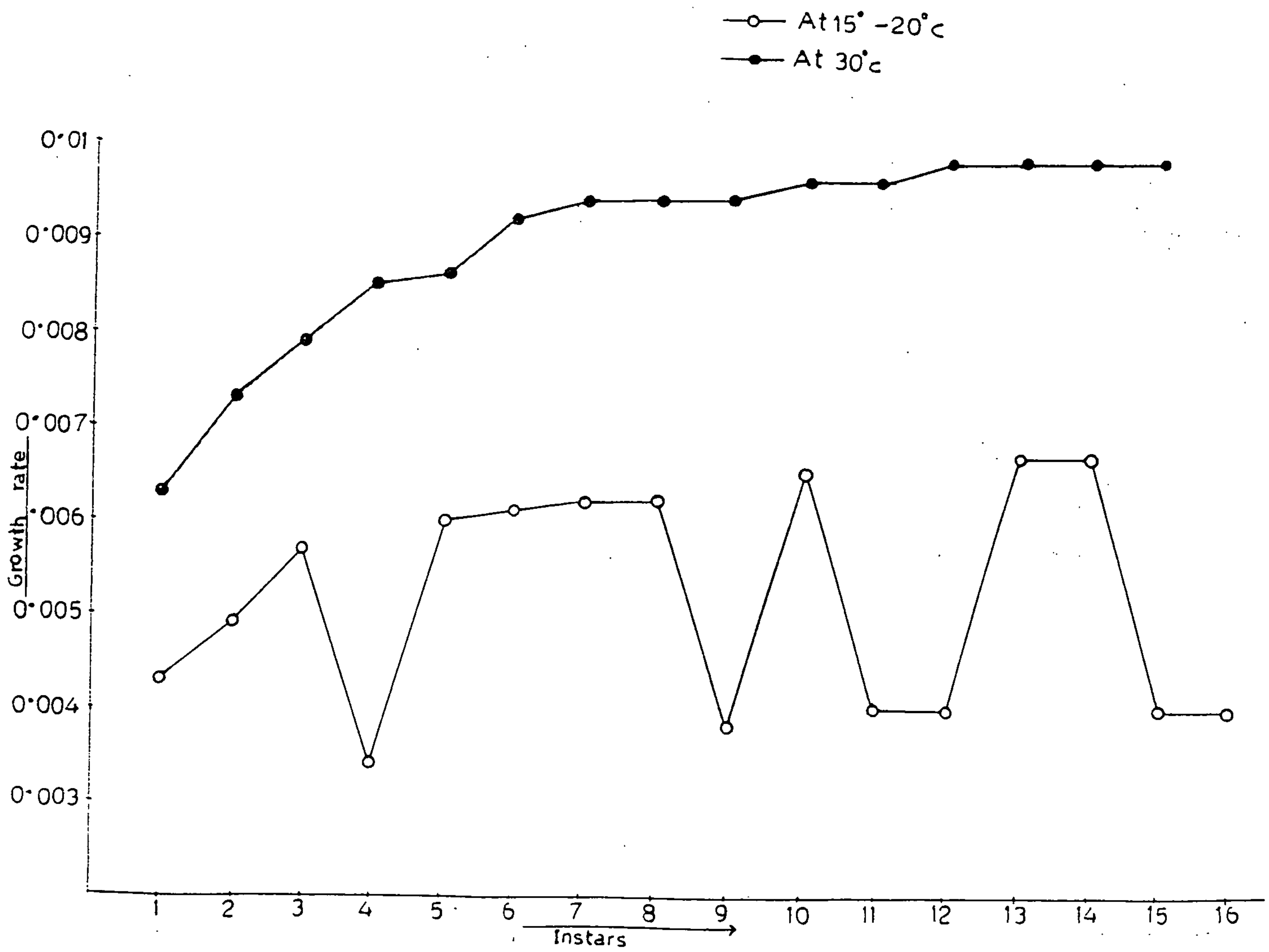
120
110
100
90
80
70
60
50
40
10
Duration of Instars
—o— At 15°—20°c
—●— At 30°c
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Instars

Fig.10. Growth rates of *Pleuroxus similis* at:

15°-20°C

30°C

Fig. 10


At 15° -20°c
At 30°c
0·01
0·009
0·008
0·007
·006
0·005
0·004
0·003
Growth rate
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Instars

Subsequently, another increase in the thirteenth instar occurred and remaining steady till fourteenth instar, and then finally decreases in the fifteenth instar and remains thus till the animal dies. The body length and the carapace height are interrelated indices of the body size. Regression analysis for parthenogenetic females was worked out for body length versus carapace height (Fig.11) and the relationship was found to be linear. The equation for the regression is $y=0.9684x - 0.099$.

Survivorship curves for *Pleuroxus similis* were plotted for two generations - N_1 and N_2. In both the generations, the curve is of Type-I, in which mortality acts heavily on old individuals (Fig.12) as also reported by Slobodkin (1962).

The life cycle of males were also observed at 15°-20°C cultured in filtered pond water. The males were observed to have three instars, out of which the first two instars were immature, and the third was the mature or adult instar. The mean length of the first instar measures about 0.30mm while the adult instar had a mean measurement of 0.35mm. The duration of the three instars were 120 hours, 48 hours and 190 hours respectively. The mean life span of the male is 14.5±0.52 days (Table:7). Growth curves for the two morphometric dimensions viz., body length and carapace height for the males are shown in Fig.13. The duration of instars in males is also graphically represented in Fig.13.

Discussion

The life history of *Pleuroxus similis* shows that it has three preadult or juvenile instars and thirteen adult instars while reared at a temperature

Fig.11. Regression analysis between body length and carapace height in *Pleuroxus similis*. $y = .9684x - .099$.

Fig. 11

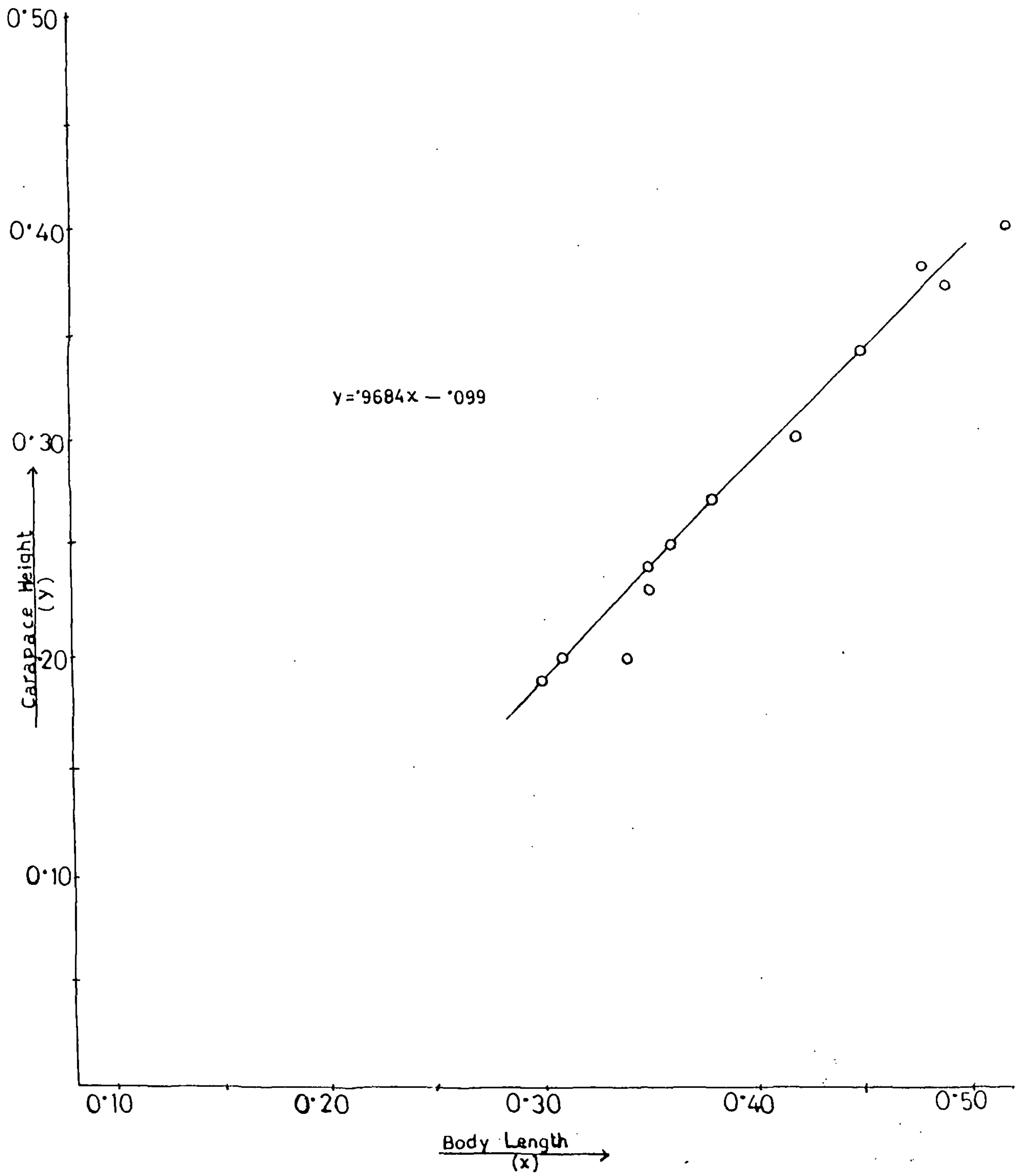

0·50
0·40
0·30
·20
0·10
Carapace Height
(y)
y = ·9684x — ·099
0·10
0·20
0·30
0·40
0·50
Body Length
(x)

Fig.12. Survivorship curve of *Pleuroxus similis* for:
1st generation
2nd generation

Fig. 12

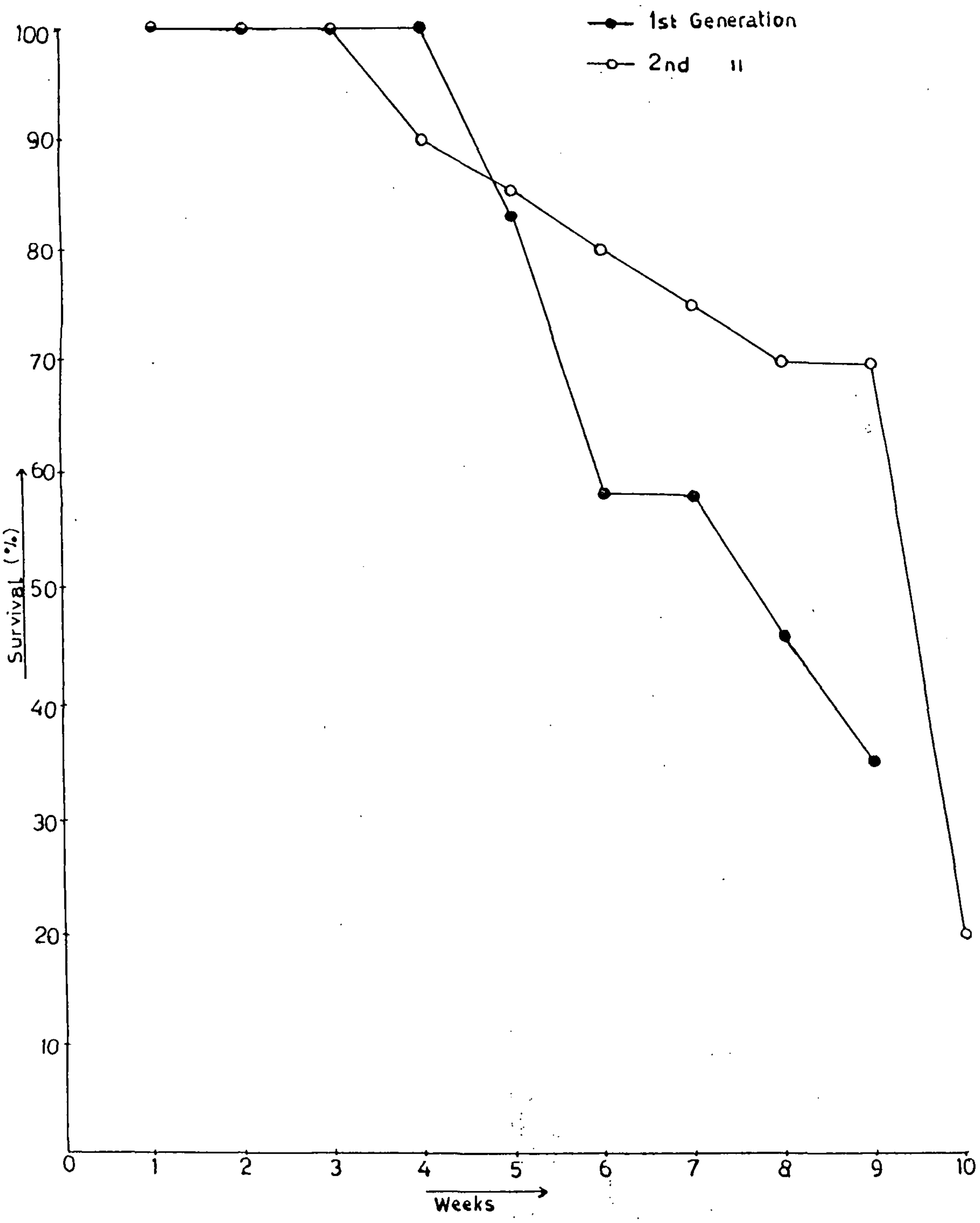
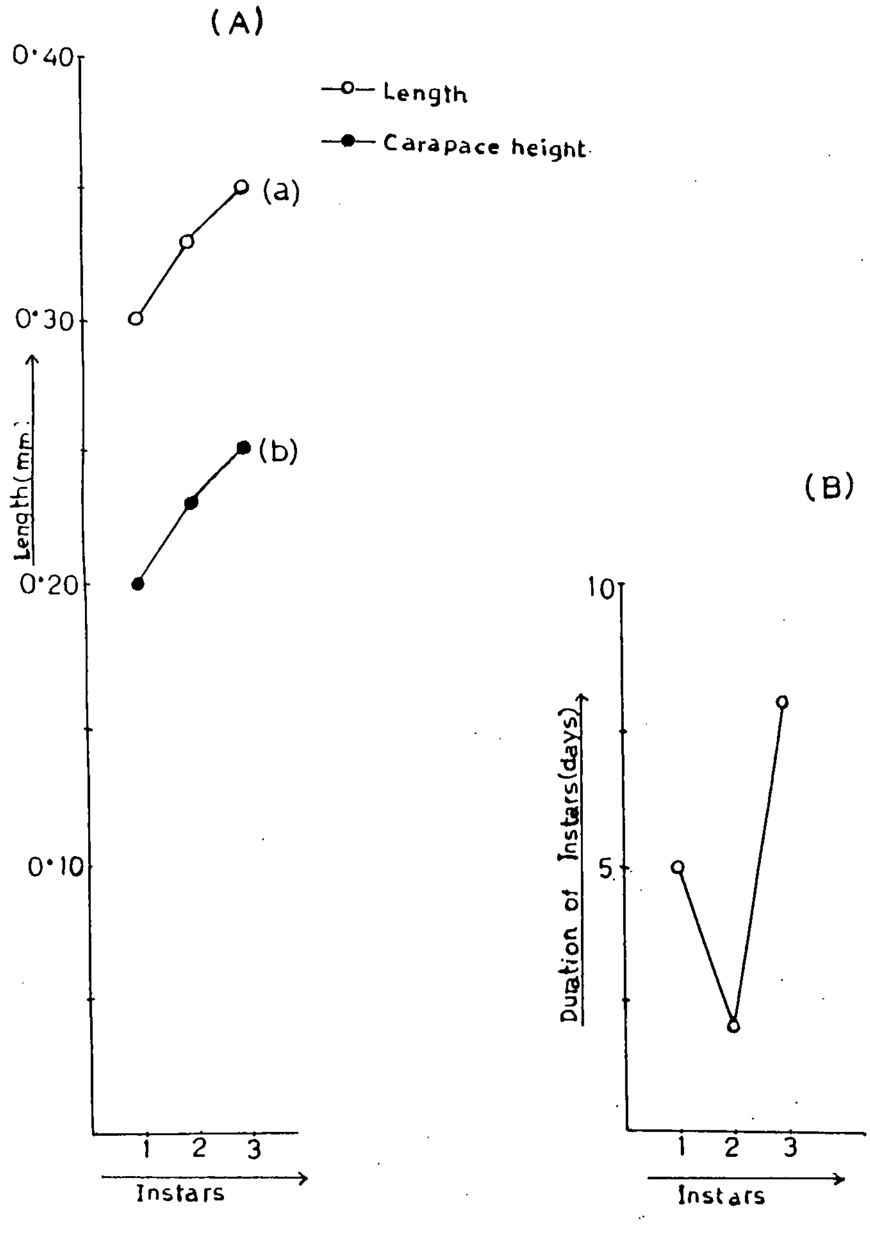

1st Generation
2nd "
100
90
80
70
60
50
40
30
20
10
Survival (%)
0
1
2
3
4
5
6
7
8
9
10
Weeks

Table 7: Mean length, carapace height and instar duration of male *Pleuroxus similis* (n = 10)

Instars	Length (mm)	S.D. ±	Carapace height(mm)	S.D. ±	Duration of Instars(hrs)	S.D. ±
1	0.30	0.004	0.20	0.003	120	0.483
2	0.33	0.004	0.23	0.005	48	1.032
3	0.35	0.006	0.25	0.006	190	2.456

Fig.13. Relationships between (A) body length carapace height and (B) duration of Instars in male Instars of *Pleuroxus similis.*

Fig. 13


(A)
0·40
0·30
0·20
0·10
Length (mm)
Length
Carapace height
(a)
(b)
1 2 3
Instars
(B)
10
5
Duration of Instars (days)
1 2 3
Instars

range of 15°-20°C under laboratory conditions and three different culture media i.e. chicken manure, rice bran and filtered pond water (The effects of these three culture media on the life cycle parameters of the animal has been discussed in 3.f (i). The average life span of the animal taken as the mean for all the three media was found to be 61 days under normal conditions (15°-20°C). The mean duration of preadult instars was around 72 hours, and that of adult instars about 96 hours or 4 days.

Earlier reports on the life cycle parameters of chydorids show that the number of preadult instars are variable to include two or three preadult instars (Shan 1965; Murugan 1982; Robertson 1988). Robertson has pointed out that the variability mainly depended on the initial size of the neonate. In the present study it was seen that the size of the juveniles were more or less constant at 0.31mm, and the number of juvenile instars were also same. Keen (1967) has pointed out that at 15°C the total life span of *Pleuroxus denticulatus* ranged from 18-121 days. In the present study at a temperature of 15°-20°C, the life span of the animal varied from 59.6-63.4 days.

The effect of temperature on the growth of cladocerans was pointed out several decades ago (Brown 1926). In the present study too temperature had immense effect on the duration of instars, as well as the total life span of the animal. At the temperature range fo 15°-20°C the mean life span of the animal was about 61 days whereas at the high temperature of 30°C, the total life span was reduced to almost half i.e. 31 days. The duration of adult instars also decreased from 72-120 hours to 48 hours. It has been reported by Bottrell (1975) that a decrease in temperature increase the developmental time of the embryo to 48 hours at 25°-29°C. However, the time taken for the first reproduction being 2 days in *Pleuroxus denticulatus* (Keen 1967) is definitely much less than that of 6 days in *Pleuroxus similis* (present study). In other words *Pleuroxus simi denticulatus* reaches maturity at a shorter period compared to that of *Pleuroxus similis*. The life span of *Pleuroxus similis* was found to be longer (31 days at30°C) as compared to that of *Pleuroxus denticulatus* (9-24 days at 25°C, as reported by Keen, 1967). Life history studies done by Murugan (1982) on the Chydorid, *Leydigia acanthocercoides* in the tropical region (28°-39°C), shows that the total life span of the animal is about 23 days and the duration of each preadult instar being 24 hours, and those of adults being 19-60 hours. Therefore, it can be said that the life span of *Pleuroxus similis* appears to be relatively longer as compared to the data available on chydorids. However, temperature has no effect on the number of adult and preadult instars in *Pleuroxus similis*. Here again it may be pointed out that reproduction does not begin in cladocerans until they have reached a particular size (Anderson 1932), in this case the size being 0.41mm. Even at the temperature of 30°C, this particular size was gained only at the fourth instar, which is the primiparous instar in this animal. In other species of Cladocera, it has been noticed that temperature did have an effect on the primiparous size, thereby resulting in the difference in numbers of preadult instars. For example, in *Daphnia magna* there were five juvenile instars at 18°-23°C and four to six juvenile instars at 25°C (Anderson, 1932; Anderson & Jenkins, 1924). In *Daphnia obtusa* three to four juvenile instars at 22°C (Green 1956), and four juvenile instars at 10°C and 20°C (Hrackova-Esslova 1962). In *Daphnia hyalina*, four to seven juvenile instars at 22°C (Green 1956). In *Daphnia carinata* five juvenile instars at 29°-31°C (Navaneethakrishnan and Michael 1971), two juvenile instars at 35°C (Venkataraman and Job 1980). In *Eurycercus* there were four juvenile instars at 16°-24°C and three juvenile instars at 12°C (Hann 1983). As could be seen from the above investigations most available data are on the *Daphnia* spp. More studies are needed on the chydorid cladocera.

Growth in terms of increment in length, was continuous and exponential till the primiparous instar, varying from 0.02-0.04mm. But immediately after the primiparous instar, growth becomes irregular thus resulting in a reduction in growth rates. There is a further decline in growth rate during the last 3-4 instars resulting in almost zero growth, and the durations of each instar being longer. Similar growth patterns in cladocerans were reported by many earlier workers (MacArthur and Baillie 1929; Anderson et al 1937; Green 1956; Richman 1958; Hall 1964; Hrbackova-Esslova 1962; Navaneethakrishnan and Michael 1971; Buikema 1973; Lei and Clifford 1974; Hann 1980; Vijverberg 1980; Murugan 1982; Robertson, 1988).

The quality of food, or the type of media used also had an effect on the growth of the animals,as a result of which the final size of the animals cultured in chicken manure was the highest (0.52mm) as compared to that of the animals cultured in filtered pond water (0.48mm), and in rice bran (0.47mm). Growth occurred in chicken manure upto the twelveth instar which was longer than that in filtered pond water and rice bran (11th instar). Hall (1964) suggested a causal relationship with food level resulting in cessation of growth at low food levels and growth till death at higher food levels. Thus, it may be said that the quality of food available in chicken manure medium was more conducive as compared to that of filtered pond water and rice bran.

Temperature also had a positive effect on the growth rate of the animal. But it should be noted that growth was mainly in terms of reduction of instar duration, rather than greater growth increments at each moulting. Similar results were reported in Daphnids by Brown (1927) MacArthur and Baillie (1929), Munro and White (1975), Lei and Armitage (1980) and Korpelainen (1986).

Continuous light conditions did not seem to have affected the growth and fecundity in *Pleuroxus similis* although there was reduction in the mean size of neonatae. It was pointed out by Smirnov (1974) that chydorid cultures kept in continuous light conditions show a slight decrease in the length of life span and also the number of offspring production. It was however observed that there was a decrease in the total life span of *Pleuroxus similis* but this could be attributed to high temperature conditions (30°C) rather than that of light conditions.

The pattern of reproduction in chydorids is very different from that of other cladoceran groups. For example, in Daphnids it is seen that the number of eggs produced increases gradually from the primiparous instar with a peak in the adult instar followed by a gradual decline in egg production close to the penultimate instars. But the number of eggs produced by *Pleuroxus similis* is uniformly constant in all the adult instars. No increase or decrease in egg production is noticed with a maximum number of two eggs per brood recorded throughout the lifespan. Similar results were obtained by Shan (1965) on *Pleuroxus denticulatus* and by

Murugan (1982) on *Leydigia acanthocercoides*. Since this species feed on detritus like most chydorids (Smirnov 1964, Murugan 1982) which is available at the bottom of the littoral region throughout the season, there is no scarcity of food during the whole year. This may possibly be the reason for the uniformity of clutch size in this species unlike other groups of limnetic cladocera, whose food supply is seasonal. The effect of food on fecundity has also been suggested by earlier workers like Dunham (1938), Anderson and Jenkins (1942) and Zhdanova and Frinovskaya (1976). Apart from temperature and food, the genetic make up of a given species also contributes to the clutch size (Bānta and Wood, 1939).

The life history strategies evolved by any Cladoceran species usually occur due to the selection pressures imposed by invertebrate predators (Lynch 1980). The life history strategy employed by *Pleuroxus similis* is very similar to that of small littoral species like *Pleuroxus truncata* and *Scapholeberis kingi* - large limnetic species, where growth is curtailed after the onset of reproduction. Though slight growth was observed in the animal even after initiation of reproduction, this growth is of little advantage to the species, since beyond a certain size the ability to obtain energy for growth and reproduction does not increase (Lynch, 1980). On the other hand *Pleuroxus similis* resembles small planktonic cladocera in terms of maturing at a smaller size i.e. 0.41mm and producing offsprings which at hatching are much closer to their adult size, as compared to those of larger planktonic species. But the production of relatively large eggs is not a necessary consequence of maturing at a small size (Lynch 1980). There are different events which have importance in the evaluation of large relative egg size like maintaining a constant offspring size and reducing size at maturity as observed in the present study. Thus the production of large sized juveniles, as compared to that of the initial adult reproductive size, suggests that less growth is required to reach size at maturity, thereby indicating a clear negative relation between neonate size and age at first reproduction. The fact that small species produce relatively large eggs, could be one of the reasons for a small clutch size of two eggs in *Pleuroxus similis*, besides the genetic makeup of the animal and chydorids in general. As it was pointed out by Lynch (1980) that species which produce large eggs and mature early, do so at the risk of having shorter life spans, although this does not apply in the present study since the total life span of *Pleuroxus similis* is quite long (61 days). However, when observing the survivorship curve of the animal, it is seen that mortality increses with size, which means that the animal has an optimal body size which is less than the optimal foraging size (12th to 14th instar). Due to early maturation of the animal, the reproductive life span of the animal is almost completed before the animal reaches its optimal foraging size. Though the animal grows after reaching the optimal foraging size, there is little advantage for the animal to grow beyond this size. In doing this viz., growing towards their optimal foraging size, they decrease their vulnerability to invertebrates and simultaneously increasing their vulnerability to vertebrate predator. Similar results on vertebrate predation on chydorids has been reported by Robertson (1988).

It should be noted that the optimal foraging size differed with temperature and different qualities of food. For instance, in filtered pond water optimal foraging size was obtained at the thirteenth instar (temperature 15°-20°C). In chicken manure it was the fourteenth instar and in rice bran it was the twelvth instar. Temperature incresed the optimal foraging size and at 30°C with filtered pond water as the medium, the optimal foraging size was obtained in the fourteenth instar.

Males of *Pleuroxus similis* was reported for the first time during the present study. The males had three instars in all, the first two being juvenile or immature instars and the last one being the adult or mature instar. The presence of three instars in chydorid males have also been reported by earlier workers like Frey 1973, 1975, 1980a, 1982a, Hann and Chengalath 1981, Hann 1982, Rajapaksa and Fernando 1982. The first instar male or the young male live for about five days. Smirnov (1967) reported that the young males of *Pleuroxus trigonellus* live for three days which is definitely shorter than that observed in the present study. The mature male of *Pleuroxus similis* did not moult after reaching maturity and it lived for about one week. On the whole the total life span of the male was about 2.5 weeks, of these, during the first week it was immature and in the second week it was in the mature phase at 15°-20°C. Hann (1980) working on *Eurycercus longirostris* reported a similar life cycle of the male at 16°C. However, the duration of the mature male instar was about 3 weeks, which is more than that of *Pleuroxus similis* (1 week). Thus it can be concluded that males of *Pleuroxus similis* have a determinate growth, as compared to the indeterminate growth in the males of other cladocerans like *Scapholeberis mucronata* which continue to moult and grow even after reaching maturity (Rammer 1928 and 1929). In *Daphnia magna* the males lived for almost as long as females (MacArthur and Baillie, 1929).

