BIOLOGY OF CLADOCERA IN AN ALTITUDINAL LAKE AND THE PONDS OF SHILLONG AREA

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ABSTRACT

Submitted in fulfilment of the requirement of the degree of the Doctor of Philosophy

TO

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As a group the Cladocera constitute one of the important biological components of the aquatic ecosystems, forming at times a major fraction of freshwater plankton. The cladocerans are important fish-food organisms that appear naturally in freshwater habitats.

Indian studies on Cladocera was initiated by Baird (1860) since when sporadic works dealing with faunistic records of different species appear in the literature. Studies on the biology of Cladocera have been indeed, fragmentory even till todate, and this is all the more true of the North Eastern Hill Regions of India. The only available report from this region is the recent faunal list by Patil (1976).

Shillong (Lat. 25°5' E, Long. 91°9'N), a small town of the North Eastern Hill Region of India is situated on a plateau at an altitude of 1600 m above the sea level. Further, its location being within about 50 Km from Maushinram - the highest rainfall area of the world - has a luxurient vegetation with humid climate which lends 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 species in the Shillong area. Also emphasis have been given to relate the field information to laboratory findings in order to obtain a more comprehensive understanding of the basic life history patterns.

The present study comes under three major parts viz., (i) seasonal survey of the Cladocera and their environment, (ii) ecology and biology of the natural populations of Cladocera and (iii) laboratory life cycle studies of a few chosen cladoceran species. In addition to these, the present trends in cladoceran research have been outlined in the preface followed by a detailed review of available earlier literature.

In Part-I, results of a survey conducted through an entire annual cycle at two-month intervals have been furnished. The surveyed impoundments were of both temporary as well as permanent nature. Hydrographical features, associated vegetation and physicochemical properties of each impoundment have been studied with a view to relate these to the occurrence and diversity of the cladoceran species. A total of 23 species belonging to six cladoceran families was recorded which adds 9 more species to the earlier record of 14 species (Patil 1976). Chydoridae was the dominant group while Daphnidae formed the second highest group in terms of species number.

Dominance of littoral species has been noted and discussed. The faunal record has been compared with those from other parts of India. Species diversity appeared to be related to morphometry of the impoundment while physicochemical properties did not show any significant relationship.

Possibilities of accidental seeding of cladoceran species has been discussed.

In Part-II, the field populations of cladoceran species have been studied at weekly intervals in three selected habitats for a total duration of 18 months. Of these, one was a permanent recreational pond with good number of fish, another a comparatively big pond with aquatic birds kept under captivity, while the third, a small cemented nursery pond. Hydrographical features, vegetational association, physico-chemical properties as well as biological properties which included different groups of phytoplankton, zooplankton and associated organisms have been studied for the entire period of 18 months and the results discussed. A moderate level of organic pollution was observed in the recreational lake and in one pond and the causes were speculated.

The occurrence and seasonal distribution of the various cladoceran species encountered have been investigated and discussed in detail for each individual species. Maximum species diversity was recorded in the largest system. Numerical density of different species differed in the six sampling stations, though a certain degree of similarity existed among them. Causes for this variation have been discussed.

Size group analysis of selected species of Cladocera have been made. Distribution of different size classes during

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the annual cycle did not exhibit any definite trend. However, appearence of more specimens with empty brood pouch generally coincided with period of low population density. Number of eggs/brood was more in daphnid species, while the bosminid contained much lower egg number which has been discussed. Occasional appearence of one egg in the chydorid species was noted and discussed. Gamogenetic females with ephippium were also recorded, though males were not encountered.

Part-III deals with the laboratory life cycle studies of two daphnid species, Daphnia lumholtzi and Simocephalus exspinosus, a moinid, Moina micrura and the chydorid, Alonella excisa . Also life cycle studies were conducted on the male of Daphnia lumholtzi. This study included the instar analysis, total life span, pattern of growth, egg/brood in different instars and the rate of egg production. Longest life span was recorded in the chydorid species which also produced the maximum number of broods. Simocephalus exspinosus produced the largest brood and also showed the second highest value for the rate of egg production so far recorded among Indian species of Cladocera. These findings have been compared with relevant reports from India and elsewhere. The studies on the life cycle of the chydorid Cladocera and the male of daphnid are the first Indian reports on the chydorid as well as male cladocerans in general. Lastly, comparisons have been made between field populations and laboratory data and a detailed discussion has been presented.

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I certify that the Thesis entitled "Biology of Cladocera in an altitudinal lake and the ponds of Shillong area" submitted by Shri Bidhan Bhattacharya for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under my supervision. He 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.

R George Michael

Date: 15.12.80
Place:Shillong

(R.GEORGE MICHAEL)
Signature of the supervisor

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SHILLONG:
15th December, 1980.

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PREFACE

Study of limnology 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 environments. Such 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 has accumulated over the years in different parts of the world (Smith 1924, Welch 1