(b) Seasonal variation and population dynamics of *Pleuroxus similis*

Results

The results of the physicochemical parameters like water temperature and pH of Ward's Lake for a period of 25 months from April 1986 to August 1988 are represented in Fig.14. The highest temperature of 26.5°C was recorded in the months of July and August for both the years (1986 and 1988). The lowest temperature of 12° and 12.5°C were recorded in January 1987 and January 1988, respectively.

The pH of the system was always in the acidic range from 6.56-6.78 throughout the study period.

The population density of *Pleuroxus similis* is represented in Fig.15. The population shows two or more peaks of different intensities from April 1986 to August 1988. Very high densities were observed in the months of January 1988 (177 individuals/l), as compared to those observed in the previous years i.e. in April 1986 (54 individuals/l) September 1986 (45 individuals/l) and March 1987 (51 individuals/l). However variation was minimum in September 1986 peak, suggesting an uniformity in peak density in this month.

The population structure of *Pleuroxus similis* was constituted of juveniles, parthenogenetic females, females without eggs, ephippial females and males (Figs 16 and 17). During major portion of the study period, the population was mainly composed of parthenegenetic females and juveniles while females without eggs and ephippial females occurred at intevals. Males appeared in the system for a short period from February 1988 to

Fig.14. Seasonal variation in pH and water temperature of Ward's Lake during 1986-88.

Fig. 14

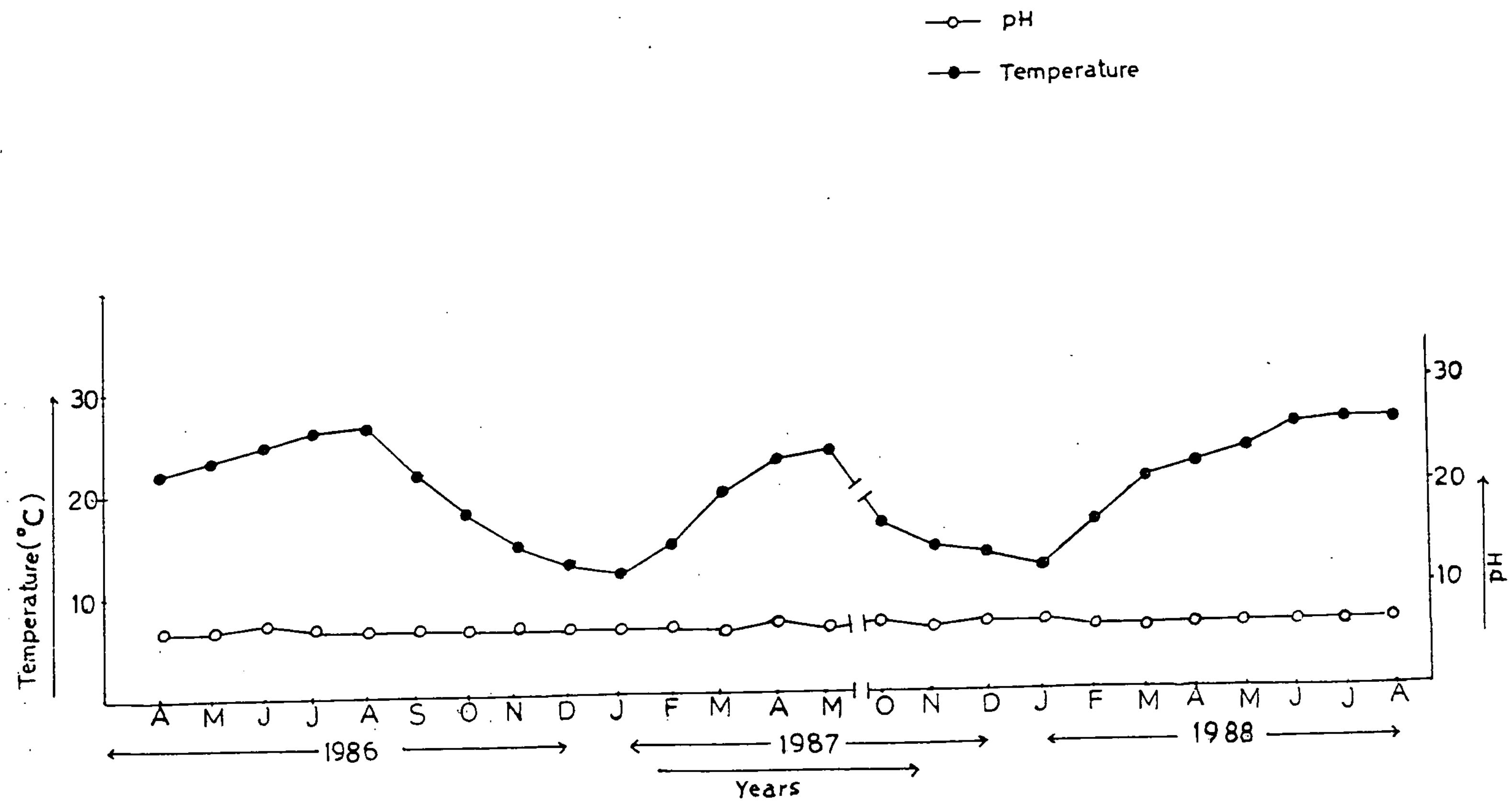

pH
Temperature
Temperature (°C)
30
20
10
pH
30
20
10
A M J J A S O N D J F M A M O N D J F M A M J J A
1986
1987
1988
Years

Fig.15. Seasonal variation in population density of *Pleuroxus similis*. during 1986-88.

Fig. 15

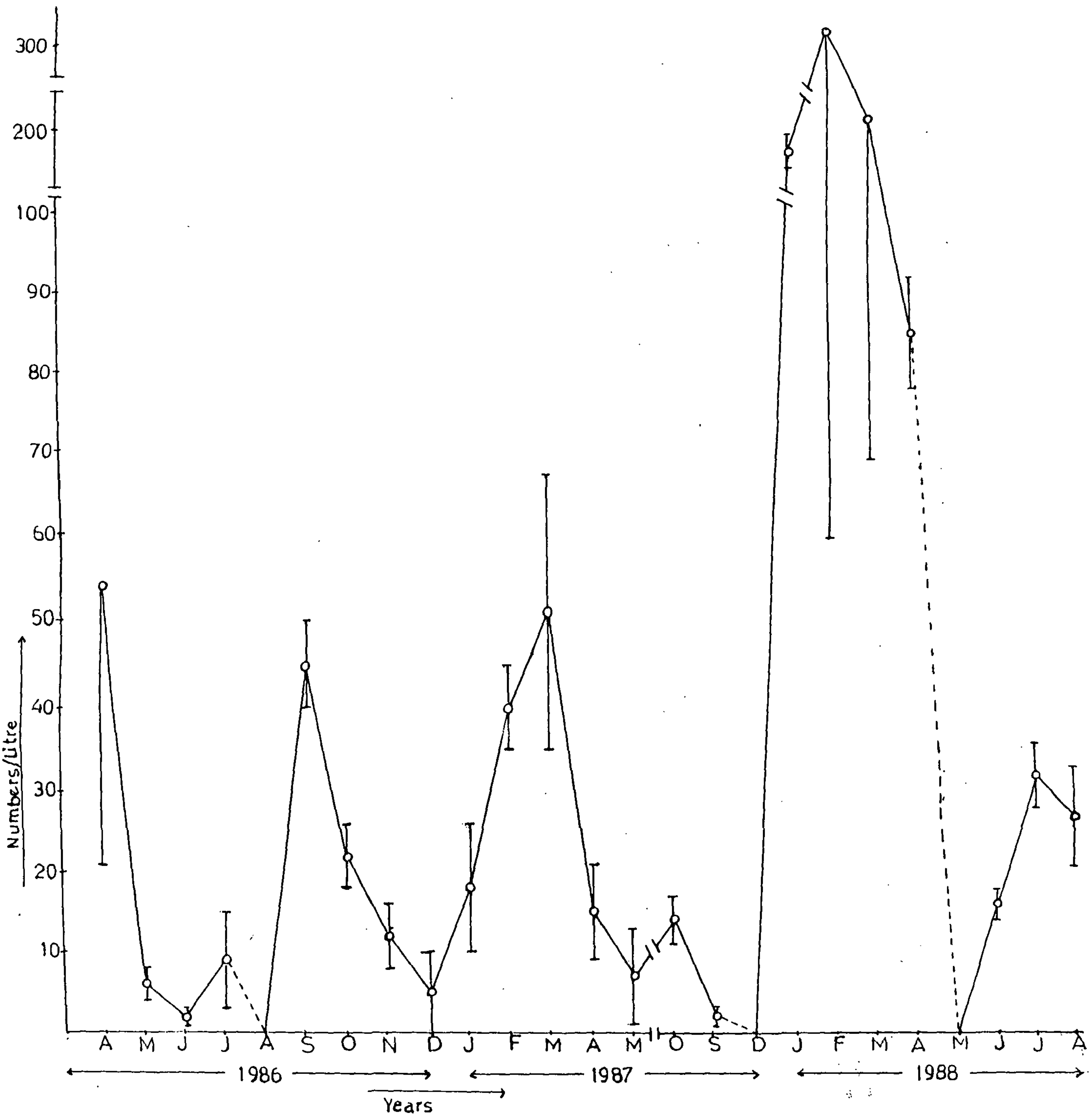

300
200
100
90
80
70
60
50
40
30
20
10
Numbers/Litre
A M J J A S O N D J F M A M O S D J F M A M J J A
1986
1987
1988
Years

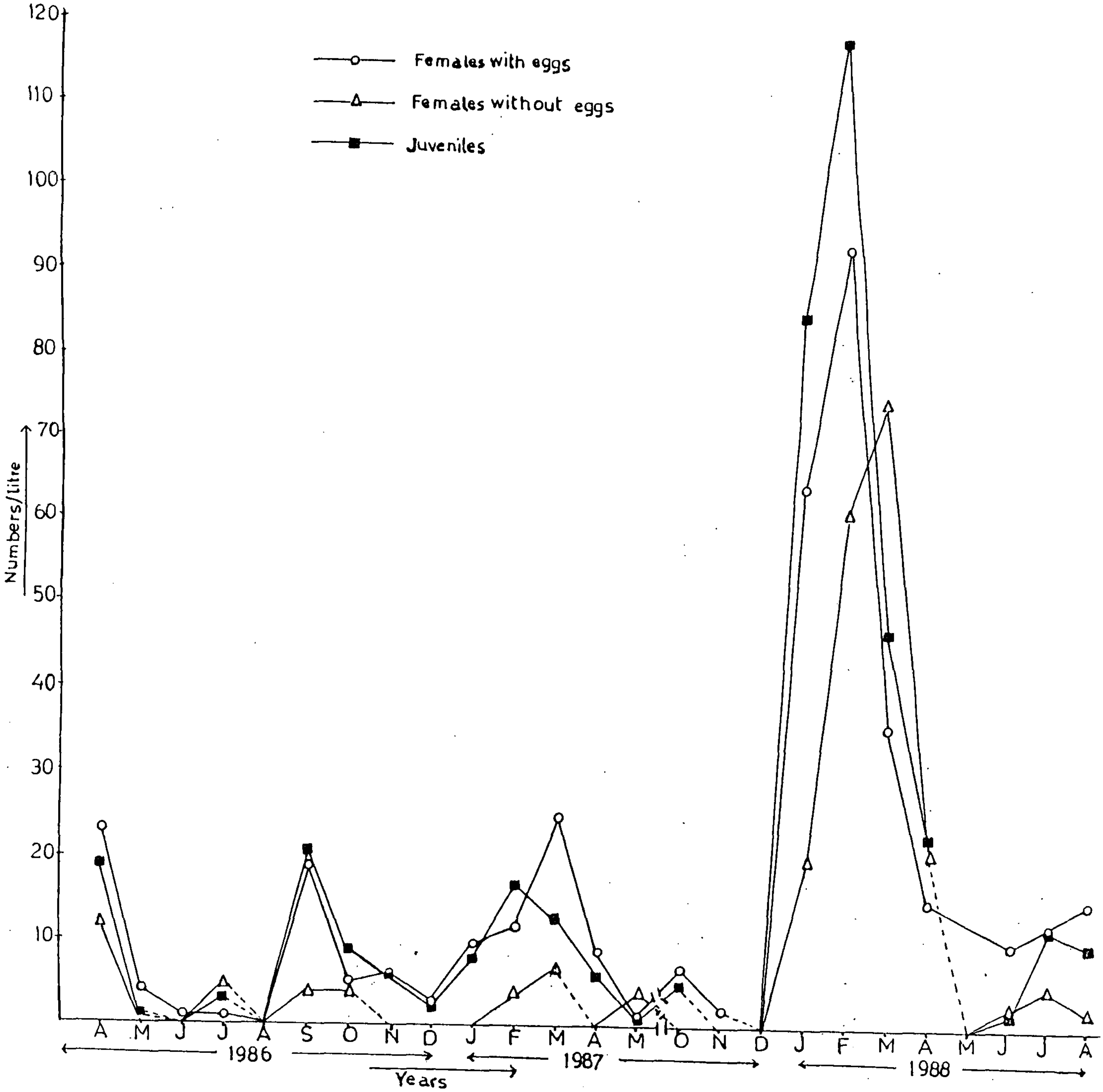
Fig.16. Seasonal variation in population structure of *Pleuroxus similis* during 1986-88.

Females with eggs

Females without eggs

Juveniles

Fig. 16



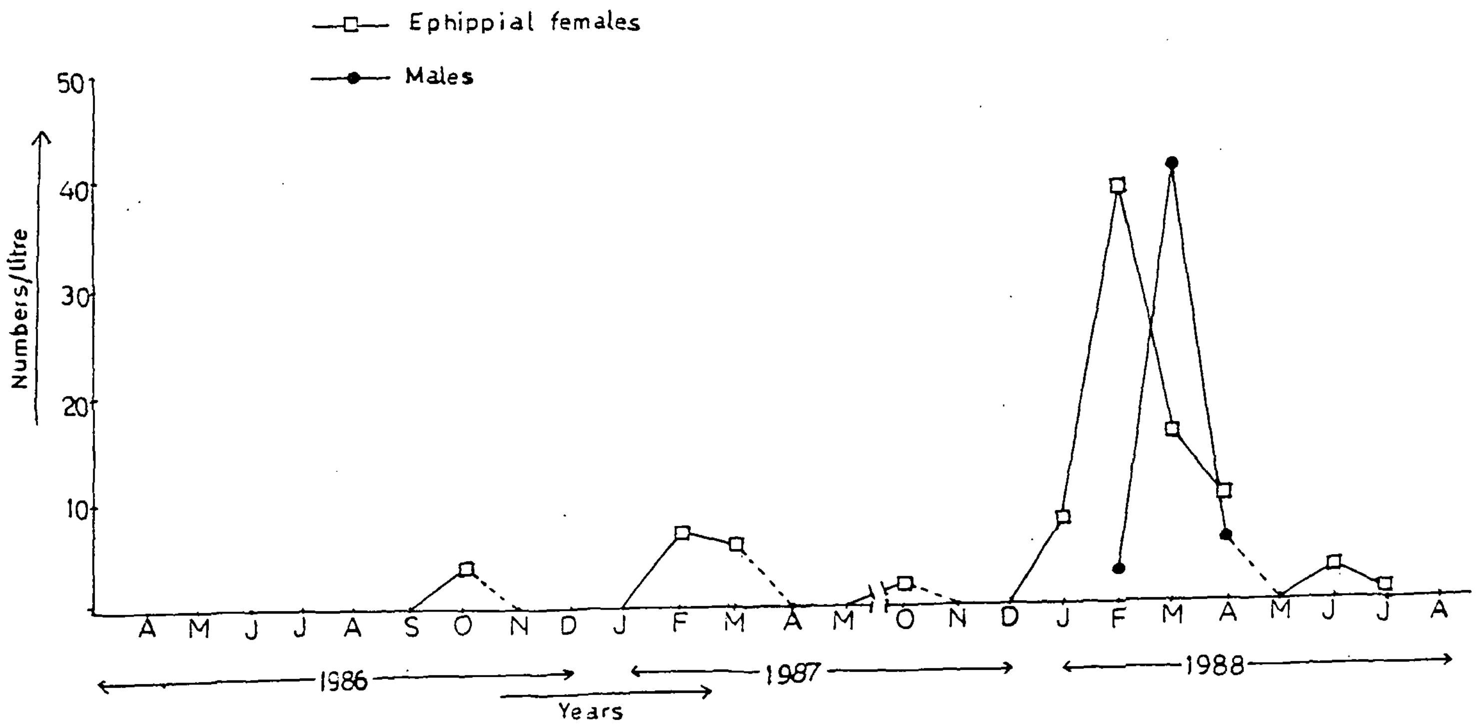
Females with eggs
Females without eggs
Juveniles
Numbers/litre
120
110
100
90
80
70
60
50
40
30
20
10
A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1986
1987
1988
Years

Fig.17. Seasonal variation in populations structure of *Pleuroxus similis* during 1986-88:

Ephippial females

Males

Fig. 17



Ephippial females
Males
Numbers/litre
50
40
30
20
10
A M J J A S O N D J F M A M O N D J F M A M J J A
1986
1987
1988
Years

April 1988, but were not recorded in the system during the previous years (1986-1987). Parthenogenetic females constituted about 42.5% of the total population in April 1986, 42.2% in September 1986, 49% in March 1987 and 29.8% in February 1988, while juveniles constituted 35.1% in April 1986, 48.8% in September 1986, 25.4% in March 1987 and 36.6% in the month of February 1988. Thus, it may be stated that the population peaks in the month of September 1986 and February 1988 had a higher percentage composition of juveniles as compared to that of April 1986 and March 1987.

Though females without eggs were seen at intervals in the population, they appeared in good numbers, even during high population densities as in April 1986 when they constituted about 22.2% of the total population, 8.8% in September 1986, 13.7% in March 1987 and 20.4% in February 1988 (Table: 8).

The highest density of ephippial females was observed in the month of February 1988 (39 individuals/l), preceding the highest density of the males in the month of March 1988 (4 individuals/l) (Fig.17).

The seasonal variation in percentage composition of different size groups of *Pleuroxus similis* is represented in Fig.18. All the six size groups were well represented in those months where the population density was high as seen for example in the months of April 1986, September 1986, January 1988, February 1988, March 1988, April 1988, July 1988 and August 1988. In other words the distribution of all the six size groups were more frequent in 1988 as compared to that of 1986-87. Throughout the study

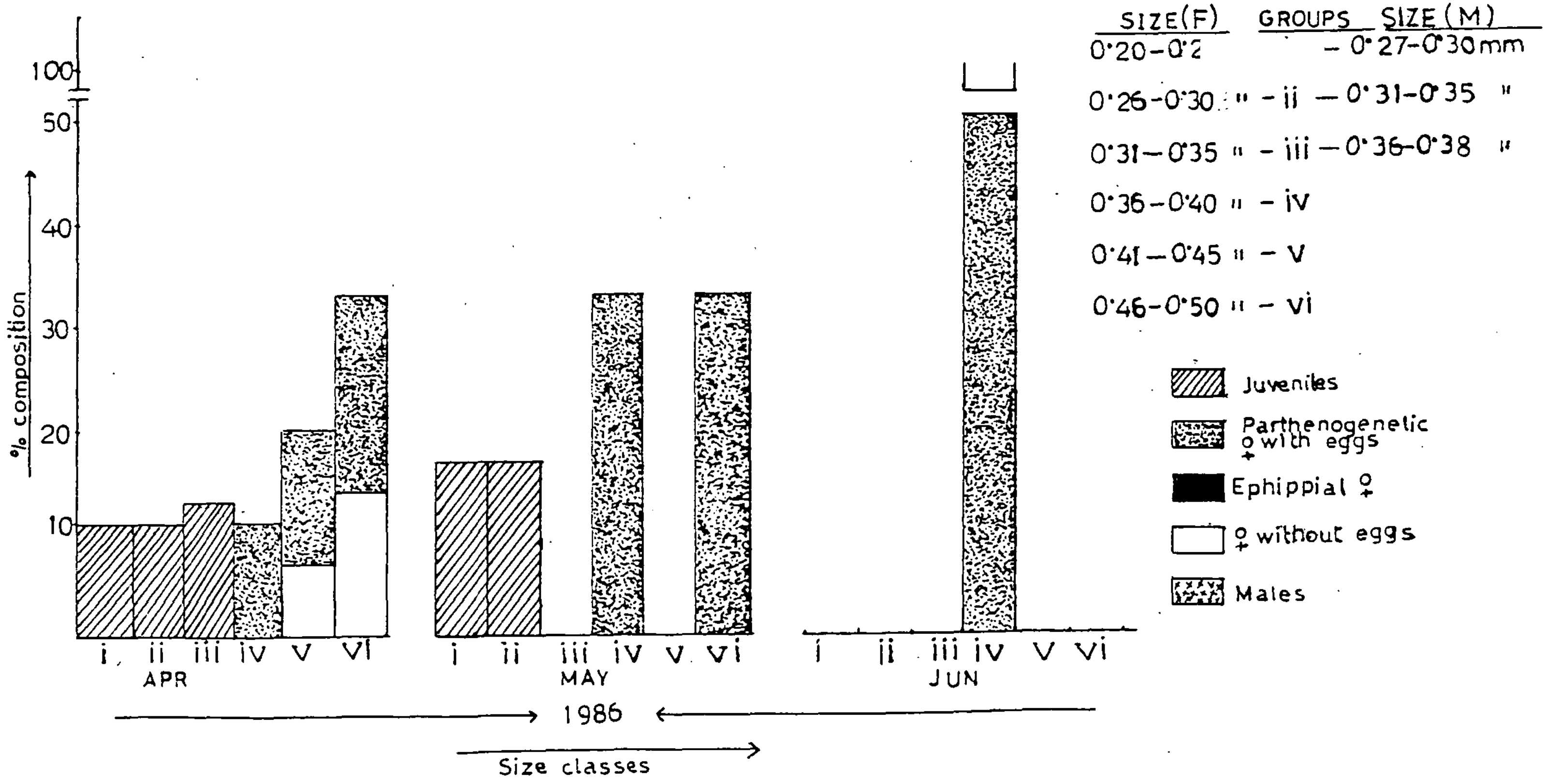
Table 8: Population composition of *Pleuroxus similis* during 1986-88.

Years and months	Adult with eggs			Adult without eggs			Ephippial females			Juveniles			Males			Total ±S.E.
	No/l	S.D. ±	%	No/l	S.D. ±	%	No/l	S.D. ±	%	No/l	S.D. ±	%	No/l	S.D. ±	%	
1986																
Apr	23	21.9	42.5	12	11.3	22.2	-	-	-	19	12.7	35.1	-	-	-	54±33
May	4	2.8	66.6	-	-	-	-	-	-	2	1.41	33.3	-	-	-	6±2
Jun	1	0.70	50	1	0.70	50	-	-	-	-	-	-	-	-	-	2±1
Jul	1	0.70	11.1	5	2.8	55.5	-	-	-	3	1.41	33.3	-	-	-	9±6.3
Aug	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sep	19	2.1	42.2	4	1.41	8.8	-	-	-	22	2.8	48.8	-	-	-	45±5
Oct	5	2.12	22.7	4	3.5	18.1	4	1.41	18.1	9	4.9	40.9	-	-	-	22±4
Nov	6	2.8	50	-	-	-	-	-	-	6	2.8	50	-	-	-	12±4
Dec	3	2.1	60	-	-	-	-	-	-	2	1.4	40	-	-	-	5±0.5
1987																
Jan	10	4.2	55.5	-	-	-	-	-	-	8	5.7	44.4	-	-	-	18±8
Feb	12	5.7	30	4	0	10	7	0.70	17.5	17	11.3	42.5	-	-	-	40±5
Mar	25	10.6	49	7	1.41	13.7	6	2.12	11.7	13	7.8	25.4	-	-	-	51±16
Apr	9	2.24	60	-	-	-	-	-	-	6	4.2	40	-	-	-	15±6
May	1	0	14.2	4	1.4	57.1	-	-	-	2	1.4	28.5	-	-	-	7±6
Oct	7	4.2	50	-	-	-	2	1.4	14.2	5	1.4	35.7	-	-	-	14±2.5
Nov	2	1.4	100	-	-	-	-	-	-	-	-	-	-	-	-	2±1
Dec	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1988																
Jan	64	1.4	36.2	20	9.9	11.3	8	4.2	4.5	85	9.9	48	-	-	-	177±2
Feb	96	16.9	29.8	66	9.9	20.4	39	8.5	12.1	118	73.5	36.6	3	1.4	0.93	322±62
Mar	36	15.5	16.7	75	14.1	34.8	16	1.4	7.4	47	21	21.8	41	36	19	215±47
Apr	25	19.8	18.3	21	18.4	25.6	10	5.7	12.2	23	12.7	28	6	1.4	7.3	85±7
May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jun	10	2.8	62.5	2	0	12.5	3	1.4	18.7	1	1.4	6.2	-	-	-	16±2
Jul	12	2.8	37.5	5	2.8	15.6	1	1.4	3.1	14	4.2	43.7	-	-	-	32±4
Aug	15	5.7	55.5	2	1.4	7.4	-	-	-	10	4.2	37	-	-	-	27±6

Fig.18. Seasonal variation in percentage composition of different size groups of *Pleuroxus similis* during 1986-88:

Apr'86 - Jun '86

Fig. 18



100
50
40
30
20
10
% composition
i ii iii iv v vi
APR
i ii iii iv v vi
MAY
i ii iii iv v vi
JUN
1986
Size classes
SIZE(F) GROUPS SIZE(M)
0·20–0·2 – 0·27–0·30mm
0·26–0·30 " – ii – 0·31–0·35 "
0·31–0·35 " – iii – 0·36–0·38 "
0·36–0·40 " – iv
0·41–0·45 " – v
0·46–0·50 " – vi
Juveniles
Parthenogenetic ♀ with eggs
Ephippial ♀
♀ without eggs
Males

Fig.18. Seasonal variation in percentage composition of different size groups of *Pleuroxus similis* during 1986-88:

Jul'86 - Sep'86.

Fig. 18

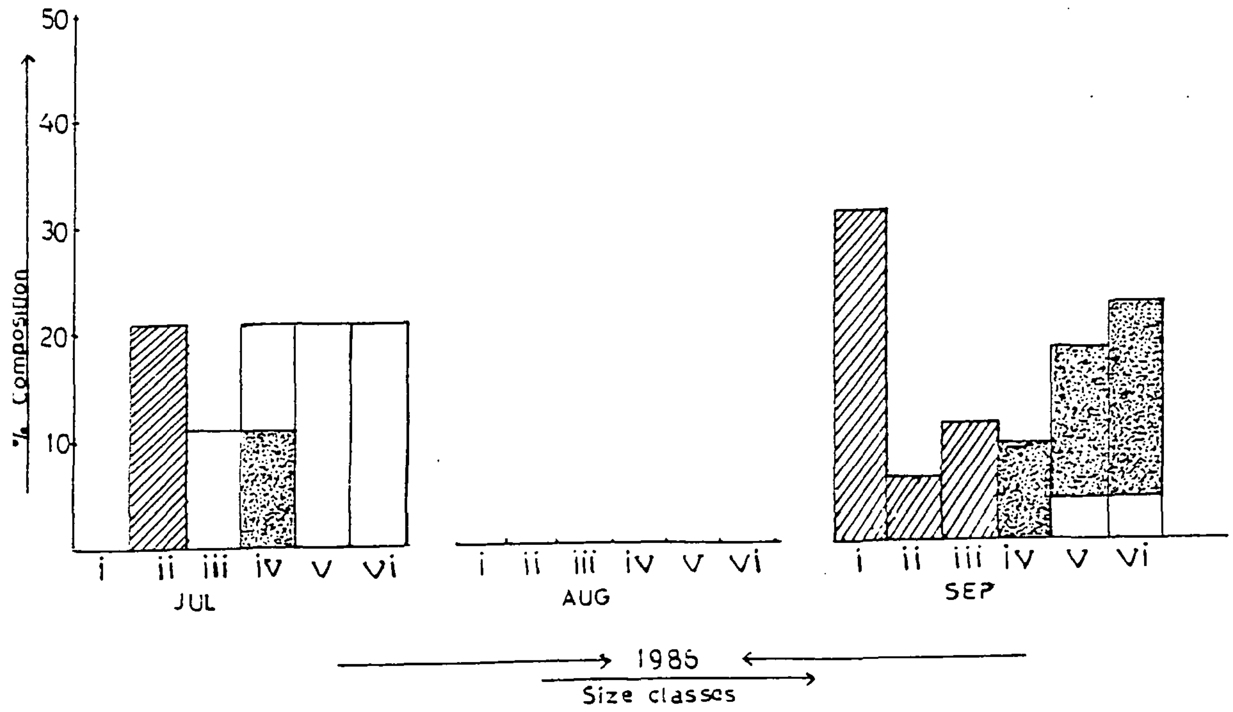
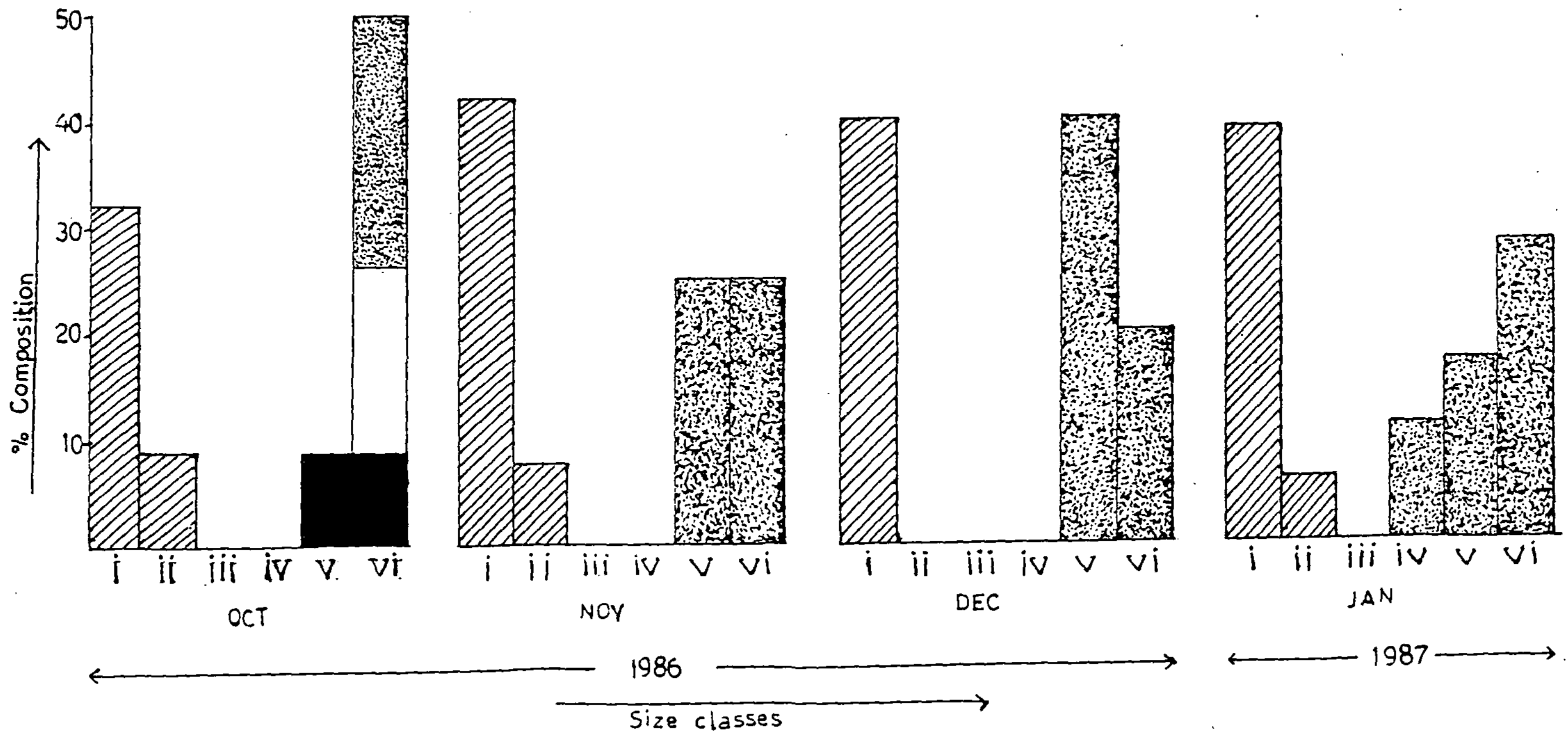

50
40
30
20
10
% Composition
i ii iii iv v vi
JUL
i ii iii iv v vi
AUG
i ii iii iv v vi
SEP
1985
Size classes

Fig.18. Seasonal variation in percentage composition of different size groups of *Pleuroxus similis* during 1986-88:

Oct'86 - Jan '87.

Fig. 18

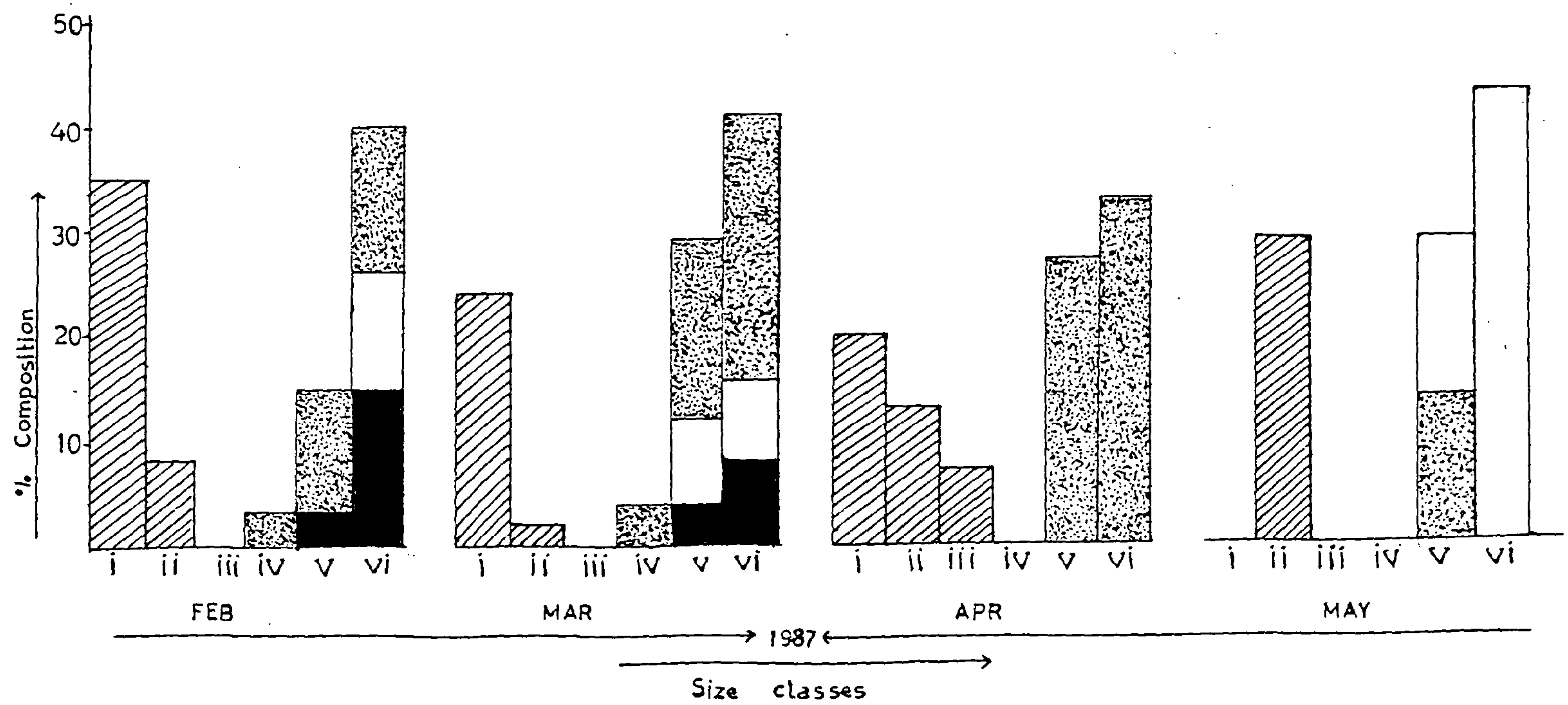


50
40
30
20
10
% Composition
i ii iii iv v vi
OCT
i ii iii iv v vi
NOV
i ii iii iv v vi
DEC
i ii iii iv v vi
JAN
1986
1987
Size classes

Fig.18. Seasonal variation in poercentage composition of different size groups of *Pleuroxus similis* during 1986-88:

Feb'87 - May'87

Fig. 18

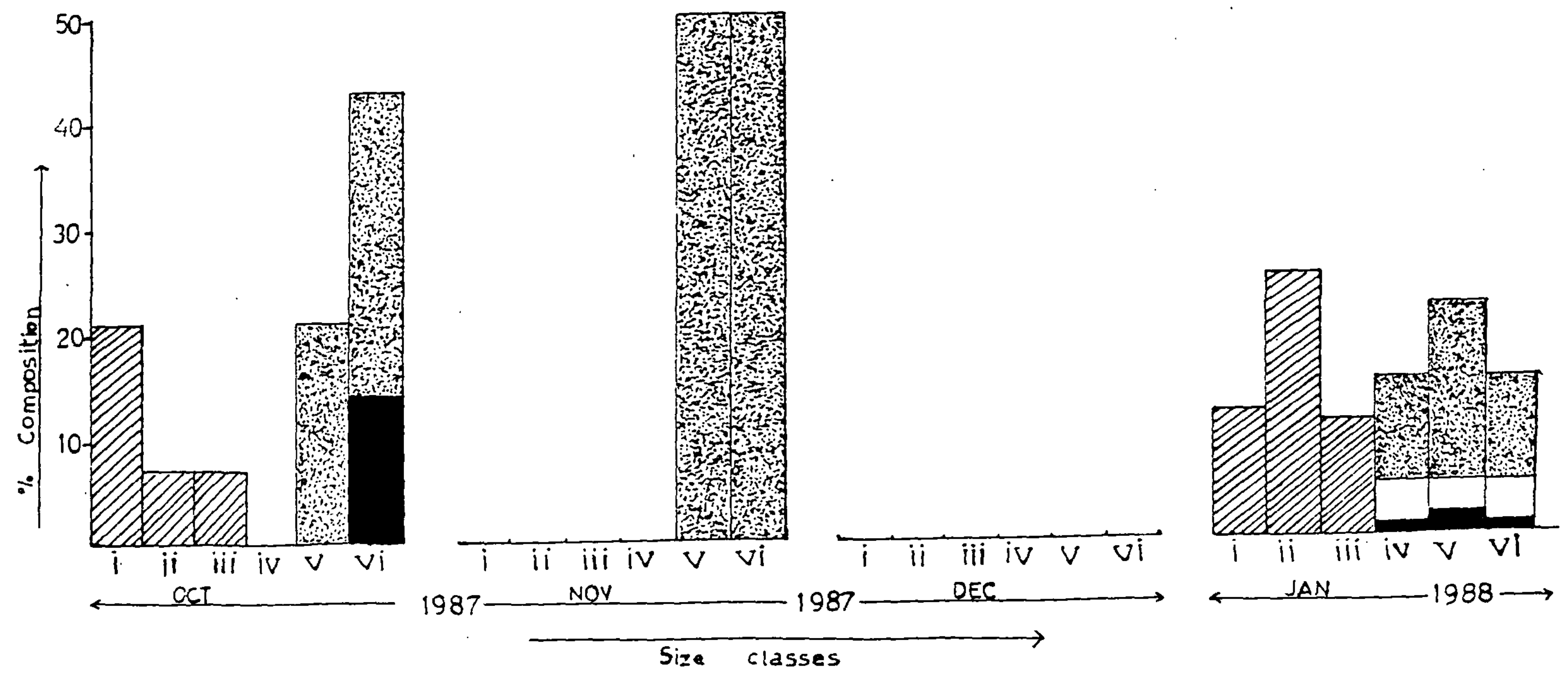


50
40
30
20
10
% Composition
i ii iii iv v vi
FEB
MAR
APR
MAY
1987
Size classes

Fig.18. Seasonal variation in percentage composition of different size groups of *Pleuroxus similis* during 1986-88:

Oct.'87 - Jan '88.

Fig. 18



50
40
30
20
10
% Composition
i ii iii iv v vi
OCT
1987
NOV
1987
DEC
JAN
1988
Size classes

Fig.18. Seasonal variation in percentage composition of different size groups of *Pleuroxus similis* during 1986-88:

Feb'88 - May '88.

Fig.18

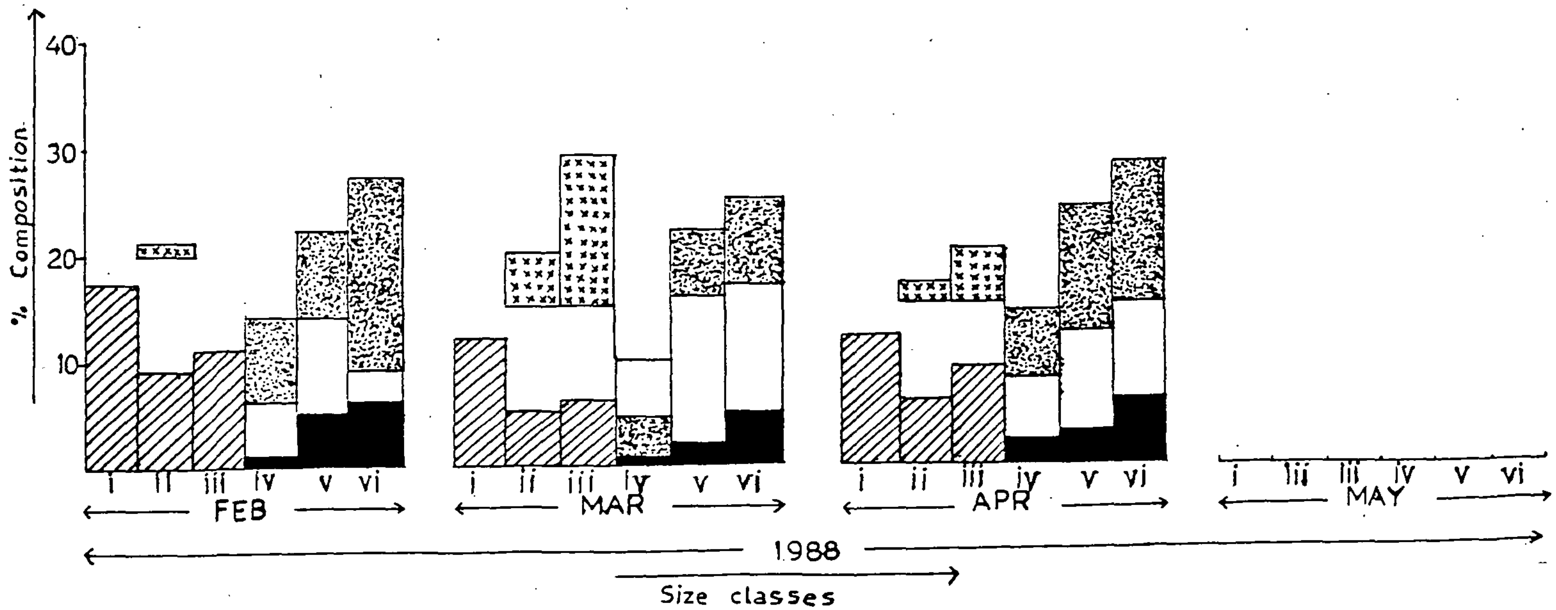
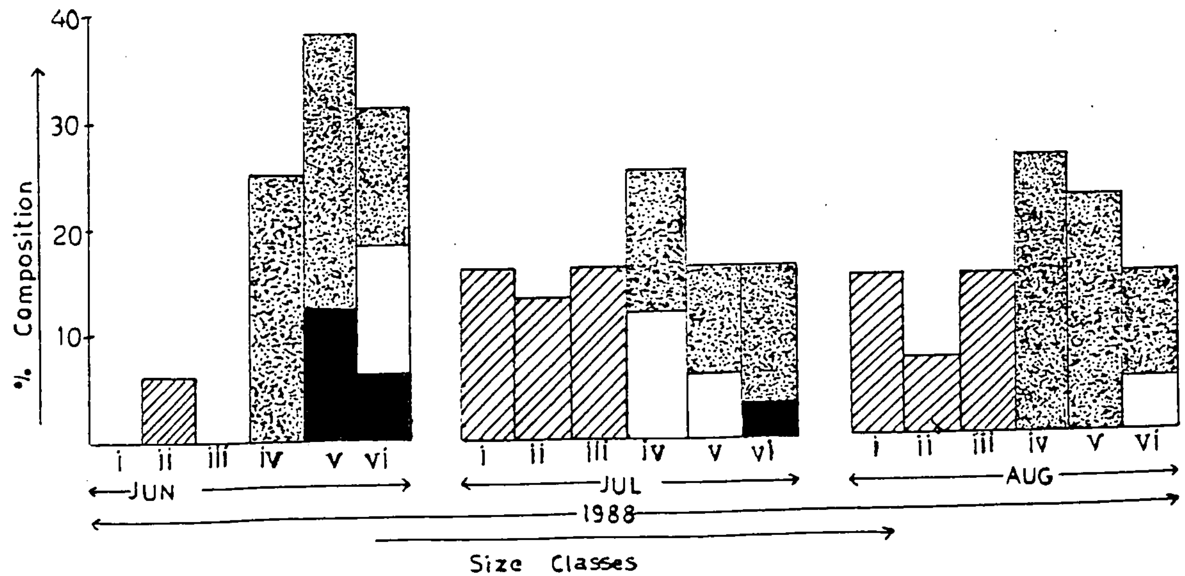

% Composition
40
30
20
10
i ii iii iv v vi
FEB
i ii iii iv v vi
MAR
i ii iii iv v vi
APR
i iii iii iv v vi
MAY
1988
Size classes

Fig.18. Seasonal variation in percentage composition of different size groups of *Pleuroxus similis* during 1986-88:

Jun'88 - Aug'88.

Fig. 18



% Composition
40
30
20
10
i ii iii iv v vi
JUN
i ii iii iv v vi
JUL
i ii iii iv v vi
AUG
1988
Size Classes

period very young individuals along with fully grown adults were seen to have composed the population structure.

The data for the various parameters of population dynamics of *Pleuroxus similis* is shown in Table:9. These functions were used by Hall (1964) and as well as by George and Edwards (1974) for populations without a stable age distribution. The potential rate of population increase (b') is comparatively higher than the observed rate of population increase (r') throughout the study period. The calculated mortality rate was found out to be higher than birth rate during major portion of the study period except for the months of July 1986, December 1986, January 1987, January 1988 and June 1988. However, the population growth shows a slight increase in the months of July 1986, December 1986, January 1987, January 1988 and June 1988. The population was totally was totally absent from the system in the months of August 1986, December 1987 and May 1988. While the total absence of the population in the month of August 1986 can be explained by the fact, that the mean brood size of the preceding months being very low. On the other hand, the absence of the population in the months of December 1987 and May 1988, inspite of the mean brood size of the preceding months being high in both cases, could be attributed to other environmental factors, rather than mortality and natality within the population.

Males of *Pleuroxus similis* appeared in the system for a very short period of just three months from February 1988 to April 1988. The sex ratios for these months were calculated as 1:67 (1 male : 67 females) in the month of February 1988, 1:3 in March 1988, and 1:9 in the month of April 1988.

Table 9: Population dynamics of *Pleuroxus similis.* during 1986-88.

Years and months	E	B	D	b'	r'	d'
1986						
Apr	1.98	42.57	4	3.77	-0.094	3.867
May	1.83	2.75	4	1.32	-0.065	1.385
Jun	1	1	4	0.693	-0.046	0.739
Jul	1	2	4	1.009	+0.008	1.091
Aug	-	-	-	-	-	-
Sep	1.89	23.15	4	3.18	-0.015	3.195
Oct	1.42	8.88	4	2.29	-0.022	2.312
Nov	1.75	7	4	2.08	-0.049	2.129
Dec	1.75	1.75	4	1.01	+0.015	0.995
1987						
Jan	1.68	4.62	4	1.73	+0.051	1.679
Feb	1.78	20.03	4	3.05	-0.015	3.065
Mar	1.77	29.21	4	3.41	-0.039	3.449
Apr	1.80	9.45	4	2.35	-0.06	2.41
May	2	4.5	4	1.70	-0.042	1.742
Oct	1.95	8.29	4	2.23	-0.031	2.261
Nov	1.84	1.38	4	0.87	-0.073	0.943
Dec	-	-	-	-	-	-
1988						
Jan	1.91	83.56	4	4.44	+0.002	4.438
Feb	1.95	187.20	4	5.24	-0.031	5.271
Mar	1.88	121.26	4	4.81	-0.029	4.839
Apr	1.82	41.86	4	3.76	-0.011	3.771
May	-	-	-	-	-	-
Jun	1.86	6.51	4	2.02	+0.018	2.002
Jul	1.80	16.20	4	2.84	-0.017	2.857
Aug	1.81	14.93	4	2.77	-0.029	2.799

E - Mean brood size

B - Finite birth rate

D - Duration of development of eggs (in days) determined in the laboratory.

b' - Instantaneous birth rate

r' - Coefficient of population growth

d' - Mortality rate.

The seasonal variation of population density of phytoplankton groups namely Chlorophyceae, Myxophyceae and Bacillariophyceae are represented in Fig.19. The peak population densities of Chlorophyceae were observed in the months of September 1986 (950 individuals/l) March 1987 (1045 individuals/l) and March 1988 (1120 individuals/l). The group was however absent in the system from the month of June 1986 to August 1986. In case of Myxophyceae the peak densities were recorded during the months of June 1986 (556 individuals/l) and October 1987 (625 individuals/l) but it was absent during the months of May 1986, October 1986 and December 1986. The group Bacillariophyceae, had its peak population densities in the months of April 1986 (800 individuals/l), August 1988 (520 individuals/l), April 1987 (500 individuals/l) and May 1988 (300 individuals/l), but was absent from the months of December 1988 to March 1987 and also during the month of October 1987.

Besides the phytoplankton groups, the associated zooplankton groups were also recorded from the system. These groups are mainly the Rotifers, Cladocerans, Copepods and Insects. Their population densities are represented in Fig.20. The maximum number of Rotifers in the system were recorded during the months of October 1986 (20 individuals/l), February 1987 (20 individuals/l) and February 1988 (20 individuals/l). They were however not recorded in the month of July 1986. The maximum density of the Cladoceran population were recorded in the months of July 1986 (85 individuals/l) and October 1987 (75 individuals/l) and were present in the system throughout the study period. The Copepods had the maximum densities of 75 individuals/l and 70 individuals/l during the months of June 1986

Fig.19. Seasonal variation in population density of phytoplankton groups in Ward's Lake during 1986-88:

Chlorophyceae
Myxophyceae
Bacillariophyceae

Fig. 19

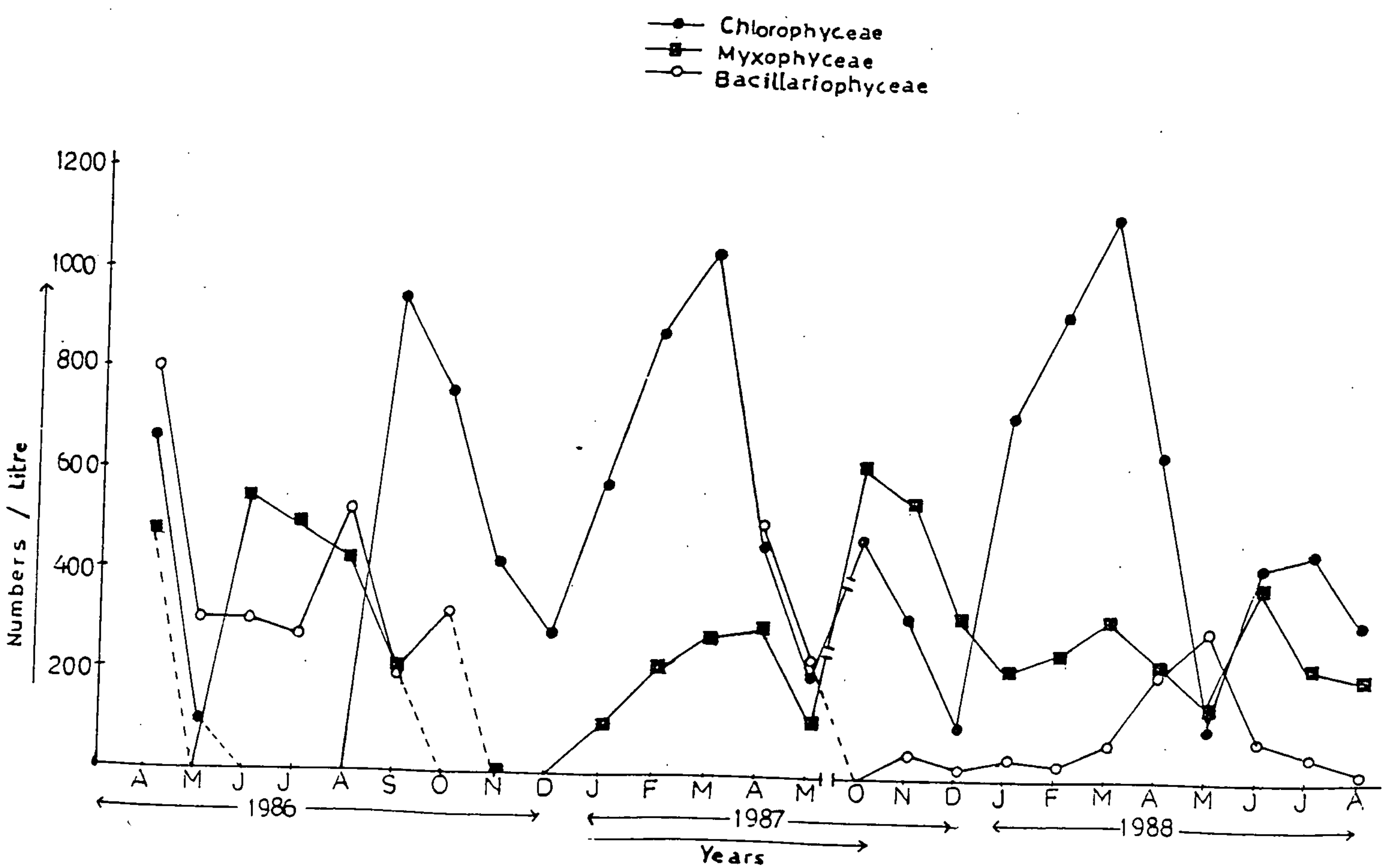

Chlorophyceae
Myxophyceae
Bacillariophyceae
1200
1000
800
600
400
200
Numbers / Litre
A M J J A S O N D J F M A M O N D J F M A M J J A
1986
1987
1988
Years

Fig.20. Seasonal variation in population density of Zooplankton groups in Ward's Lake during 1986-88:

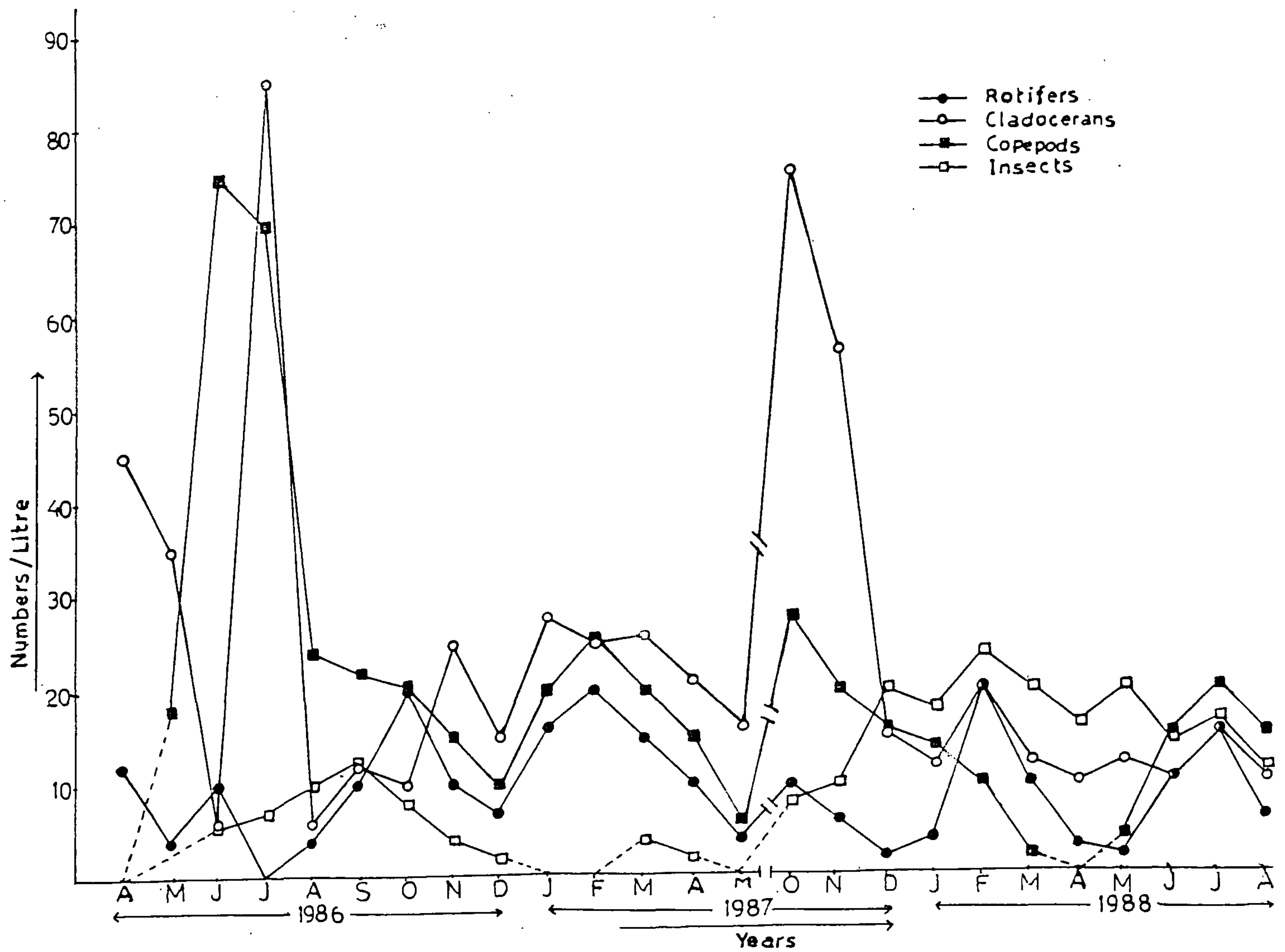
Rotifers

Cladocerans

Copepods

Insects.

Fig. 20


Numbers/Litre
90
80
70
60
50
40
30
20
10
Rotifers
Cladocerans
Copepods
Insects
A M J J A S O N D J F M A M O N D J F M A M J J A
1986
1987
1988
Years

July 1986, respectively. They were however absent from the system during April 1988. The insect larvae (predators) had a high population density of 20 individuals/l in February 1988, 20 individuals/l in March 1988 and 20 individuals/l in May 1988. They were however absent from the system during the months of April 1986, May 1986, January 1987, February 1987 and May 1987.

Simple and multiple correlations were worked out between the population density of *Pleuroxus similis* and the various abiotic and biotic factors like temperature, pH, phytoplankton, zooplankton groups; and insect larvae (predators) and the coefficient of determination value (R^2) was found out (Table:10).

From the above results it is observed that there is a significant relation between population density of *Pleuroxus similis*, and biotic factors like phytoplankton and predators. However, there was a negative or non-significant correlation between density of *Pleuroxus similis* and temperature, pH and zooplankton groups. In other words the population density of *Pleuroxus similis* is affected by the phytoplankton composition and by predators, but not by temperature, pH and zooplankton groups. The coefficient of determination value was 0.637. Thus it can be said that approximately 64% of the correlation can be explained by the factors used in the analysis for the correlation.

Discussion

The present study revealed the occurrence of multimodal peaks in the population density of *Pleuroxus similis*, during spring and autumn,

Table 10: Corelation coefficient between *Pleuroxus similis* and various abiotic and biotic factors.

	Temperature	pH	Phytoplankton	Zooplankton	Predators	Coefficients
P. similis	$r = -0.206$	$r = 0.288$	$r = 0.449$	$r = -0.006$	$r = 0.564$	RSQR
	$P > .05$	$P > .05$	$P < .05$	$P > .05$	$P < .05$	$= 0.637$

alternating with low population densities during summer and winter. The presence of these multimodal peaks in chydorid population was also reported by Goulden (1971) and Whiteside (1974). The reduction in the population density during the months of May 1986, June 1988, July 1986, March 1987 and December 1986, and its complete disappearance from the system in the months of August 1986, December 1987 and May 1988 was found to be related to both intrinsic factors like mortality and natality and also extrinsic factors like effect of predators, availability of habitat and to a certain extent temperature. Temperature might have played same role in reducing the population. Though no significant correlation was obtained between temperature and the population density of *Pleuroxus similis*, and the correlation was negative suggesting that, when the temperature was high, the density of *Pleuroxus similis* was low. For example, in the month of August 1986 temperature was highest (26.5°C) when the population was absent from the system. Similarly, it was observed that during the whole study period generally when temperature was high, the population was low and vice versa. Keen (1967) also pointed out that *Pleuroxus denticulatus* survived better at cooler temperature (15°C) rather than in warm temperature (25°C).

Predation also likely to have played an important role in regulating the population density of *Pleuroxus similis*. In August 1986, December 1987 and May 1988 when the population was absent, the number of insects predators was high (10 individuals/l, 20 individuals/l and 20 individuals/l, respectively). Besides predation, the presence of phytoplankton communities like Chlorophyceae, Myxophyceae and Bacillariophyceae in the system also affected the popu-

population density. In the months of December 1987 and May 1988, when the chydorid population was absent, the phytoplankton number/l was also comparatively less as compared to the other months (445 individuals/l and 550 individuals/l). Smirnov (1974) and Whiteside (1978) reported the association of chydorids with vegetative substrate. But however, it should be noted that this association is not significant in terms of food, but significant with reference to the habitat. According to Smirnov (1974) the role of vegetation in the ecology of chydorids is indirect and consists in the development of a specific phytoplankton, and formation of overgrowth or accumulation of special quality detritus. Besides all these extrinsic factors, the intrinsic factors like mortality and natality also have an effect on the population density. Thus, it may be stated that the increase and decrease in the population density of *Pleuroxus similis* throghout the study period could be correlated to the abiotic and biotic factors (extrinsic factors) for upto 64% (coefficient of determination value = 0.637) and 36% of the correlation may probably be explained by intrinsic factors like mortality and natality. However, the presence of other zooplankton groups in the system did not have any effect on the population density of *Pleuroxus similis*. So it may be said that competition was not very pronounced in the system. Goulden (1971) and Williams (1982) attributed the causes of population growth in chydorids to different factors like lack of food, temperature and predation which finds support also in the present study.

It was observed in the present study *Pleuroxus similis* had two peaks in its population density, one in autumn and the other in spring, in fact that peak density in spring was higher than that of autumn. In this respect its temporal pattern of distribution is different from other chydorid species, which have either a single peak in summer (e.g. *Kurzia latissima, Alona affinis* and *Alona quadranqularis* or two peaks one in summer and the other in fall or autumn (e.g. *Chydorus sphaericus, Pleuroxus denticulatus, Pleuroxus trigonellus, Pleuroxus aduncus, Camptocercus rectirostris* and *Eurycercus)* (William 1982). Thus it is seen that in *Pleuroxus similis* the summer peak is absent, whereas it is present in most of the other chydorid groups. While observing the population structure of *Pleuroxus similis*, it was seen that the population was composed of parthenogenetic females and juveniles for the greater part of the year. Gamogenetic females (ephippial) occurred only during short periods in October 1986 and again in February 1987, March 1987, October 1987, February 1988 to April 1988 and a small number in June and July 1988. The highest number of gamogenetic females was observed from the months of February 1988-April 1988 and males too appeared in the system only during this time. Surprisingly, during the previous years (1986 and 1987) males were not recorded in the system, even though ephippial females appeared. So it was seen that gamogenesis occurred in the system mainly during spring and autumn, though the number of gamogenetic females during autumn was relatively less. Frey (1982) pointed out that in tropics and subtropics, gamogenesis does not occur on a regular basis in any season which is unlike that of the present situation. He had also suggested that in "northern" species autumnal gamogenesis is replaced by vernal gamogenesis, suggesting a shift in the season of major stress for these species from winter to summer. Thus according to Frey's suggestion, it may be stated that this particular species of chydorid could be a winter associated species and it reacts to summer stress conditions by producing vernal gemogenetic females. However, during the months of June 1988 and July 1988 a small percentage (18% and 3%) of ephippial females were observed in the system and these animals must have formed epphippum, triggered by the presence of males in the system, as it was observed that the peak population density of the males was found during the month of March 1988 succeedding the population peak of ephippial females in February 1988 and was recorded in the system till April 1988. The other possible explanation could be that since ephippial formation usually takes place under adverse environmental conditions and also associated with production of males (Pennak, 1953) the high temperature in the months of June 1984 and July 1988 (26° and 26.5°C respectively), could have initiated the production of ephippial females since a negative correlation was obtained with temperature and population density of the animal. The effect of temperature in initiating gamogenesis has been mentioned by Stross (1987) in *Daphnia*. A small number of gamogenetic females were however noticed in the system during the month of October 1986 and October 1987. This occurrence of gamogenetic females during autumn could possibly be explained as since the location of this lake is in the north eastern part of India (25°34'N lat. 91°36'E long.) has shorter day length and longer nights during autumn. Since photoperiods play an important role in controlling the formation of gamogenetic females (Shan 1975, Stross and Hill 1968, Stross 1987), this change in photoperiod could have caused the occurrence of the small number of gamogenetic females in the system.

While studying the population dynamics of the natural population of *Pleuroxus similis* in the field, one notices the overlap of high densities and high mortality factor or death rate (Table:9 with Fig.15). The death rate is high in those months when population density shows peak and low in those months showing population crashes, these two factors coinciding with time. Although this finding seems paradoxical, one can explain the contradiction if Fig.18 is taken into consideration, where the percentage composition of different size groups in relation to the different categories of *Pleuroxus similis* (i.e. juveniles, parthenogenetic females, females without eggs and ephippial females) are given. Recruitment of new individuals subsequent to the peaks is slow, though the mortality factor was also less. It was seen that in the months showing peak population the number of non reproductive adults were high and hence recruitment must have been low. In other words parthenogenetic famales (or ephippial females under active reproduction were low, hence reflecting high mortality rate. The opposite may be true of those months showing low mortality or death rates.

In August 1986 however, juveniles individuals and parthenegenetic females were absent. This crash in the population could be possibly due to the fact that the mean brood size of the preceding months was low, hence resulting in low recruitment coupled with the high eutrophic condition prevailing during this period in the system. Recruitment thereafter is probably from ephippial eggs which unfortunately could not be quantified during this study.

In the month of December 1986, the population crash can be attributed to the low population density in the previous month. Though the mean brood size was high, recruitment must have been slow, since low temperature incrases the development time, thus resulting in a slow population growth.

However, the population crash in the month of May 1988 could not be explained in terms of population density of the previous month (i.e. April 1988 - 85 individuals/l) nor by the mean brood size of the animals (1.82). As far as the recruitment of new individuals was concerned, it should have been fast enough (temperatue 22.5°-24°C) to observe some population numbers in the system, and besides that a reasonably good population number was recorded in the succeeding months during June 1988 and July 1988. So this crash in population might have been habitat-induced due to the effect of some environmental factors. The phytoplankton composition of the system could have been altered resulting in the changes of the population. Another possible explanation could be due to patchiness in distribution exhibited by chydorid populations ((Goulden 1971; Keen 1973; Whiteside 1974). Whiteside (1974) outlined the various factors that cause chydorid patchiness such as: (i) Heterogeneity of habitat (ii) Clumped food sources (iii) Predation (iv) Lack of dispersal and (v) behaviour. Out of these factors, the heterogeneity of habitat and predation could have caused patchiness in the population density of the animal. So during collection, the population having patchiness of distribution resulted in their absence during the month of May 1988.

If the above condition is responsible for population crash in May 1988 then the ephippial females recorded in the population during June and July 1988 had sexual eggs, since males were recorded in the system during the preceding months. However, ephippial females which were found in the system during other periods did not have sexual eggs, thereby suggesting that ephippial formation is independent of the occurrence of males in the population, eggs being produced through gamogenesis only in the presence of males.

(c) Studies on laboratory cultures of *Pleuroxus similis*

(i) Life history parameters of *Pleuroxus similis* reared in different culture media with different inoculum densities

Results

Informations gathered regarding the life history parameters of *Pleuroxus similis* is given in Table:11. The time at first reproduction (A), in the three different media and three different inoculum densities varied from 6.6-9.0 days. In chicken manure medium, 'A' or first reproduction time varied from 8.2-8.6 days in three different inoculum densities (i.e. 3, 5 and 8 animals). In filtered pond water 'A' varied from 8.8-8.7 days and in rice bran medium 'A' varied from 8.8-9.0 days.

The maximum longevity of 50.3 days was observed in filtered pond water as culture medium, with the initial inoculum density of 3 animals. The lowest life span of 16 days was observed in the culture with rice bran as the medium, and 8 animals as the initial inoculum density.

The reproductive life span of the animal was maximum in chicken manure with the inoculum density of 3 animals (44 days) and minimum of 16 days in rice bran medium with the initial inoculum density of 8 animals.

The total offspring production of 17 offsprings/female was maximum in chicken manure medium with the initial inoculum density of 3 animals and a minimum of 4 offsprings/female was recorded in case of rice bran medium with the initial inoculum density of 8 animals.

The net reproductive rate (Ro) was maximum in filtered pond water with the initial inoculum density of 5 animals (15.92) and the minimum being

Table 11: Life history parameters of *Pleuroxus similis* grown in three different culture media at three different inoculum densities.

Medium	A			W			S			Reproductive life span			R_o			T_c		
	3	5	8	3	5	8	3	5	8	3	5	8	3	5	8	3	5	8
Chicken manure	8.2	8.4	8.6	49.6	40	30.8	17.7	14.8	7.8	44	32	24	10.98	14.29	11.3	27.94	21.68	18.50
Filtered pond water	8.8	8.9	8.8	50.3	40	36.8	15	15.6	8.4	40	32	32	11.11	15.92	14.18	29.07	23.37	21.70
Rice bran	8.3	9	8.8	35.5	25.2	16.1	6	6.6	4.6	32	20	16	3.55	5.74	4.37	20.99	16.04	14.65

A - First reproduction time (days)
W - Longevity (days)
S - total female offspring/female life time
R_o - Net reproduction rate
T_c - Average generation time.

(3.55) in rice bran, with initial inoculum density of 3 animals. The maximum average generation time (T_c) of 29.07 was recorded in filtered pond water with the initial inoculum density of 3 animals. The minimum (T_c) of 14.65 was observed in rice bran medium with initial inoculum density of 8 animals.

Two way analysis of variance for the different life history parameters i.e. *longevity (W), total offspring production (S), net reproductive rate* (R_0) and average generation time (T_c), in different culture media and different inoculum densities was done (Table:12). There was a significant difference between the life history parameters in the three culturing media, as well as between the three different inoculum densities.

In general, it was observed, that the values for most of the life history parameters of *Pleuroxus similis*, were much less in rice bran medium as compared to the other two media of chicken manure and filtered pond water.

The survivorship curves of *Pleuroxus similis* in the three different media, with three different initial inoculum densities is represented in Fig.21. With low inoculum density of three animals (Fig.21A) a stepwise type of survivorship curve is obtained for rice bran and chicken manure media. But in the case of inoculum density of 5 animals (Fig.21B) shows different types of survivorship curves in the three different media. In chicken manure medium, the curve is slightly convex or type I (according to Slobodkin 1962), in which mortality acts most heavily on the old individuals. In filtered pond water the curve is of type III, where mortality rate is constant. And in rice bran medium the curve is of type II where a constant number of animals die per unit time. With the initial inoculum density of 8 animals (Fig.21C) the

Table 12: Two-way ANOVA of life history parameters and total population density of *Pleuroxus similis* in three different media and three different initial inoculum densities.

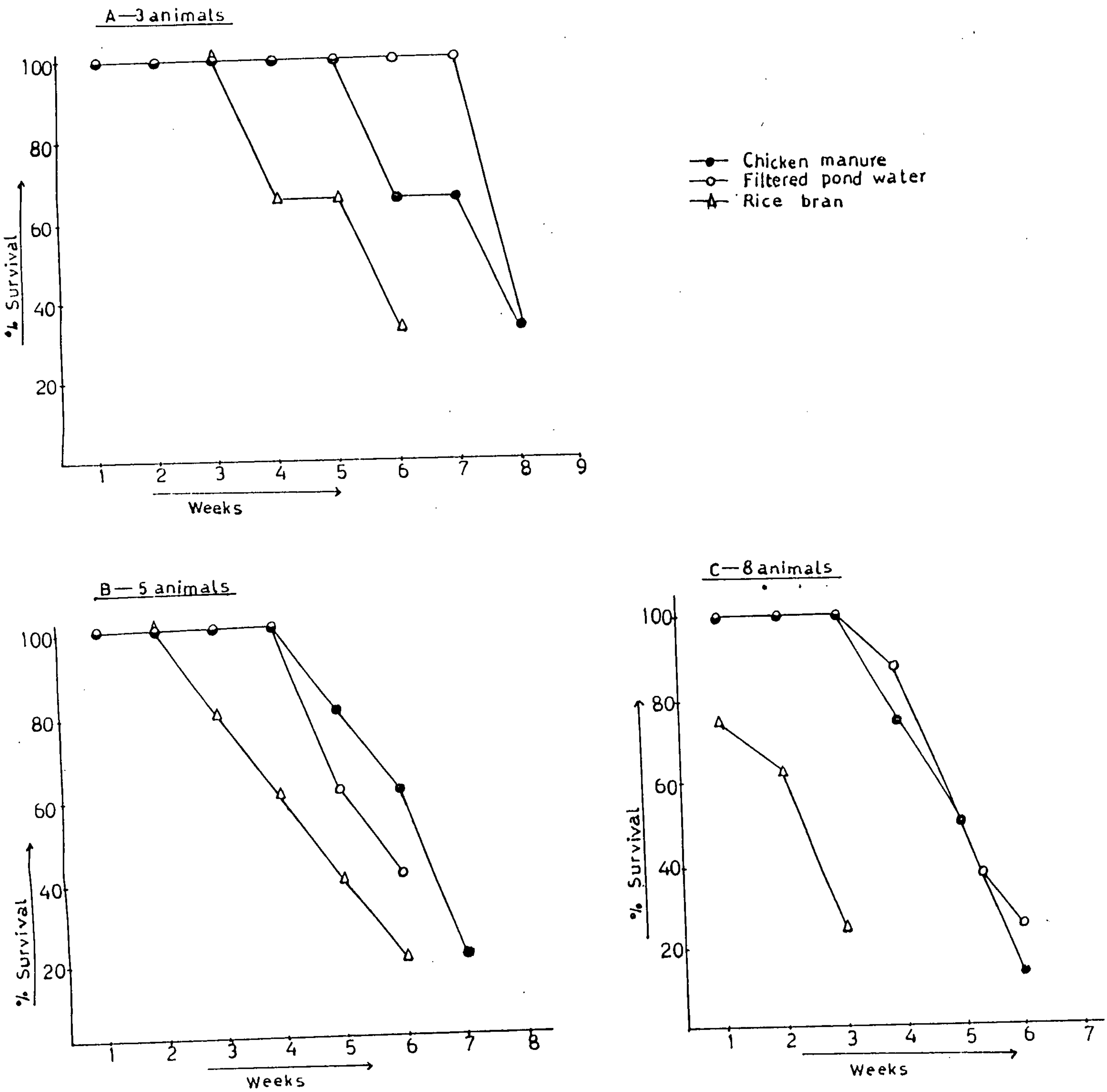
Parameters	Sources of variance	d.f.	MSS	Variance Ratio
Longevity	Between medium	2	248.45	F_1 = 55.83**
	Between densities	2	228.1	F_2 = 51.25**
	Error	4	4.45	
Total offspring production	Between medium	2	54.1	F_1 = 9.1****
	Between densities	2	34.1	F_2 = 5.7****
	Error	4	5.95	
Net Reproduction rate(R_o)	Between medium	2	72.54	F_1 = 95.44**
	Between densities	2	8.95	F_2 = 11.8***
	Error	4	0.76	
Average generation time(T_c)	Between medium	2	45.03	F_1 = 68.2**
	Between densities	2	47.8	F_2 = 72.4**
	Error	4	0.66	
Total population density	Between medium	2	33387.1	F_1 = 126.5**
	Between densities	2	7012.1	F_2 = 26.6**
	Error	4	263.95	

* P < .01 *** P < .1

** P < .05 **** P < .2

Fig.21. Survivorship curves of *Pleuroxus similis* in three different media and three different inoculum densities.

Fig. 21


A—3 animals
Chicken manure
Filtered pond water
Rice bran
% Survival
Weeks
B—5 animals
% Survival
Weeks
C—8 animals
% Survival
Weeks

survivorship curve in filtered pond water and rice bran media, is of type I whereas in chicken manure medium the curve is of type I till the 3rd week which then becomes type III from 6th week onwards.

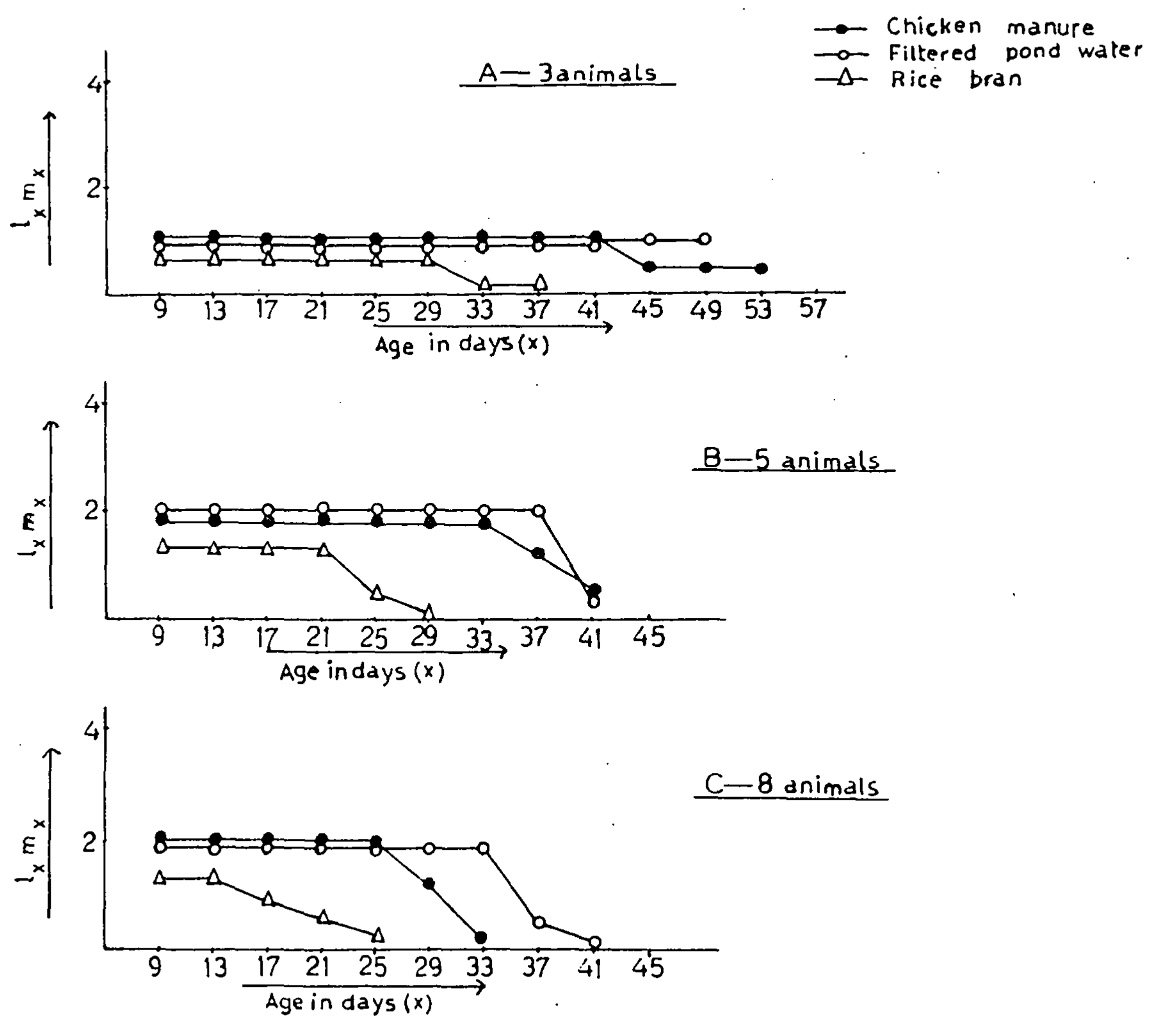
The survivorship-fecundity function l_x m_x for different cultures and different inoculum densities is represented in Fig.22. The number of offsprings produced are initially constant, but then decreases as the age of the animals increases. This pattern is observed in all the cases.

The population density of *Pleuroxus similis*, increased progressively with time in all the media, and all the different inoculum densities (Fig.23A,B&C). In filtered pond water the population peaked during the 4th week (79 individuals/l, 5th week (70 individuals/l) and 3rd week (63 individuals/l) for inoculum densities of 3, 5 and 8 animals respectively. A maximum population density of 112 individuals/l was observed in the 4th week, with the initial inoculum density of 3 animals, in chicken manure medium. The maximum density of 93 individuals/l (inoculum density 5 animals) and 92 individuals/l (inoculum density 8 animals) was observed in the 4th and 3rd week. In rice bran medium, the peak population of 54 individuals/l was reached on the 4th week with initial inoculum density of 3 animals. With the initial inoculum density of 8 animals, the population peak of 58 individuals/l was observed in the 3rd week. Whereas in the case of 5 animals being the initial inoculum density, the population peaked during the 4th week (51 individuals/l) and remained high upto the 5th week (51 individuals/l) and then gradually decreased in the successive weeks.

A two way ANOVA was done for total population density in three media

Fig.22. Relationship between fecundity and life span of *Pleuroxus similis* in three different media and three different inoculum densities.

Fig. 22



Chicken manure
Filtered pond water
Rice bran
A— 3animals
B—5 animals
C—8 animals
$l_x m_x$
4
2
9 13 17 21 25 29 33 37 41 45 49 53 57
9 13 17 21 25 29 33 37 41 45
Age in days (x)

Fig.23. Weekly population density of *Pleuroxus similis* in:

(A) filtered pond water with three different inoculum densities.

Fig. 23

'A' - Filtered pond water

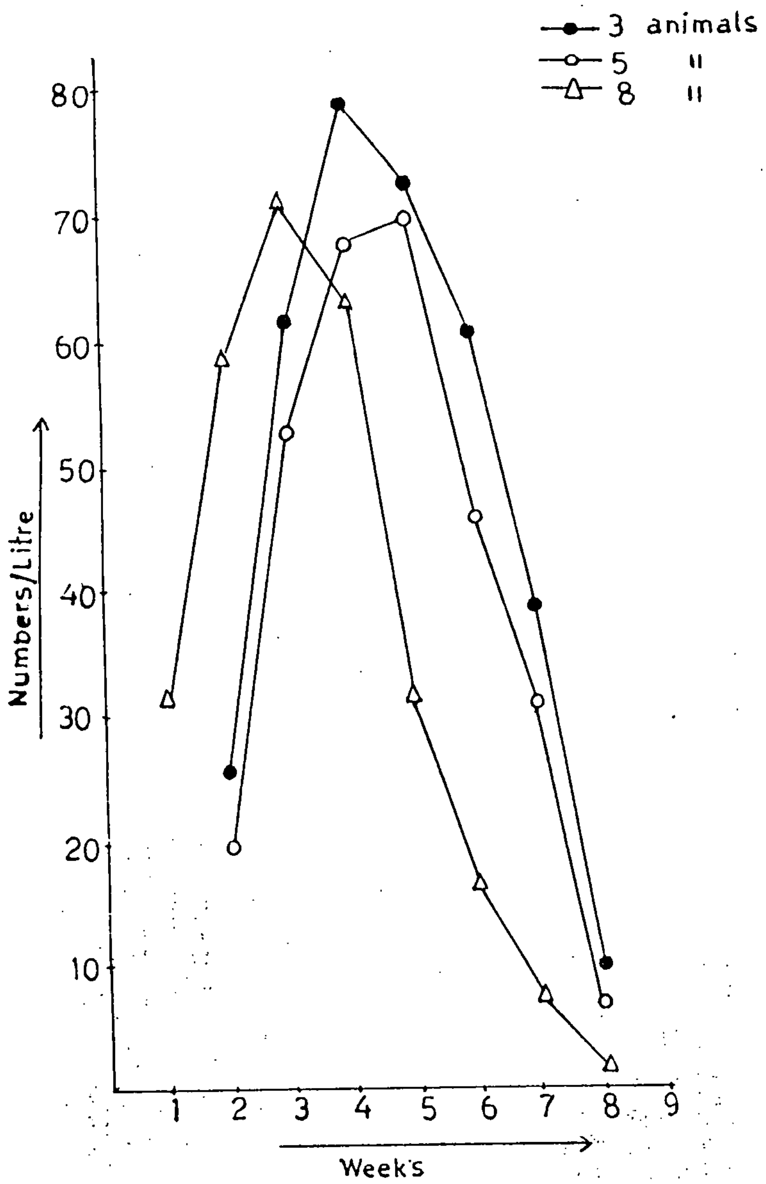


Fig.23. Weekly population density of *Pleuroxus similis* in:

(B) Chicken manure with three different inoculum densities.

Fig.23

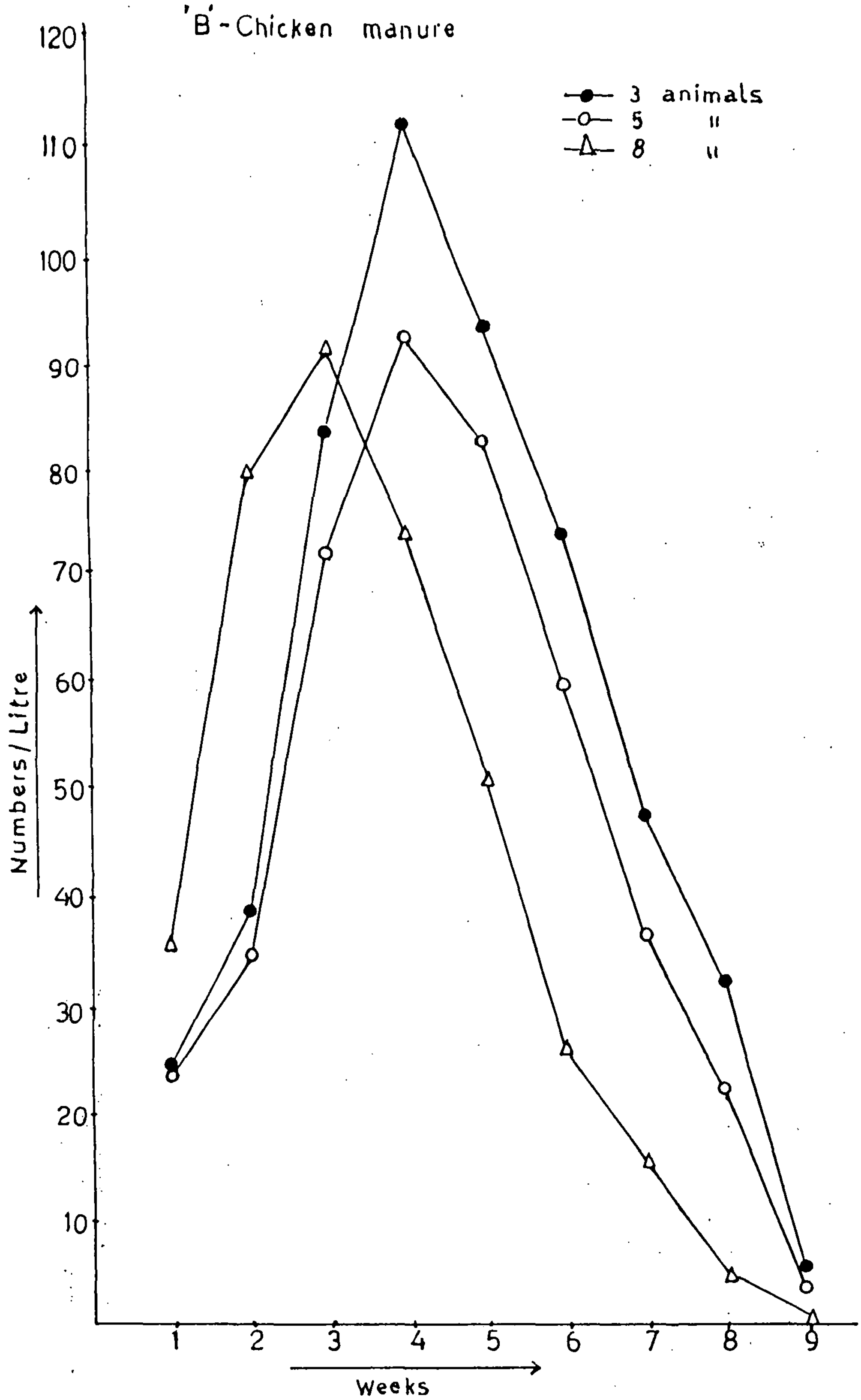
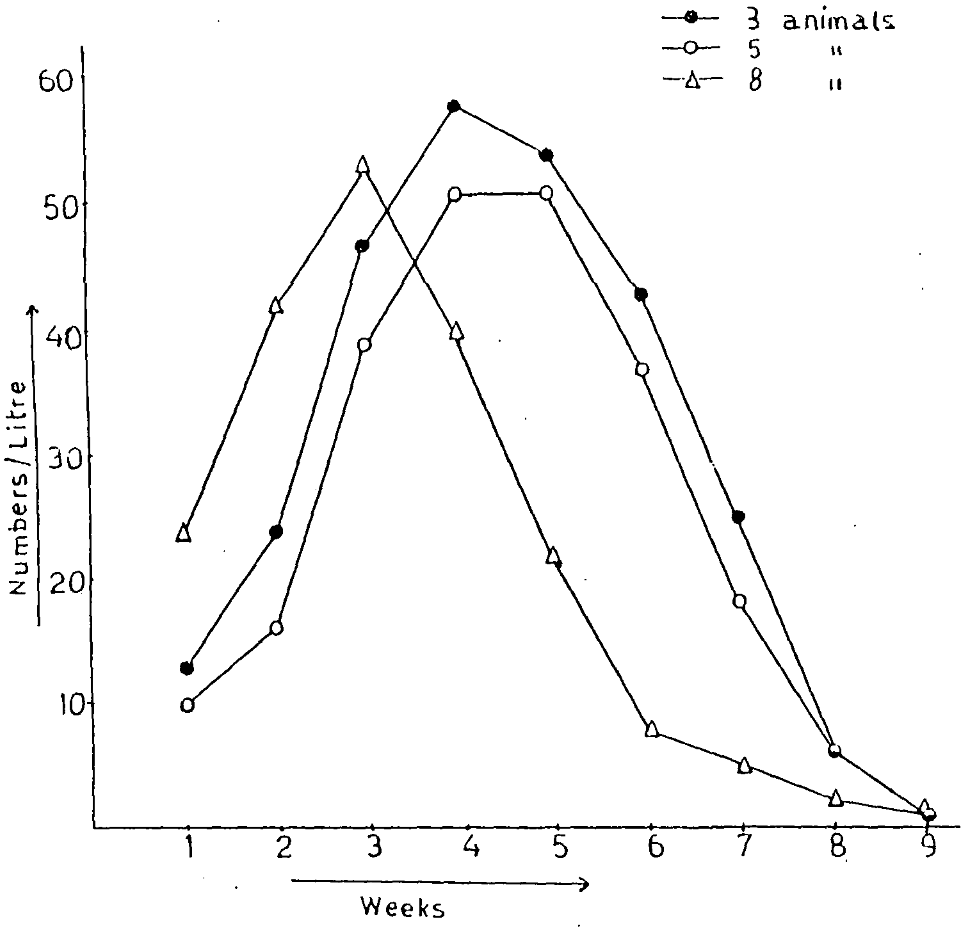

'B'-Chicken manure
3 animals
5 "
8 "
Numbers/Litre
120
110
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
Weeks

Fig.23. Weekly population density of *Pleuroxus similis* in:

(C) Rice bran with three different inoculum densities.

Fig. 23

'C' - Rice bran



with three different initial inoculum densities, and a significant difference was observed in the total population density in the three media and in between the three initial inoculum density (Table:12).

The population structure of *Pleuroxus similis* in the three media, with three different initial inoculum density is represented in (Fig.24A,B&C). The population is mainly composed of four categories of animals: (a) Neonatae (b) Parthenogenetic females (c) Females without eggs (d) Ephippial females. Neonatae and parthenogenetic females constitute the major portion of the population in all the three media, with different inoculum densities. Females without eggs seen in high number during the stage when the population begins to decline. In filtered pond water, with three different initial inoculum density, the population peaks were constituted of neonatae which were comparatively higher (28 individuals/l, 36 individuals/l and 32 individuals/l - initial inoculum density of three animals, 25 individuals/l, 31 individuals/l, 27 individuals/l - I.D.* of 5 animals, and 25 individuals/l, 28 individuals/l and 23 individuals/l - I.D. of 8 animals) as compared to that of the parthenogenetic females (25 individuals/l, 29 individuals/l, 27 individuals/l - I.D. of 3 animals, 22 individuals/l, 25 individuals/l and 24 individuals/l - I.D. of 5 animals, 18 individuals/l, 26 individuals/l and 24 individuals/l - I.D. of 8 animals). Ephippial females were observed in the population between the 2nd and 7th week, their numbers being higher (4 individuals/l - I.D. of 3, 5 and 8) during the peak population. Females without eggs had a higher number (16 individuals/l - I.D. of 3 animals, 15 individuals/l - I.D. of 5 animals and 14 individuals/l - I.D. of 8 animals)

---

* I.D. denotes Inoculum Density.

Fig.24. Weekly population structure of *Pleuroxus similis* in :

(A) Filtered pond water with three different inoculum densities.

(Inoculum densities - 3 and 5 animals)

Fig. 24

'A' – Filtered pond water

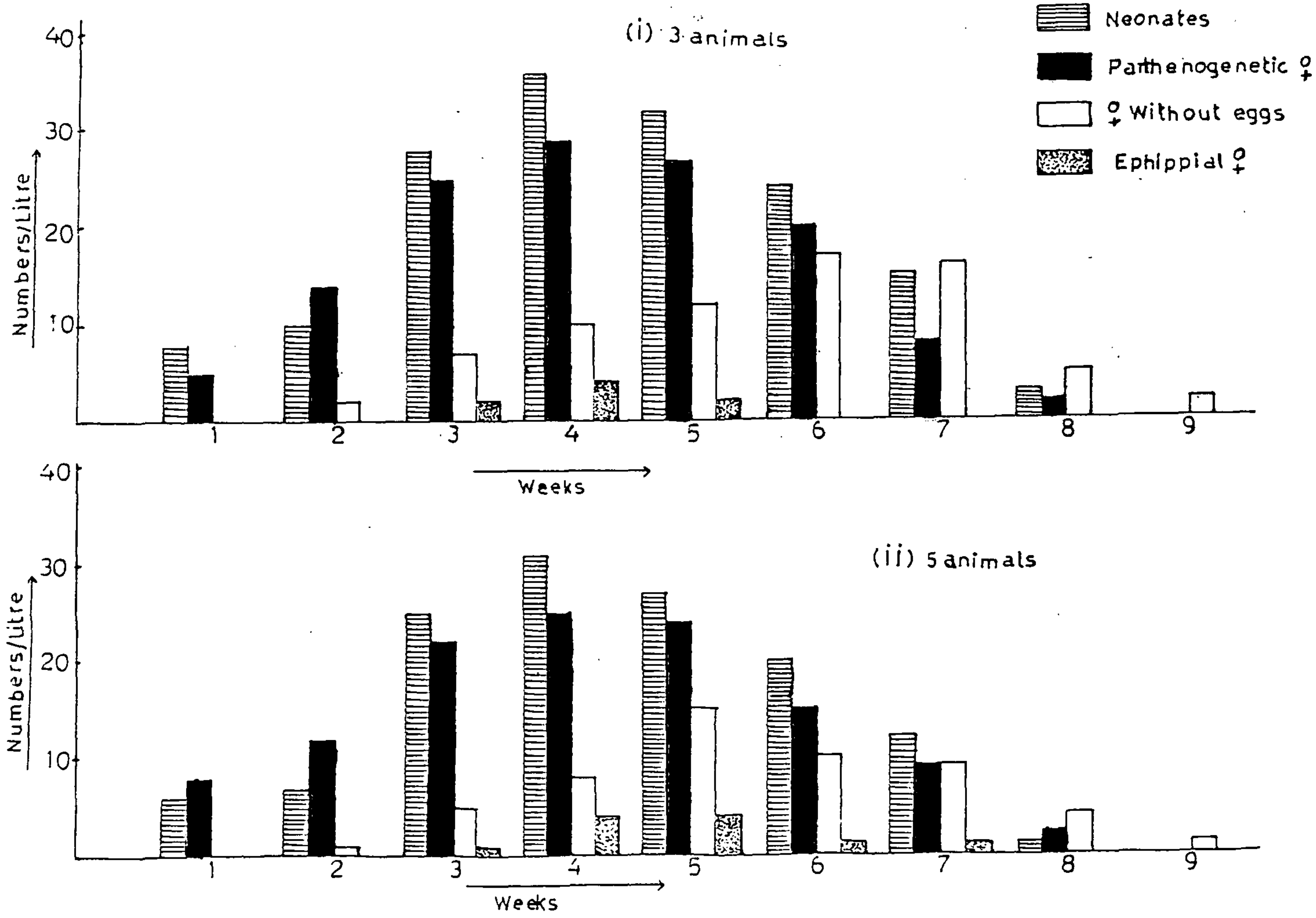
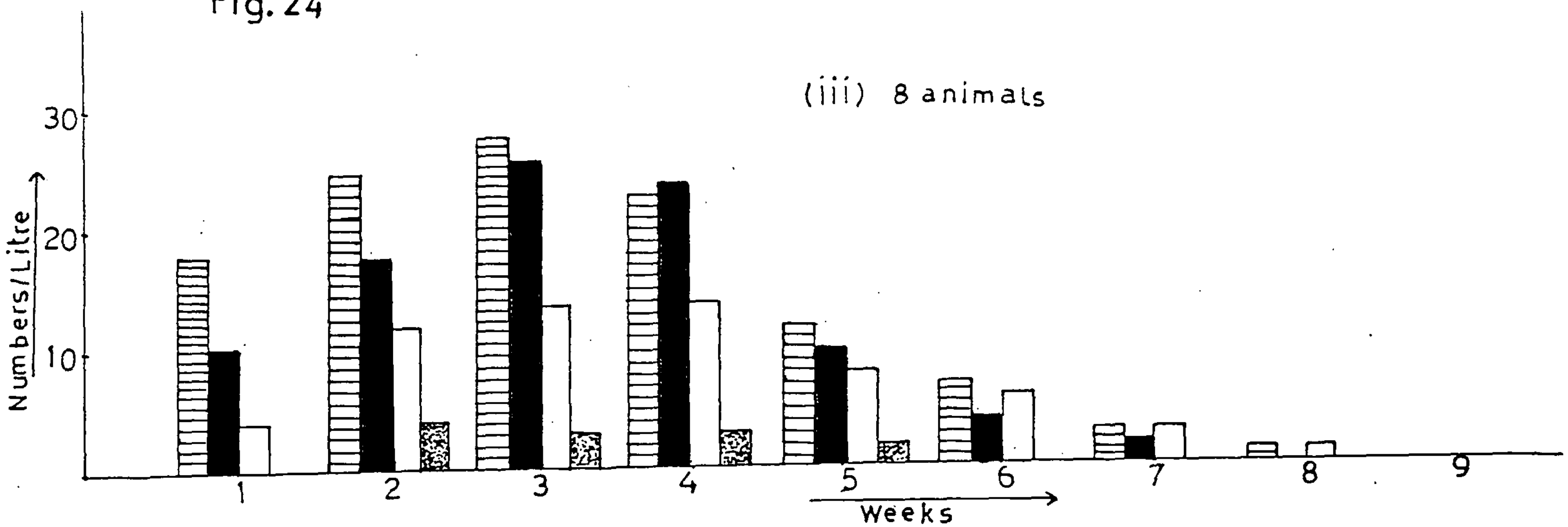


Fig.24. Weekly population structure of *Pleuroxus similis* in:

(A) Filtered pond water with three different inoculum densities. (Inoculum density - 8 animals).

(B) Chicken manure with three different inoculum densities. (Inoculum density - 3 animals).

Fig. 24


(iii) 8 animals
30
20
10
Numbers/Litre
1
2
3
4
5
6
7
8
9
Weeks

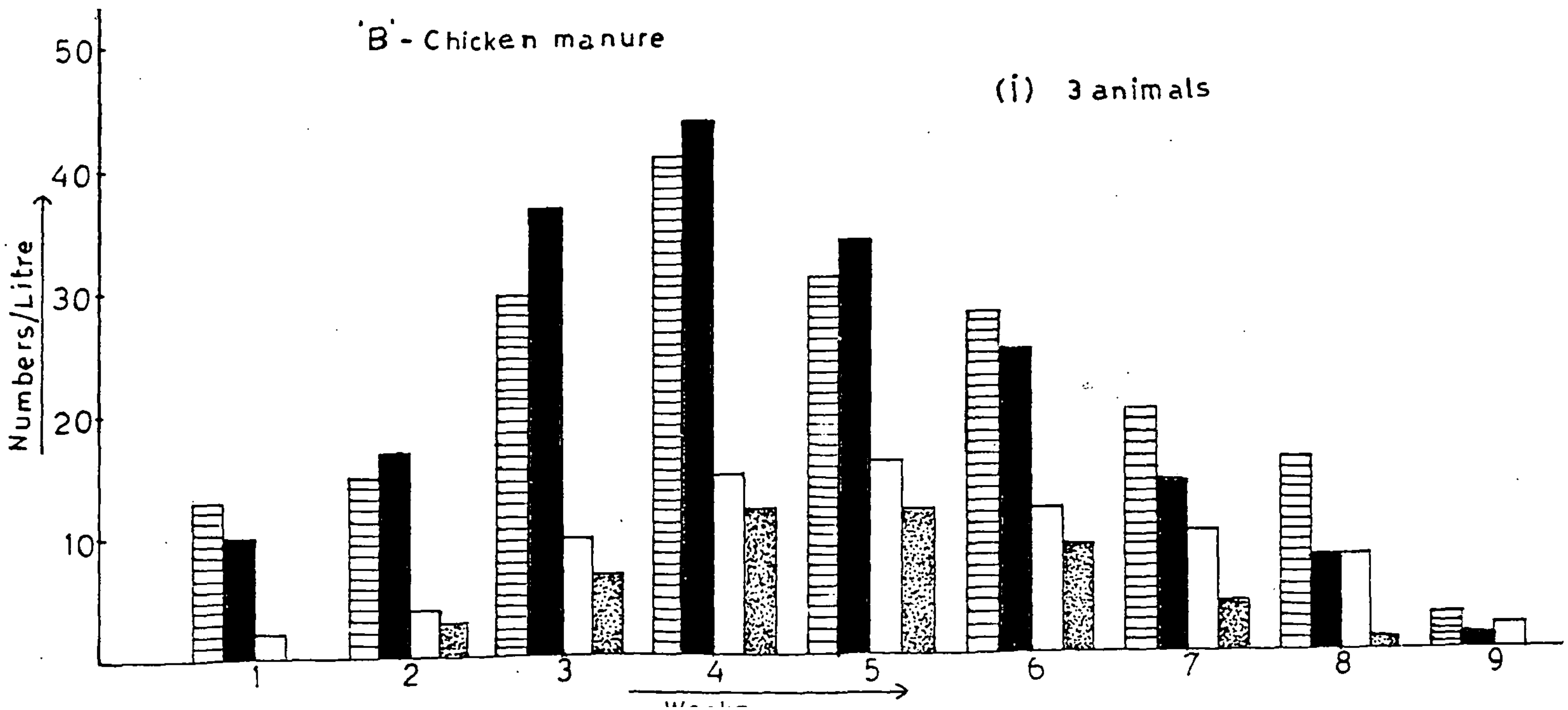

'B' - Chicken manure
(i) 3 animals
50
40
30
20
10
Numbers/Litre
1
2
3
4
5
6
7
8
9

Fig.24. Weekly population structure of *Pleuroxus similis* in:

(B) Chicken manure with three different inoculum densities. (Inoculum densities - 5 and 8 animals).

Fig. 24

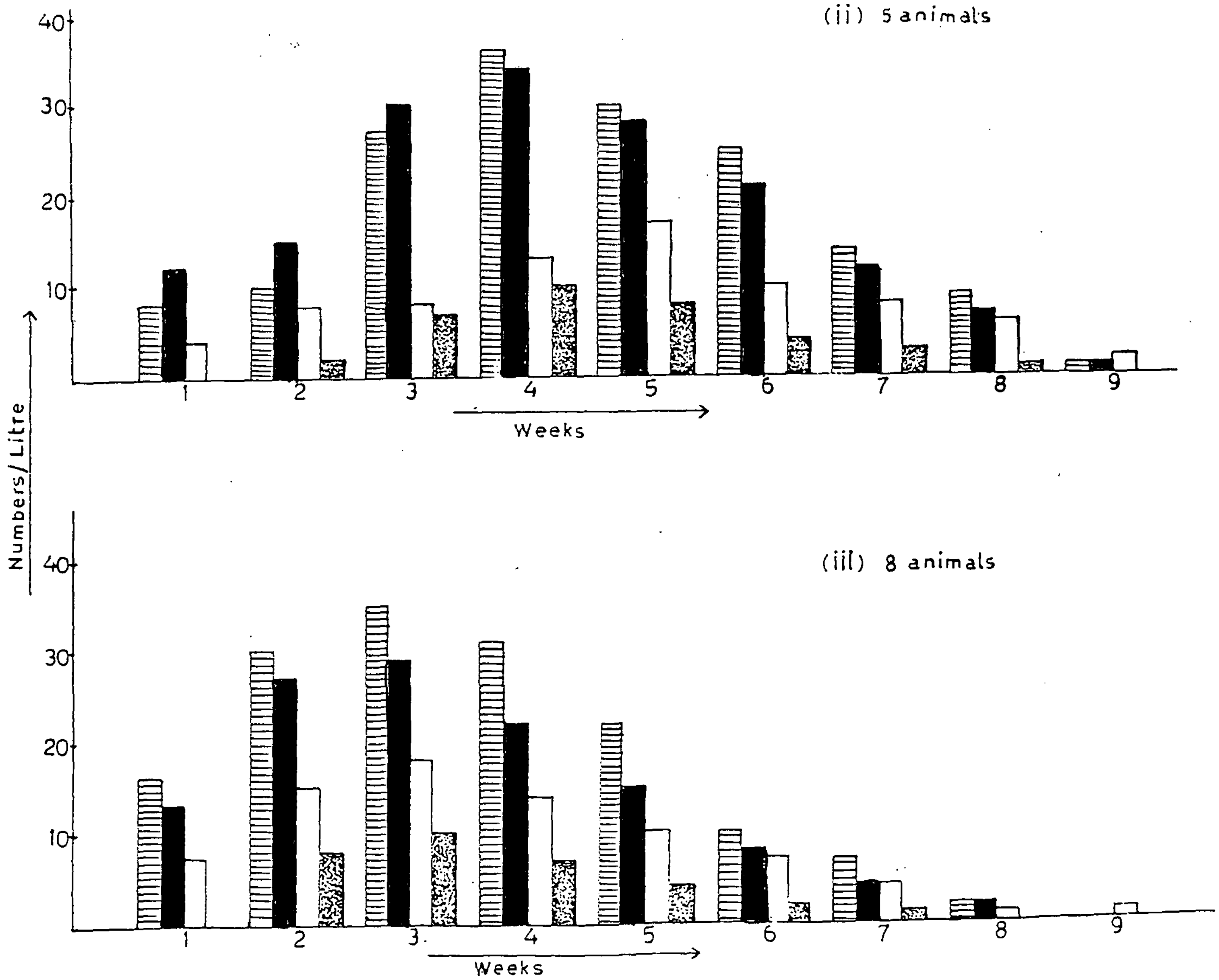
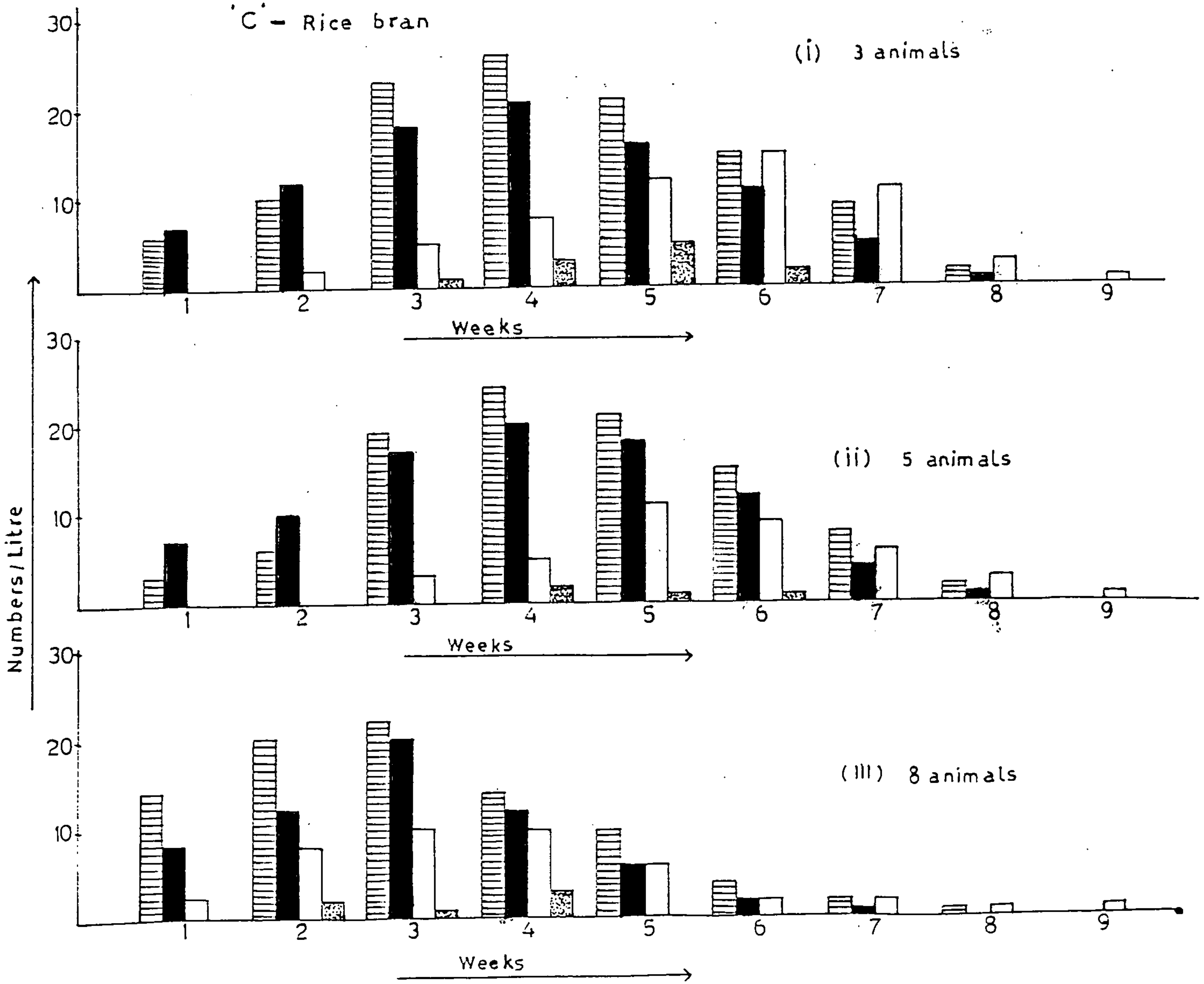

(ii) 5 animals
(iii) 8 animals
Numbers/Litre
40
30
20
10
1
2
3
4
5
6
7
8
9
Weeks

Fig.24. Weekly population structure of *Pleuroxus similis* in:

(C) Rice bran with three different inoculum densities.
(Inoculum densities - 3, 5 and 8 animals).

Fig. 24


'C' – Rice bran
(i) 3 animals
(ii) 5 animals
(III) 8 animals
Numbers / Litre
Weeks
Weeks
Weeks
30
20
10
30
20
10
30
20
10
1
2
3
4
5
6
7
8
9

during the declining period of the population. In chicken manure medium with initial inoculum density of 3 animals, the number of parthenogenetic females were more during the peak population (44 individuals/l, 34 individuals/l and 25 individuals/l) as that compared to that of neonatae (41 individuals/l, 31 individuals/l and 28 individuals/l). In this medium, Ephippial females were present in the population from the 2nd-8th week i.e. almost throughout the whole population time period. In case of population with the initial inoculum density of 5 and 8 animals, the number of neonatae was more. 36 individuals/l (I.D. = 5) and 35 individuals/l (I.D. = 8) as compared to that of parthenogenetic females 34 individuals/l (I.D. = 5) and 29 individuals/l (I.D. = 8). In rice bran medium during the peak population, in all three inoculum densities, the number of neonatae was more with 26 individuals/l (I.D. = 3), 24 individuals/l (I.D. = 5) and 32 individuals/l (I.D. = 8), as comapred to that of parthenogenetic females with eggs, 21 individuals/l (I.D. = 3), 20 individuals/l (I.D. = 5) and 20 individuals/l (I.D. = 8). Ephippial females were present in the population for a short time period of 3-4 weeks in all the three initial inoculum densities, 3rd-6th week in the population with the initial inoculum density of 3 animals, 4th-6th week in 5 animals, and 2nd-4th week in the population with inoculum density of 8 animals. Females without eggs were present in higher number of 15 individuals/l, 12 individuals/l and 11 individuals/l (I.D. = 3), 11 individuals/l and 9 individuals/l (I.D. = 5), during the time when the population was declining. But in the case of the population with the initial inoculum density of 8 animals, the number of females without eggs, was higher (8 individuals/l, 10 individuals/l and 6 individuals/l) from the 2nd-4th week.

Discussion

Several features on the life history parameters of *Pleuroxus similis*, cultured under laboratory conditions emerge from this study. It was evident that the quality of medium, as well as varied density conditions, played a minor role in determining the time of first reproduction (A). But it definitely played an important role in determining the total life span of the animal. In general, the total life span (W) of *Pleuroxus similis* cultured in rice bran medium under varied inoculum densities was shorter as compared to that of filtered pond water and chicken manure. Taub and Dollar (1964) had observed retarded development, reduced brood size and higher mortality of certain cladocera in nutritionally inadequate culture medium. Jana and Pal (1985) however pointed out that quality of medium played little part in determining the life span in *Moina micrura*.

Total offspring production(S), was not a highly significant variable in the three different media under three varied inoculum densities. The variation ranging from 4.6 individual under inoculum density of 8 animal in rice bran, to 17.7 individual under inoculum density of 3 animals in filtered pond water. This variation is not considerable when compared with that of *Daphnia magna*, where it ranges from 160-1072 (Allan 1976). The reason for a small variation of (S) in *Pleuroxus similis* is largely due to the fact that the clutch size of the animal is fixed at a maximum of 2 eggs/individuals which is a characteristic feature of almost all chydorids.

The average reproductive life span of *Pleuroxus similis* was markedly reduced in rice bran medium (22.6 days) as compared to that of chicken manure (33.3 days) and filtered pond water (34.6 days). Thus, it may be said that rice bran medium was not suitable for the culture of *Pleuroxus similis*, since it retarded the growth of the animal by reducing its longevity (25.6 days) and its reproductive potentialities.

So it was observed that both filtered pond water which was used as control, and chicken manure were equally suitable for the culture of *Pleuroxus similis*, since in both cases, the reproductive life span as well as total offspring production 'S' was high. In fact reproductive life span was slightly higher in filtered pond water (34.6 days) as compared to that in chicken manure (33 days) while total offspring production was the same with 13 offspring per female in chicken manure. As far as longevity of the animal was concerned, it had the highest longevity in filtered pond water (42.4 days) as compared to that of chicken manure (40 days). But the maximum body length was attained in chicken manure (data presented in Chapter: 5a) as compared to that of filtered pond water. Though temperature had been suggested as affecting longevity of cladocerans in general (Brown 1926; Bottrell 1975; Wetzel 1983), differences in longevity between the media could not be explained by this, since the temperature was constantly maintained at 17°-22°C in all cases. So greater longevity of *Pleuroxus similis* cultured under filtered pond water could be explained based on Hutchinson (1967) who stated that when a cladoceran was maintained for part of its life in a poor medium, its life expectancy was enhanced over either well fed (chicken manure in present study) or as poorly fed (rice bran in present study) individuals.

That chicken manure was more suitable for culture of *Pleuroxus similis* was reiterated by the fact that the average total population density for all the three inoculum densities was markedly higher (442 individuals/l) as compared to that of filtered pond water (320 individuals/l) and rice bran (232 individuals/l) (fig.23A, B & C). Though the net reproductive rate (R_0) was higher (13.9) in filtered pond water as compared to that of chicken manure (12.2), the total population density in the latter was markedly higher as compared to former, because the average generation time in chicken manure was less (22.7) than that of filtered pond water (24.7), which means that offsprings were generated at a faster rate in chicken manure. In rice bran though the average generation time was the least (17.2) mortality was high, thereby resulting in a low population density (232 individuals/l).

The population density in the three diferent media under the different inoculum densities, showed similar growth patterns i.e. the population started growing from the first week, reached its peak around 3rd-4th week and then declined (Fig.23A,B,C). It was generally observed that under higher inoculum densities (8 animal) the peak population was reached earlier compared to that of low densities (i.e. 3 animals) in all the three culture media. This may be due to the fact that the average generation time in higher densities was less as compared to that at lower densities (Table:11). The result of this is that the population built itself up at a faster rate and the peak reached sooner. Once this stage is reached, there occurs a reduction in egg production (since net reproductive rate (R_0) is less in higher densities) mediated through a feedback mechanism as the population size approach the carrying capacity. Besides reduction in egg production, mortality also sets in which results in a low population density. Frank (1952) observed that the production of young females decreased with increasing density in laboratory cultures of

Daphnia pulicaria. It should however be noted that the variation in egg production in *Pleuroxus similis* is not so pronounced as those of Daphnids, owing to the fact that the clutch size in chydorids is invariably fixed.

The population structure of *Pleuroxus similis*, under three different inoculum densities in three different media, constitutes mainly of females with eggs during the peak populations, but as the population starts declining, the number of females without eggs starts increasing. Ephippial females occur during the time when the population starts increasing. This is indicative of the fact that crowded conditions result in the formation of ephippial females which is a well known phenomenon among cladocera (Pennak 1953) and confirmed also by the present studies.

The survivorship curves seemed to be both density-dependent and also affected by the culture medium. There was 100% survival till the 8th week in filtered pond water under an initial inoculum density of 3 animals. In case of chicken manure and rice bran the survival was 100% till the 5th week and 3rd week respectively. Similarly in case of inoculum density of 5 animals, there was 100% survival for both chicken manure and filtered pond water till the 4th week, while in case of rice bran 100% survivability was observed only till the 2nd week. Whereas under inoculum density of 8 animals, in rice bran medium there was an initial mortality of 25%, in filtered pond water and chicken manure survivability was 100% upto 3rd week. In other words it can be said that in rice bran medium, survivability was less as compared to that of chicken manure and filtered pond water. However, under low inoculum density (3 animals) survivability was distinctly higher in filtered pond water as compared to that of chicken manure, followed by a reduction in survivability upto 67%.

Thus it can be stated that at low inoculum densities filtered pond water can support a population for a longer time period. But in case of chicken manure and rice bran a 'Stepwise' survivability curve was obtained under low inoculum densities, whereas at higher densities the curve was slightly convex, or nearly a straight line, implying that population mortality rate was low almost equal till towards the end of the life span. Similar survivorship curves were alsoreported by Jana and Pal (1983) in *Daphnia carinata.*

Survivorship and fecundity data for *Pleuroxus similis* were combined in the survivorship-fecundity function, $l_x m_x$ for the different culture media (Fig.22). The curve describes almost a straight line, and is very different from the characteristically triangular-shaped curve obtained by Allan (1976) in *Daphnia pulex*, by Jana and Pal (1983; 1985) in *Daphnia carinata* and *Moina micrura*. One of the main reasons for this flat survivorship-fecundity curve is because of the fixed brood size in chydorids. Allan (1976) has also pointed out that one of the factors affecting the shape of these curves in Daphnids is the relationship between temperature, body size and brood size. It is usually seen for cladocerans in general that lower temperature delays first reproductive time and enlarges body size (McLaren 1963). As a result larger individuals have larger clutches which are laid and hatched at slower rates thereby increasing the longevity of animals. Nevertheless, in spite of these opposing effects the brood size remains rather constant (MacLaren 1974). But in the present study this view was not totally supported, since at higher temperature the broods laid become more, as a result the value of 'S' increases and r_{max} (intrinsic rate of population increase) also increases steeply (McLaren 1974). When this estimate of r_{max} was applied to field populations the result does not always tally (exp: high r_{max} with high temperature) which could obviously be explained by the various biotic and abiotic factors that interact on the population under field conditions.

It should be noted that Lewontin's (1965) formula could not be used in the present study for determination of r_{max} and instead egg ratio method used by Edmondson (1960), subsequently modified by Hall (1964) and George and Edwards (1974) was used. If instantaneous birth rate (b') is considered as r_{max} then it is obseved that growth is very high ranging from 0.693 to 5.24 in the field and 0.41-3.57 under laboratory conditions. High value of r_{max} in case of Cladodera have also been reported by earlier workers like Hall (1964), Wright (1965) and Allan (1973). However, it is noticed that the culture media and density also play same role in determining r_{max} since r_{max} depends on 'S' (total ofspring production per female) and 'S' in turn is correspondingly affected by the quality of the culture medium and as well the density.

(ii) Effect of Inoculum Density on different population parameters in *Pleuroxus similis* using chicken manure.

(a) Growth: Measurements of mean body length of *Pleuroxus similis* grown under varied density conditions (3, 5, 8 and 12 animals) with the fixed container size, are shown in Table:13. The average body length of these animals ranged from 0.01-0.05mm in these treatments on different dates. The body length of the animal was affected to some extent by the population density. In the densities of 3, 5, 8 and 12 animals, the average body length was found to be 0.45mm, 0.44mm, 0.41mm and 0.39mm respectively. In all the variants the average body length tended to rise with the passage of time reaching the maximum on the 32nd day of inoculation. There was a decline in the mean length of the population thereafter due to the death of the adult individuals, and also due to the appearance of the young ones in the population.

(b) Survival: Survivorship curves of the animal grown under varied inoculum densities, are shown in Fig.25A, B, C & D. In case of density of 3 animals there was 100% survival upto the 5th week, and thereafter mortality sets in. In case of 5 animals there was 100% survival only upto the 2nd week, and thereafter mortality occuredthat was almost constant. In the remaining two densities of 8 and 12 animals, the survivorship curve described almost a straight line, which meant that mortality ratewasconstant per unit time.

(c) Fecundity: The daily average egg production under different inoculum densities are represented in Fig.26B. The daily mean of egg production

Table 13: Average body length (mm) in *Pleuroxus similis* grown in various inoculum densities.

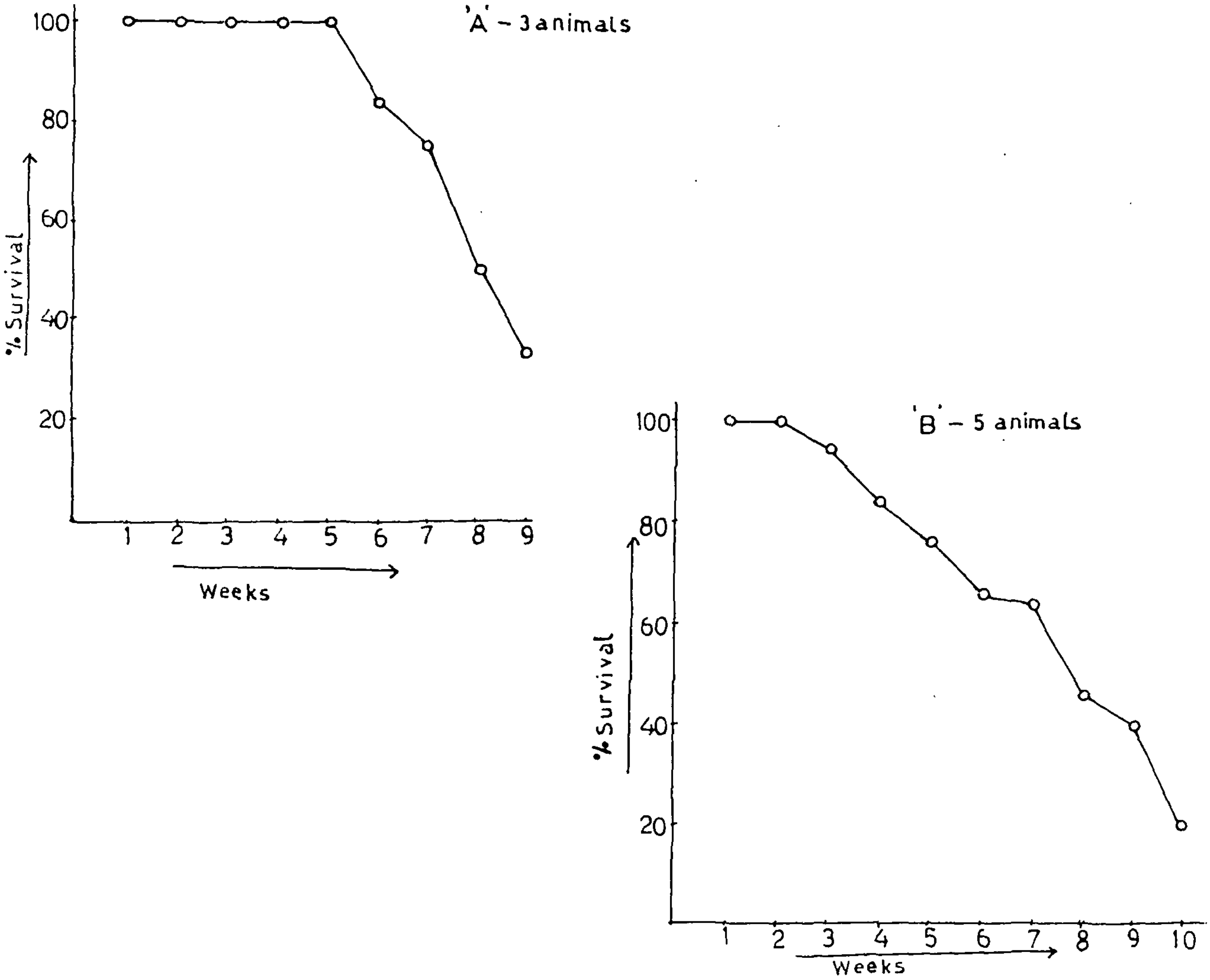
Inoculum density (number of animals)	Volume of flask (ml)	Days after inoculum																
		1st	3rd	6th	10th	13th	16th	19th	23rd	26th	29th	32nd	35th	38th	39th	43rd	47th	51st
3	60	0.31	0.35	0.38	0.43	0.44	0.46	0.47	0.48	0.49	0.50	0.51	0.51	0.52	0.52	0.52	0.52	0.52
5	60	0.31	0.35	0.37	0.38	0.42	0.44	0.45	0.46	0.48	0.48	0.49	0.49	0.50	0.51	0.51		
8	60	0.31	0.33	0.34	0.37	0.39	0.43	0.44	0.45	0.46	0.48	0.48	0.48					
12	60	0.31	0.32	0.33	0.36	0.36	0.37	0.39	0.41	0.43	0.45	0.46	0.46					

Fig.25. Survivorship curve of *Pleuroxus similis* in chicken manure medium with three inoculum densities of:

(A) 3 animals

(B) 5 animals.

Fig. 25



'A' - 3 animals
% Survival
100
80
60
40
20
1
2
3
4
5
6
7
8
9
Weeks
'B' - 5 animals
% Survival
100
80
60
40
20
1
2
3
4
5
6
7
8
9
10
Weeks

Fig.25. Survivorship curve of *Pleuroxus similis* in chicken manure medium with three inoculum densities of:

(C) 8 animals

(D) 12 animals.

Fig. 25

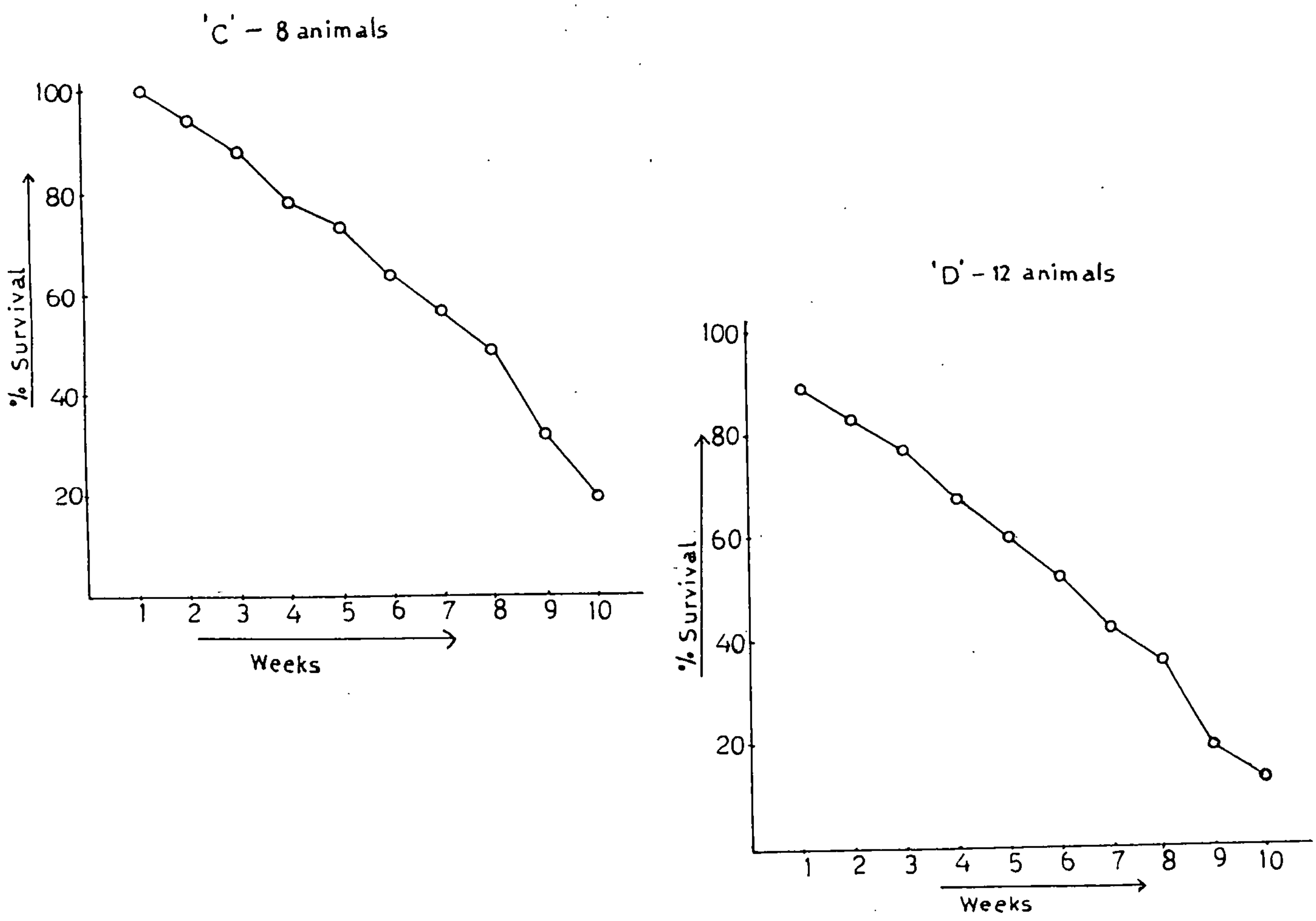

'C' – 8 animals
100
80
60
40
20
% Survival
1 2 3 4 5 6 7 8 9 10
Weeks
'D' – 12 animals
100
80
60
40
20
% Survival
1 2 3 4 5 6 7 8 9 10
Weeks

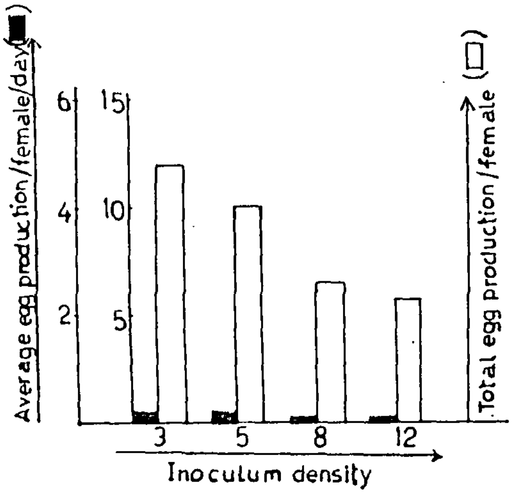
Fig.26A: Relationship between total egg production/female, average egg production/female/day vs inoculum density.

B: Daily variation in average egg production in different inoculum densities of:

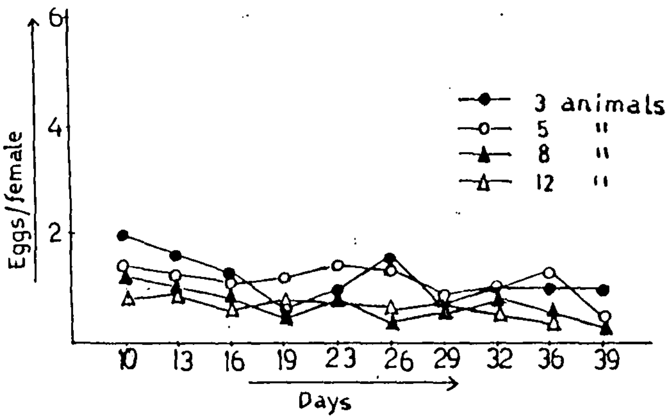
3 animals
5 animals
8 animals
12 animals.

C: Relationship between cumulative progeny production/female/life span vs inoculum densities.

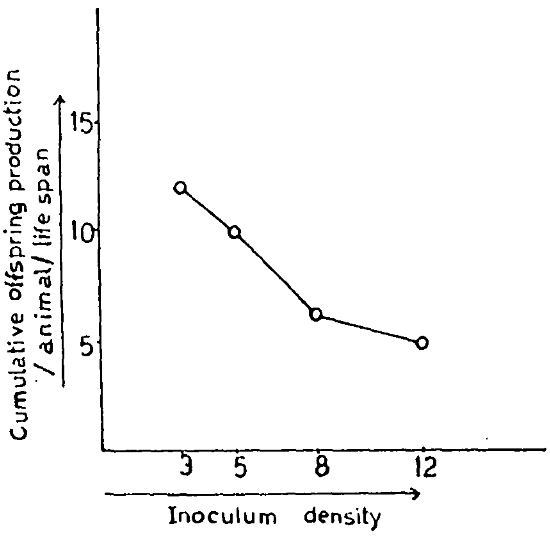
Fig. 26



Average egg production/female/day
Total egg production/female
6
4
2
15
10
5
3
5
8
12
Inoculum density



Eggs/female
6
4
2
3 animals
5 "
8 "
12 "
10
13
16
19
23
26
29
32
36
39
Days



Cumulative offspring production / animal/ life span
15
10
5
3
5
8
12
Inoculum density

was maximum (1.2) under the stocking density of 3 animals, with maximum available space of 20cm^3/individual. It was minimum (0.45) under the stocking density of 12 animals with the maximum available space of 5cm^3/individual. The production rate was highest (12.0) in the stocking density of 3 animals and minimum (5.8) in the stocking density of 12 animals (Fig.26A). The cumulative offspring production per individual per life span was maximum (12.0) in the stocking density of 3 animals, and minimum (5.0) in the stock density of 12 animals (Fig.26C). However, when one way analysis of variance was done for total fecundity ($F_{5,26}$ = 1.98 P >.2) the result was not highly significant between the varied density conditions. But when comparison between the total egg production per female in the stocking density of 3 and 12 animals was done, a significant difference was noticed (df = 18, t=3.9, P > .005). Therefore, it can be said that the total egg production /female was much higher in the stocking density of 3 animals, as compared to that of 12 animals.

(d) Population: The population density of *Pleuroxus similis* varied largely among different inoculum densities as represented in Fig.27A. The population reached its peak of 51 individual for the density of 8/60cm^3, and 35 individuals/l for the density of 12/60cm^3 on the 21st day. Thereafter the population declined. For the density of 5/60cm^3, the peak of 55 individuals/l was seen on the 35th day, while for the density of 3/60cm^3 the peak of 77 individuals/l was noticed during the 40th day. Analysis of variance was done utilizing the data of total population on common days of survival. The result was significant ($F_{3,44}$=3.66, P > .05) suggesting a variance among the four inoculum densities.

Fig.27A: Temporal changes in total population number in different inoculum densities of:

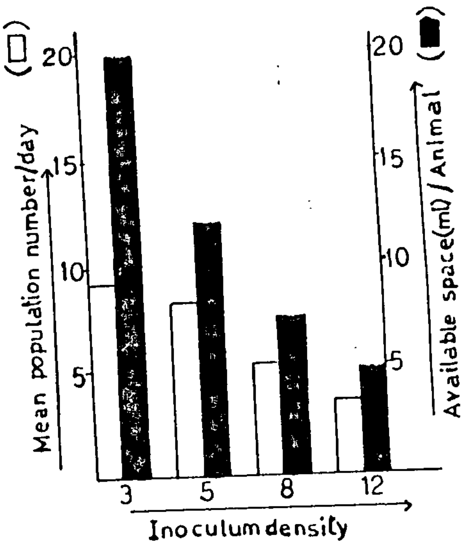
3 animals
5 animals
8 animals
12 animals

B: Daily mean population number in relation to available space in different inoculum densities of:

3 animals
5 animals
8 animals
12 animals.

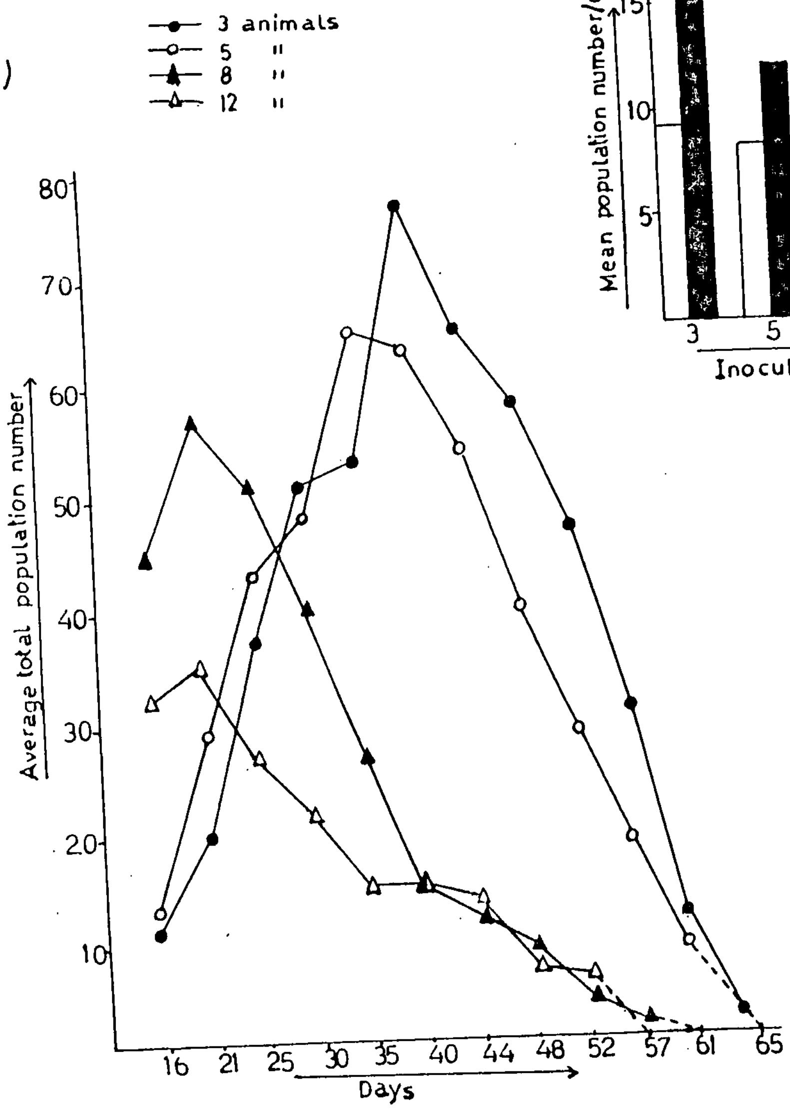
Fig. 27

(B)



Mean population number/day
Available space(ml)/Animal
20
15
10
5
3
5
8
12
Inoculum density

(A)



3 animals
5 "
8 "
12 "
Average total population number
80
70
60
50
40
30
20
10
16
21
25
30
35
40
44
48
52
57
61
65
Days

The daily population size was maximum (9.8) and minimum (3.5) under the density of $3/60cm^3$, and $12/60cm^3$ respectively (Fig.27B). The maximum population obtained in the former was significantly higher (df=22, t=38.2 P >.001) than the population found in the highest inoculum density.

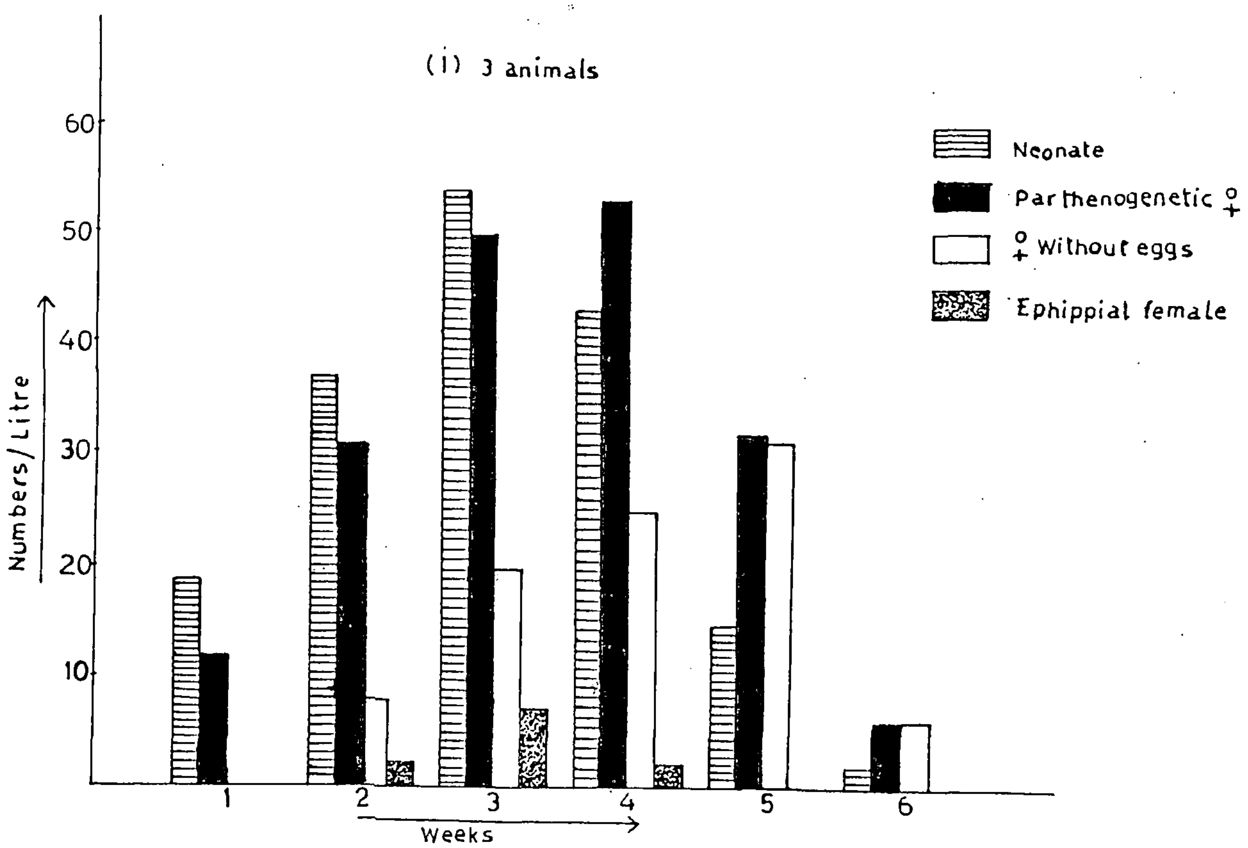
The weekly population structure of *Pleuroxus similis* in different inoculum densities are shown in Fig.28. With the density of $3/60cm^3$, the number of neonatae was higher (54 individuals/l) than that of parthenogenetic females (50 individuals/l) during the population peak on the 3rd week whereas with the density of $5/60cm^3$, the number of neonatae and parthenogenetic females was same (53 individuals/l) on the 3rd week when the population peaked. In case of higher inoculum density of $8/60cm^3$ and $12/60cm^3$ the population peaked on the 1st week after inoculation, and in both cases the number of parthenogenetic females was more (50 individuals/l) i in $8/60cm^3$, and 36 individuals/l in $12/60cm^3$) as compared to that of neonatae (48 individuals/l in $8/60cm^3$ and 19 individuals/l in $12/60cm^3$).

Weekly population dynamics for the varied inoculum densities of $3/60cm^3$, $5/60cm^3$, $8/60cm^3$ and $12/60cm^3$, were worked out following methods used by Hall (1964), and George and Edwards (1974) (Table:14). The potential rate of population increase (b') is comparatively higher than the observed rate of population increase (r') in all the inoculum densities. The calculated mortality rate (d') was found to be higher than birth rate, from 3rd week to 5th week in both the inoculum densities of $3/60cm^3$ and $5/60cm^3$. In other words, just after the peak population mortality sets in, thereby causing the decline in the population. Similarly, mortality rate was found to be higher than birth rate, from 2nd week to 5th week in

Fig.28. Population structure of *Pleuroxus similis* in inoculum density of:

3 animals.

Fig. 28



(i) 3 animals
Neonate
Parthenogenetic ♀
♀ without eggs
Ephippial female
Numbers/Litre
60
50
40
30
20
10
1
2
3
4
5
6
Weeks

Fig.28. Population structure of *Pleuroxus similis* in inoculum density of:

5 animals.

Fig. 28

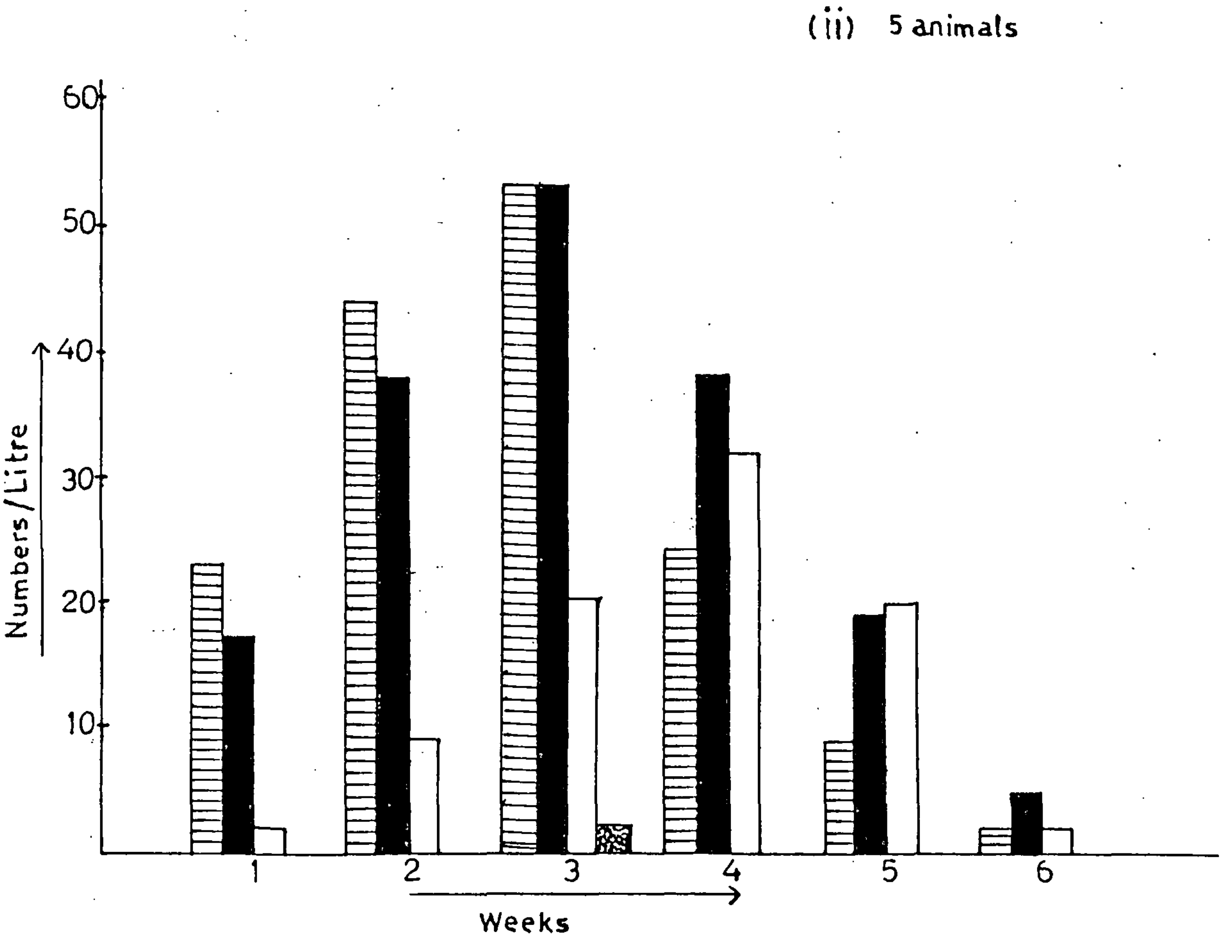


Fig.28. Population structure of *Pleuroxus similis* in inoculum densities of:

8 animals
12 animals.

Fig. 28

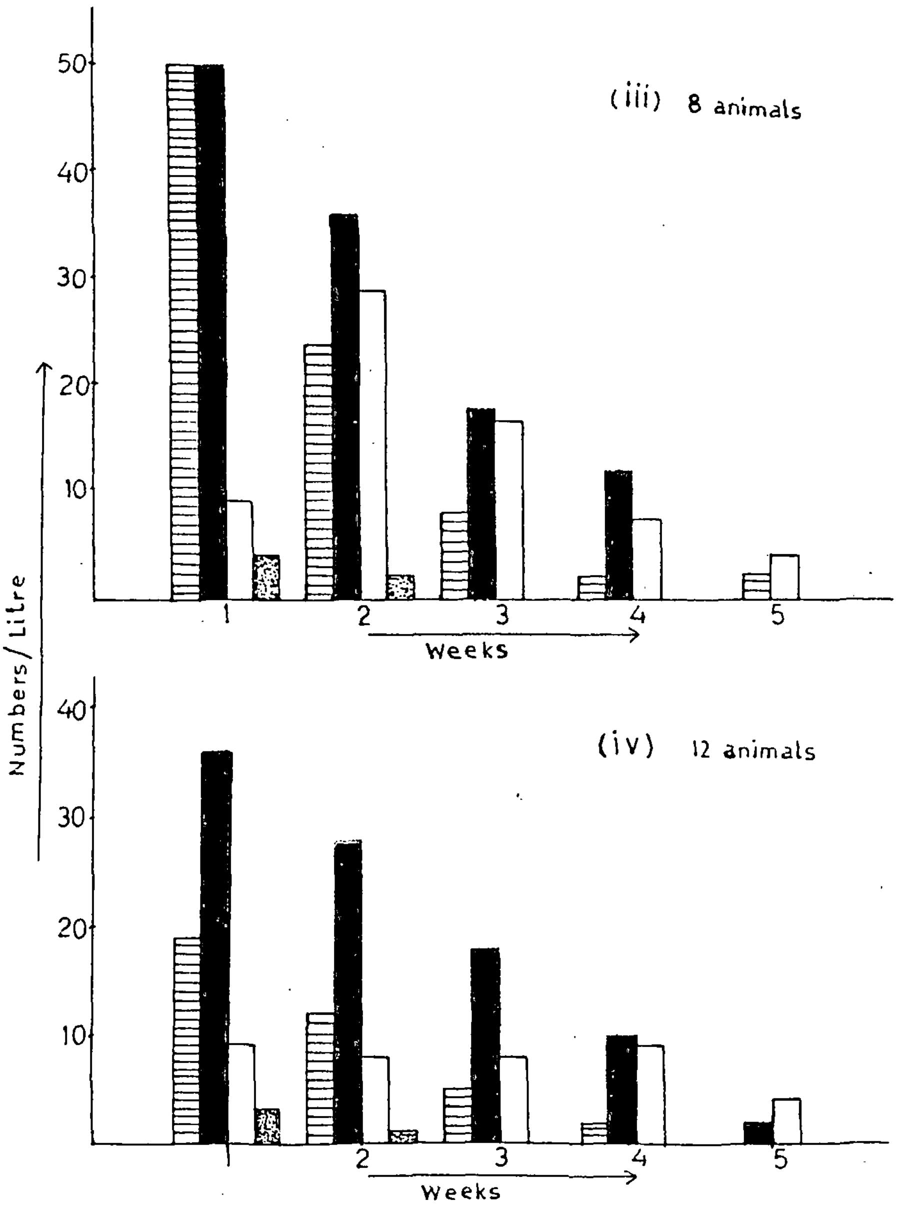

50
40
30
20
10
(iii) 8 animals
1
2
3
4
5
Weeks
Numbers/Litre
40
30
20
10
(iv) 12 animals
2
3
4
5
Weeks

Table 14: Weekly population dynamics of *Pleuroxus similis* under varied inoculum densities.

(a) Inoculum Density: 3 animals.

Time	E	D	B	b'	d'	r'
1st week	1.9	4	9.5	2.35	2.226	+0.124
2nd week	1.8	4	22.95	3.18	3.172	+0.008
3rd week	1.8	4	34.65	3.57	3.604	- 0.034
4th week	1.6	4	23.2	3.19	3.232	-0.042
5th week	1.4	4	10.85	2.47	2.66	-0.19

(b) Inoculum Density: 5 animals.

Time	E	D	B	b'	d'	r'
1st week	1.7	4	5.52	1.87	1.708	+0.162
2nd week	1.8	4	19.35	3.01	2.988	+0.022
3rd week	1.6	4	26	3.30	3.306	-0.006
4th week	1.6	4	21.6	3.12	3.18	-0.06
5th week	1.3	4	9.42	2.34	2.426	-0.086

E - Mean brood size

B - Finite birth rate

D - Duration of development of eggs (in days) determined in the laboratory.

b' - Instantaneous birth rate

r' - Coefficient of population growth

d' - mortality rate.

Table 14: Weekly population dynamics of *Pleuroxus similis* under varied inoculum densities.

(c) Inoculum Density: 8 animals.

Time	E	D	B	b'	d'	r'
1st week	1.8	4	20.25	3.06	3.014	+0.046
2nd week	1.6	4	20.4	3.06	3.108	-0.048
3rd week	1.6	4	10.8	2.47	2.576	-0.106
4th week	1.2	4	3.6	1.53	1.67	-0.14
5th week	0.5	4	0.5	0.41	0.768	-0.358

(d) Inoculum Density: 12 animals.

Time	E	D	B	b'	d'	r'
1st week	1.6	4	12.8	2.62	2.602	+0.018
2nd week	1.5	4	4.79	1.76	1.802	-0.042
3rd week	1.2	4	4.5	1.70	1.685	+ 0.012
4th week	1.2	4	4.2	1.65	1.788	-0.138
5th week	0	0	0	0	0	0

E - Mean brood size

B - Finite birth rate

D - Duration of development of eggs (in days) determined in the laboratory.

b' - Instantaneous birth rate.

r' - Coefficient of population growth

d' - mortality rate.

the inoculum density of $8/60cm^3$. But in the case of inoculum density of $12/60cm^3$, mortality rate was higher than birth rate in the 2nd and 4th week, and the reverse on 1st and 3rd week.

Discussion

From the present study, it is very much evident that population growth in *Pleuroxus similis* was density-dependent and also the average production of offspring per female showed an inverse relationship with inoculum density.

Besides population growth and offspring production, the mean body length as well as survival of the animal also varied under different density conditions. It was observed that under the available space of $20cm^3$/ animal survivability and growth was maximum as compared to that of $5cm^3$/animal where both survivability and growth were minimum. The marked depletion of total egg production in *Pleuroxus similis* under crowded conditions could be explained by the phenomenon of food scarcity and accumulation of metabolic wastes under overcrowded conditions.

Since chydorids have a fixed brood size of just two eggs, the average egg production per female per day did not vary much under different density conditions i.e. under different available space, but the total egg production per female in its life time differed markedly under varied density condition; highest being under the available space fo $20cm^3$ and lowest under the available space of $5cm^3$ (Fig.26A). Thus it may be stated that maximum number of progeny produced by a female during her life span was highly dependent upon the relative space available, whereas on the other hand daily offpsring production per female was not affected to a great extent by the space conditions. It was pointed out earlier, the survivability was maximum under the available space of $20cm^3$/individual. Similar effects of density on longevity were observed through the earlier works of Pratt (1943) on *Daphnia magna*, who found that maximum longevity was found at 5 animals per $50cm^3$. He also found that egg production was negatively density-dependent. Frank (1952) also reported similar results with *Daphnia pulicaria* and *Simocephalus vetulus* in pure or mixed cultures in the laboratory. Jana and Pal (1985) working on *Moina micrura* also found support for this view.

Since population peak was higher (> 53%), under the available space of $20cm^3$ than the population peak under other densities, it could be suggested that the density of $3/60cm^3$ might be considered optimal for an unrestricted, rapid and exponential population growth, with the limit of environment. With a constant space, further rise in inoculum density results in gradual reduction of population size, due to space competition and hence food under crowded conditions.

However, it is noticed that every population rise was followed by a complete crash of the population under all the density conditions except at $12/60cm^3$, where the population maintained a brief steady state before crashing. This was also indicated by the rate of population increase (r') calculated for all the density conditions. For instance, in the case of densities of $3/60cm^3$, $5/60cm^3$ and $8/60cm^3$, there was an initial increase in the population thus resulting in population growth till the peak was reached to 71 individuals/l under available space of $20cm^3$ ($3/60cm^3$), 64 individuals/l under available space of $12cm^3$ ($5/60cm^3$) and 51 individuals/l under available space of $7.5cm^3$ ($8/60cm^3$). These densities can be considered as the maximum that can be carried by the environment under the respective available space conditions. And once this limit was reached, mortality increases thus resulting in the negative value of 'r' or decrease in the rate of population increase, thereby causing the population crash. In case of the density condition of $12/60cm^3$, the maximum carrying capacity of the environment (33.5 individuals/l) was reached on the 1st week, and thereafter mortality sets in causing a population decline during the 2nd week, which must have been just below the carrying capacity of the environment. This in turn acted as a stimulus for increasing the population, resulting in the positive 'r' value during the 3rd week. The decline in the population after the 3rd week could be due to reduced natality rate in the population and increase in mortality rate, and this reduced natality most probably was caused by the accumulation of metabolicwaste in the culture medium. Jana and Pal (1985) had pointed out that brood strength in cladocerans often declined in static cultures with passage of time due to attendant accumulation of metabolic waste in culture medium.

(iii) Population growth of *Pleuroxus similis* as a direct function of available space.

Results

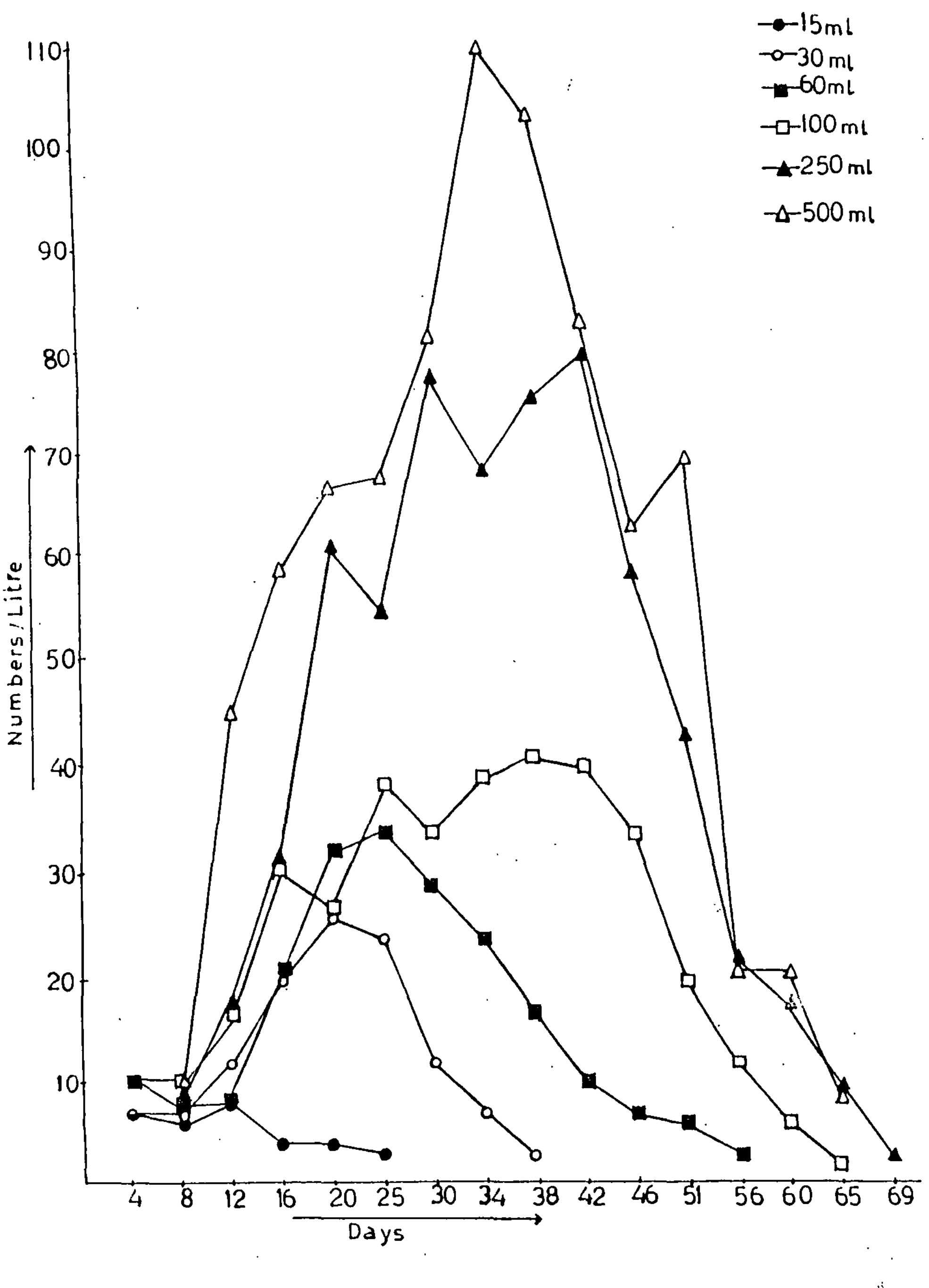
Results obtained on population size of *Pleuroxus similis* in beakers of varied spatial capacities are presented in Fig.29A. It was observed that the mean population density in general tended to rise with increasing flask capacities, so that the largest population was seen in the beaker of maximum capacity upto $500cm^3$ (Fig.29B). Under the minimal space conditions of $1.5cm^3$ per individual, there was no progeny production and there was an initial 30% mortality. When the available space was doubled to $3cm^3$/individual, longevity increased and a population increase was noticed. However the total duration of the population was only 38 days under the spatial condition of $3cm^3$/individual as compared to 56 days under space of $6cm^3$/individual, 65 days under space of $10cm^3$/individual and 69 days under the spatial condition of $25cm^3$/individual and $50cm^3$/ individual respectively.

Although the population stock under relatively small space conditions survived for shorter period than in larger ones, the absolute number of the population at any given date was not always minimal in the flask of lower capacities i.e. $15cm^3$ and $30cm^3$. Comparison of mean population size analysed upto 25th day of inoculum by means of Duncan's Multiple Range test (Table:15), showed that the mean population size under the beaker capacity of $15cm^3$ showed a significant difference from the beaker capacities of $60cm^3$, $100cm^3$, $250cm^3$ and $500cm^3$, the C.D. (critical difference) values being 19, 20, 36.75 and 55 respectively. But there was

Fig.29A: Variation in average number of total population of *Pleuroxus similis* on progressive days in different flask capacities of:

15 ml
30 ml
60 ml
100 ml
250 ml
500 ml

Fig. 29



15 ml
30 ml
60 ml
100 ml
250 ml
500 ml
Numbers / Litre
110
100
90
80
70
60
50
40
30
20
10
4
8
12
16
20
25
30
34
38
42
46
51
56
60
65
69
Days

Fig.29B: Relationship between average population number of *Pleuroxus similis*/ day at different flask volumes.

Fig. 29

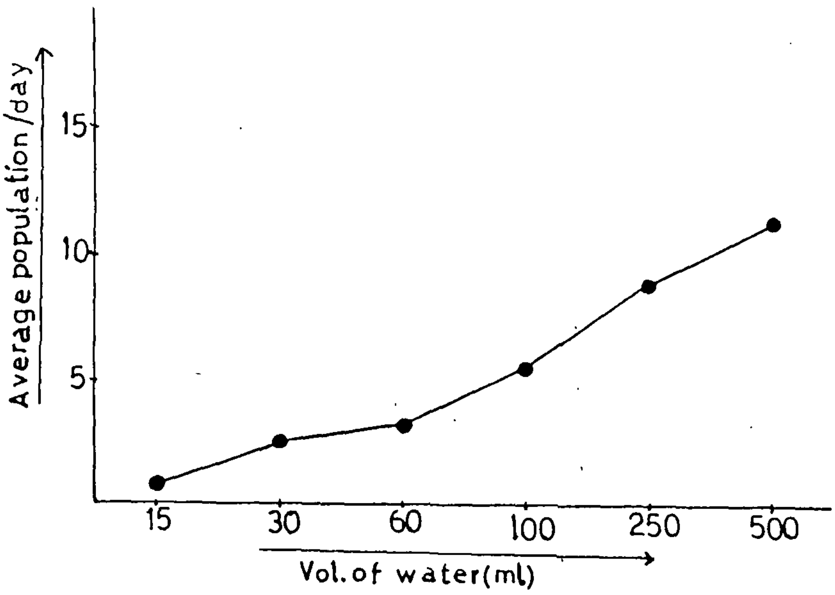

Average population/day
15
10
5
15
30
60
100
250
500
Vol. of water(ml)

Table 15: Comparison of mean population size analysed upto 25th day of Inoculum by means of Duncan's Multiple Range Test (df=18, standard error of mean = 5.5, r = 2-6).

Capacities	Differed from capacities of:	C.D. values	Did not differ from capacities of:	C.D.values
15cm^3	60cm^3	19	30cm^3	15.75
	100cm^3	20		
	250cm^3	36.75		
	500cm^3	55		
30cm^3	250cm^3	21	60cm^3	3.25
	500cm^3	39.25	250cm^3	4.25
60cm^3	15cm^3	19	30cm^3	3.25
	250cm^3	17.75	100cm^3	1.0
	500cm^3	36		
100cm^3	15cm^3	20	30cm^3	4.25
	500cm^3	18.25	60cm^3	1.0
			250cm^3	
250cm^3	15cm^3	26.75		
	30cm^3	21.00		
	500cm^3	18.25		
500cm^3	15cm^3	55		
	30cm^3	39.25		
	60cm^3	36		
	100cm^3	18.25		
	250cm^3	18.25		

however no significant difference (C.D. value = 15.75) in the mean population size between the beaker capacities of $15cm^3$ and $30cm^3$. Similarly, the population size under the beaker capacities of $30cm^3$ varied significantly from the capacities of $250cm^3$ and $500cm^3$ (C.D. values = 21 and 39.25) respectively, but not from those of $60cm^3$ and $200cm^3$ capacities (C.D. values = 3.25 and 4.25) respectively. The mean population size under the beaker capacities of $60cm^3$ varied from the beaker capacities of $15cm^3$, $250cm^3$ and $500cm^3$ (C.D. values = 19, 17.75 and 36) respectively, but the population did not vary from the beaker capacities of $30cm^3$ and $100cm^3$ (C.D. values = 3.25 and 1.00). Comparing the mean population size in the beaker capacities of $100cm^3$, it was noticed that the population significantly differed from those of beaker capacities of $15cm^3$ and $500cm^3$ (C.d. values = 20 and 18.25) but not from those of $30cm^3$, $60cm^3$ and $250cm^3$ (C.d. values = 4.25, 1.0 and 16.75) respectively. The population size in the beaker capacity of $250cm^3$ differed from those populations under beaker capacity of $15cm^3$, $30cm^3$, $60cm^3$ and $500cm^3$ (C.D. values = 26.75, 21, 17.75 and 18.25) respectively, but not from the beaker capacity of $100cm^3$ (C.D. value = 16.75). Thus, it was observed that the population size in $500cm^3$ capacity distinctly differed from all the other capacities of $15cm^3$, $30cm^3$, $60cm^3$, $100cm^3$ and $250cm^3$, the maximum being from the capacity of $15cm^3$ (C.D. value=55) and the next from $30cm^3$ (C.D. value = 39.3). It was also observed that when the population density under the capacity fo $15cm^3$ was compared with those of other beaker capacities of $30cm^3$, $60cm^3$, $100cm^3$, $250cm^3$ and $500cm^3$ the C.D. value was always very high ranging from 19-55, which indicates that the population density under this capacity is significantly low as compared to the other capacities.

Again the total population size of 19 individuals/l, 82 individuals/l, 95 individuals/l, 99 individuals/l, 166 individuals/l and 239 individuals/l was significantly different from each other ($F_{5,18}$ = 12.12 p> .001) among the flask capacities of 15cm^3, 30cm^3, 60cm^3, 100cm^3, 250cm^3 and 500cm^3 respectively. The population in all the beakers of relatively larger volume capacities started rising gradually and showed an initial peak by 16th-25th day under the capacities of 30cm^3, 60cm^3, 100cm^3 and 250cm^3. However, the initial peak is smaller in all the above cases. Under the initial capacities of 30cm^3 and 60cm^3 only a single peak was observed. In case of 100cm^3 and 250cm^3 there were three peaks. In 500cm^3 capacity there were two peaks, the first on the 34th day and the second on 51st day.

One way analysis of variance done for total population shows a highly significant value ($F_{5,18}$=51.7, p > .001) suggesting that the total population size under different beaker capacities of 15cm^3, 30cm^3, 60cm^3, 100cm^3, 250cm^3 and 500cm^3 were highly variable. The highest peak of 110 individuals/l, under the beaker capacity of 500cm^3, was distinctly higher (>61%) from the peak in the remaining beaker capacities of 15cm^3, 30cm^3, 60cm^3, 100cm^3 and 250cm^3.

Discussion

Since *Pleuroxus similis* failed to produce offsprings under the spatial capacity of 1.5cm^3/individual (15cm^3), it would suggest that a volume of 30cm^3 was the lower limit below which no progeny production could occur and can be considered as the minimal limit of space for their growth and survival under experimental conditions. It was also evident that the abundance of *Pleuroxus similis* per unit volume also increased linearly with the rise in absolute volume apparently due to the increased amount of relative space and food available, since the inoculum density for all the containers remained fixed at 10 animals. In the present study the living space of $50cm^3$/individual appeared to be optimum for *Pleuroxus similis* because the population increase under this space conditions was consistently higher (11.6 individual/day) than other space conditions. The optimum space requirements for *Pleuroxus similis* ranged from $20cm^3$/individual (Chapter 5.C(ii)) to $50cm^3$/individual. Nevertheless, when compared with the space capacity fo $20cm^3$/individual, the space capacity of $50cm^3$/ individual is considered to be more favourable due to the fact that the total population in the latter is more (800 individuals/l) as compared to that of 464 individuals/l in the former. Jana and Pal (1983; 1984; 1985) observed that the space of $120cm^3$/individual and $13.33cm^3$/individual, which was less than that for *Daphnia carinata* and *Diaphanosoma*, but more than that of *Moina micrura*. Thus, it may be stated that body size did not play an important role in determining optimal space capacity for population growth, since the body size of *Moina micrura* is larger (0.88mm) (Jana 1985) as compared to that of *Pleuroxus similis* (0.52mm). The present result is in agreement with Pratt (1943) who observed maximal longevity of *Daphnia magna* under laboratory conditions at 5 animals/$50cm^3$.

The lower limit of space for growth and survival of *Pleuroxus similis* was $3cm^3$/individual ($30cm^3$), which was much less when compared with that of *Daphnia carinata*, $12cm^3$/individual (Jana 1983) and $6cm^3$/individual and $12cm^3$ in *Diaphanosoma* (Jana and Pal 1984). So it may be said that the space requirement for population growth of *Pleuroxus similis* is comparatively smaller. This is expected in view of the rather small intrinsic size of this chydorid species. It may thus be concluded that for the highest production of *Pleuroxus similis*, the suitable medium is chicken manure with the optimal living space of $50cm^3$/individual.

Several other earlier workers have also suggested organic media to be the most suitable for culturing cladocera. Masters (1970) suggested the following media as suitable for culture of *Daphnia*, such as cotton seed meal, animal manures, dried yeast, milk, head of lettuce, egg yolks and soya bean meal. Bhanot and Vass (1976) suggested poultry manure as the most suitable culture medium for *Daphnia carinata*. Murugan (1983) referred to cowdung as being the suitable culture medium for *Daphnia carinata*. Jana and Pal (1985) have also suggested cowdung medium mixed with superphosphate and urea as being the ideal medium for culture of *Moina micrura* and *Diaphanosoma* in the context of raising fish food organisms. Khan *et al.* (1987) too suggested raw cowdung as a suitable medium for the mass cultivation of *Ceriodaphnia cornuta*. Thus, the present optimal success achieved through the chicken manure corroborates the findings of most investigators referred above.

(d) **Karyological Observations**

Weismann (1886) for the first time showed that cladoceran eggs form only one polar body and therefore mature through a single division without a reduction in the number of chromosomes. This type of reproduction is known as Apomictic parthenogenesis (Suomalainen 1950) and is widespread among diverse groups in the animal kingdom like Turbellaria, Trematoda, Nematoda, Rotifera, Mollusca and Crustacea. In this type of reproduction there is no reduction in chromosome number during the maturation phase, thereby maintaining a non-reduced chromosome number in the egg. So there is no true pairing of homologous chromosome and parthenogenesis is therefore ameiotic.

Among the animals which develop through apomictic parthenogenesis *Daphnia* (Cladocera: Crustacea) has been a classical object of study and many workers have observed the chromosome behaviour and the type of maturation division taking place during development in this animal (Kühn 1908; Schrader 1926; Mortimer 1936; Lumer 1937; Ojima 1958; Zaffagnini and Sabelli 1972 and Zaffagnini 1987).

Besides apomictic parthenogenesis, this organism has a phase of bisexual reproduction that occurs only during certain period of its life cycle. During this development the amphigonic oocycte (bisexual) undergoes normal meiosis, forming two polar bodies and thereby halving the chromosome number; the diploid number being restored through the fusion of the male and female gametes.

A detailed description of reproduction and chromosome behaviour during different phases of development, differentiation and maturation of germ cells in both parthenogenetic and bisexual reproduction in the Genus *Daphnia* was given by Ojima 1958; Zaffagnini and Sabelli 1972 and Zaffagnini 1987.

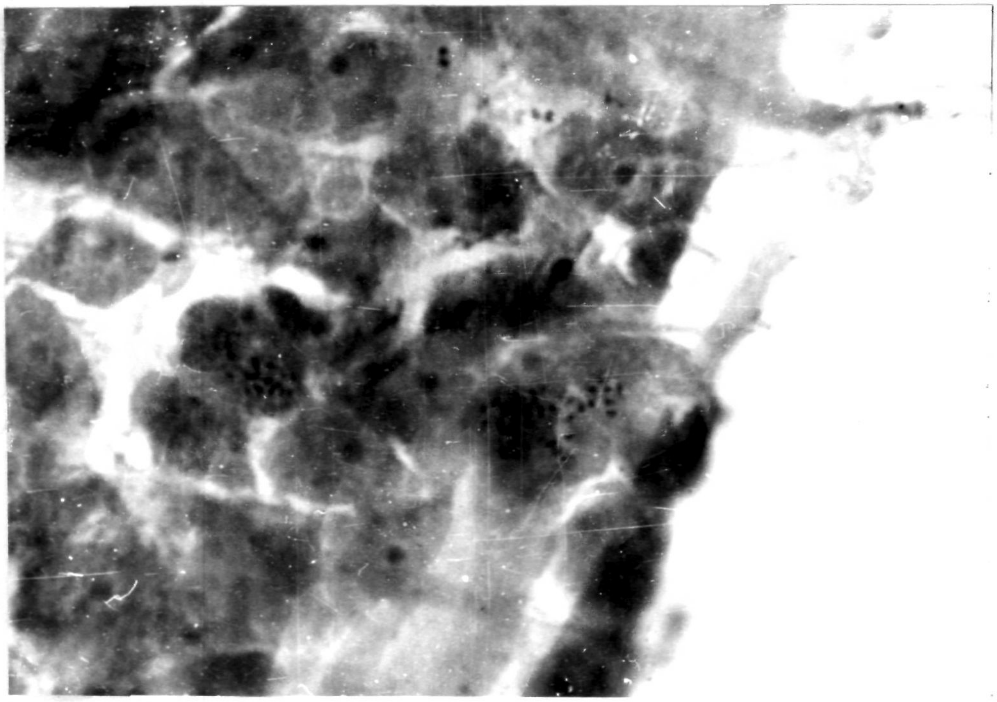
However, there has been no such account of reproduction and chromosome behaviour regarding the chydorid cladocera due to the technical difficulties presented by the very minute size of the animal, both the cells and the chromosomes as well being very small. Thus, the present study is probably the first attempt to obtain some preliminary information regarding the chromosome number of chydorid cladocera. The results obtained therefore, in the present study are of a very preliminary nature.

In the present study, most of the metaphase plates obtained were from parthenogenetic females, which have just moulted and released the young embryos with their brood chamber being empty. This timing of maturation division of parthenogenetic eggs agrees with those made by Ojima (1958) in *Daphnia pulex* and in *Daphnia magna* byZaffagnini (1987).

The chromosomes being extremely small in size proved difficult in their morphological studies. In other words, the distinctive characteristics of the chromosomes in view of their more or less uniform shape and size precludes positive assessment of the exact number and structure of individual chromosomes. In the present investigation, the karyotypic stuides were done using the metaphase of the maturation division in parthenogenetic eggs and the diploid chromosome number counted. For *Pleuroxus similis* 2n = 30 (Plate.XVI which was more than that for *Daphnia* spp., presented in the Table;

Plate XVI. Metaphase plate of parthenogenetic egg of *Pleuroxus similis*. Smith's technique. X1000.

Plate XVI



given below.

Species	Chromosome number	Authors
Daphnia pulex	2n = 24	Mortimer 1936
Daphnia magna	2n = 20	Mortimer 1936
Daphnia middendorffiana	2n = 24	Zaffagnini and Sabelli 1972
Daphnia pulex	2n = 20	Ojima 1958
Daphnia obtusa	2n = 24	Zaffagnini and Trentini 1975
Daphnia hyalina	2n = 20	Zaffagnini and Trentini 1975
Daphnia galeata	2n = 20	Trentini 1979
Daphnia curvirostris	2n = 20	Trentini 1980
Daphnia longispina	2n = 20	Trentini 1958
Pleuroxus similis	2n = 30	present study

However, the maturation division of amphigonic eggs and also the primary and secondary spermatocytes, could not be followed through in this species due to the technical problems mentioned earlier.

The above study provides a very preliminary idea about reproduction and chromosome behaviour of the chydorid cladoceran *Pleuroxus similis* and so it is difficult to draw any conclusive evidence about the different phases of development, differentiation and maturation of germ cells, especially during the amphigonic reproduction and also during spermatogenesis. Therefore, further investigation regarding these aspects are required to give a detailed picture about the reproduction in chydorids.

GENERAL DISCUSSION

The present study whose objectives were to gain some insight regarding the taxonomy, zoogeographic pattern of distribution, biology and culture aspects of the chydorid cladoceran *Pleuroxus similis* in this sub-tropical region, has yielded some useful results.

The information gathered on the pattern of distribution of *Pleuroxus similis* showed that like most other species of chydorids, this species too is intercontinental in distribution occurring in South America (Chile, Argentina), Asia (USSR and India) and Australia (Northern N.S.W.)

When *Pleuroxus similis* was first described by Vavra (1900) and subsequently by Sars (1901), Smirnov (1971) and Timms and Smirnov (1983) none of them reported the presence of ephippial females or males in the population thus suggesting that the population was comprised exclusively of parthenogenetic females. But with a report for the first time of the males and ephippial females during the present investigation, it was proved that the species originally thought to have been constituted only of parthenogenetic females also has a well developed gamogenetic phase in its life cycle. However, this gamogenetic population occurs only during certain periods of the year.

Gamogenetic population occurs mainly during winter and spring i.e. from February to April. further, when this gamogenetic strategy of *Pleuroxus similis* is compared with those of other chydorids of Europe and America it is evident that this species may be categorised as "Northern" species or may even be a strictly 'Vernal' species and would thus be favourably adapted to colder regions rather than the sub-tropical region. This was further confirmed by the fact that the population density of *Pleuroxus similis* was very low or even absent from the system in the field during the summer months.

The life cycle of *Pleuroxus similis* as studied under laboratory conditions in room temperature and at three different culture media of filtered pond water, chicken manure and rice bran, shows that in case of females the average life span was 61 days, with three preadult or juvenile instars followed by thirteen adult instars. The mean duration of the preadult instars was around 72 hours, and that of adults around 96 hours. The quality of the culture medium also affected the growth of the animal. Since final maximum adult size of 0.52mm was obtained in the chicken manure medium that suggest this medium the most favourable for growth of *Pleuroxus similis.*

In case of males there were a total of three instars and the average life span was about 2.5 weeks. Out of the three instars the first two were juvenile or immature instars when the third was the mature instar. This is typical of chydorids studied so far elsewhere. In general, the life span of *Pleuroxus similis* female is longer as comapred with those of other chydorids whereas that of male is intermediate when compared with *Pleuroxus trigonellus* and *Eurycercus longirostris*. At high temperatures however the total life span of the female was reduced to 31 days, with the instar duration reduced to 48 hours.

The life history strategy adopted by *Pleuroxus similis* is partly similar to that of small littoral species in terms of maturing at a smaller size, and partly similar to the large planktonic species as far as the growth pattern is concerned, where growth is curtailed with the onset of reproduction.

These life history strategies help the species to overcome the selection pressure imposed on it by the predators.

Field studies on the seasonal distributional pattern of *Pleuroxus similis* showed the occurence of multimodal peaks in population density during spring and autumn, and low population density during summer and winter periods. These changes in the population density was brought about mainly by the extrinsic factors like predation, effect of temperature and habitat, although the effects of intrinsic -factors like mortality and natality cannot be ruled out. The correlation between the population density and the latter two factors referred *Vide Supra* were 64% and 36% respectively. In this context it may be mentioned that in addition to natality and mortality factors, the presence of parthenogenetic females, ephippial females and females without eggs in the population also determines the density of population at any given time, in terms of recruitment of new individuals, as evidenced by the analysis of population dynamics in the field.

It was noticed that in case of *Pleuroxus similis*, the temporal pattern of distribution is different from those of many other chydorids due to the absence of a peak population density during the summer month suggesting that this species would be more favourably adapted to colder climate of temperate latitudes. This fact is further confirmed by the occurrence of gamogenetic females and males in the system during winter and spring. The occurrence of gamogenetic females in the field during other seasons of the year especially during autumn could be mainly due to the changes in the photoperiod. However, males were not recorded in the system during any other period except in spring. This suggests that ephippial formation is not induced by the presence of males, but an inherent character of the animal, induced by changes in the environmental conditions. Thus, it is apparent that the stimulus that causes the formation of the ephippial case need not be the same as the one which induces the production of the ephippial egg.

Studies on the laboratory cultures of *Pleuroxus similis* in terms of preference of different culture media namely chicken manure, rice bran and filtered pond water and also availability of space, for the different life history parameters revealed that the quality of culture media and varied inoculum density conditions affected the total life span, productive life span, total offspring production, net reproduction rate, and average generation time of the animal. In general it was observed that chicken manure as a medium was most conducive for the culture of *Pleuroxus similis* in the concentration of 8gm/litre. The total life span of the animal, reproductive life span, total offspring production and net reproductive rate were higher as compared to that of results obtained from rice bran medium. However, filtered pond water was also equally suitable as a medium, though the total population density was higher in chicken manure medium, and this was probably due to the fact that the average generation time was less in chicken manure which resulted in a fast population build up with correspondingly low mortality rate. Besides the quality of the medium, the density of the animals in the culture also affected the population structure, with peak population densities building faster at high densities of the animal, due to the average generation time being less. Gamogenetic females in these laboratory cultures usually occur under crowded conditions. Thus, the survivability of the animals cultured in the laboratory was affected both by inoculum density and the culture media. The survivability in general was less in rice bran medium under all the three inoculum density condition. The population dynamics shows that b' or r_{max} - the intrinsic rate of population increase is very high in case of *Pleuroxus similis*, as also observed in other cladoceran groups. Further r_{max} depends on the quality of culture medium used and density of the animal per unit area.

Although chicken manure medium was found to be most suitable for the culture of *Pleuroxus similis*, it was observed that density of the animal per unit area, or the space available to the animal also had a pronounced effect on the population growth, average offspring production per female, mean body length and as well as the survivability of the animal. A space capacity of $20cm^3$/individual was found to be essential for a healthy population growth and reproduction. It was also noticed that a minimum spatial capacity of $3cm^3$/individual was required for growth and survival of *Pleuroxus similis* . The optimal space requirement for *Pleuroxus similis* ranged from $20cm^3$/individual to $50cm^3$/individual, the latter being more favourable, because the total population density in the latter was more than that of the former. The minimum space requirement for population growth of this animal is less as compared with other cladoceran species which is only as expected, in view of the small size range of this chydorid, though it is not necessary that body size should always determine the optimal space requirement for growth and reproduction.

The genetic make up of any organism is an important factor which decides its external and internal characteristics, growth and development. In fact the different characteristics inherited by the organism are from the parents through the genes located on the chromosomes that form the physical basis of heredity. So, for better understanding of any animal, its genetic make up should be well understood, and the simplest way to begin this is to ascertain the chromosome number in the animal. In the present study too, this preliminary work was taken up towards that goal. Though the detailed picture of the karyological changes during different phases of life history of *Pleuroxus similis* could not be fully ascertained, the chromosome number in parthenogenetic females could be determined as 2n=30 with reasonable degree of certainity.

Thus, it may be concluded that the present study deals with the various ecobiological, cultural and karyological aspects of the chydorid cladoceran *Pleuroxus similis* that has led to the understanding of only some of the intricate relationships of this species with reference to its environmental requirements.

Nevertheless, the present study has revealed some fundamental knowledge with regard to the successful culture of this animal under laboratory conditions when provided with adequate food and space conditions. It is hoped that this information will help in the successful culturing of not only chydorids, but even other cladoceran species that are still important from the pisciculture point of view, particularly for raising the food of carp fry for the tropical fish farmers.

SUMMARY

To sum up the results of the present investigation regarding the ecobiology and culture aspect of *Pleuroxus similis*, it could be said that *Pleuroxus similis* (Vavra, 1900) is intercontinental in distribution and occurs in South America, Asia and Australia. Though it was initially thought to have consisted only of parthenogenetic populations, during the present study for the first time it was confirmed that this species does have a gamogenetic phase in the population.Judging from the season of occurrence of gamogenetic females and males in the system, this species could be broadly categorised as a Northern species or as a Vernal species *Sensu stricto*.

The females of this species had a maximum life span of 61 days, with three juvenile instars and thirteen adult instars, and during its life time produced 20-22 eggs. At higher temperature the total life span of the animal was reduced to 31 days. The males had three instars in total, the first two being juvenile instars and the third the adult instar. The average life span of the male was determined to be 2.5 weeks under laboratory conditions.

The seasonal distributional pattern of *Pleuroxus similis*, with occurrence of peaks in population densities during spring and autumn with intervening low population densities in summer and winter were mainly due to extrinsic factors like predation, effect of temperature and habitat, and intrinsic factors like mortality and natality acting upon the population. During major part of the year the population consisted of parthenogenetic females, juveniles and females without eggs. Males occurred during spring while gamogenetic females occurred during spring and autumn, suggesting that gamogenesis is resorted to under stressful environmental conditions and as well as due to changes in photoperiod.

The laboratory culture studies show that chicken manure as a medium was highly suitable for the culture of *Pleuroxus similis*. In this medium the total life span of the animal, reproductive life span, total offspring production, net reproductive rate and survivability were higher resulting in a high population density, as compared to the media of rice bran and filtered pond water. This suggests that *Pleuroxus similis* prefers organic media and nutrients with high percentage of nitrogen content for its growth and reproduction. Besides food preference, the availability of space per animal also affects the population growth and reproductive potentialities of this species. A minimum space of $3cm^3$/individual was required for growth and survival of *Pleuroxus similis*, while the optimum space required for healthy growth and reproduction ranged from $20cm^3$/individual to $50cm^3$/individual. The chromosome number of *Pleuroxus similis* was determined as 2n=30.

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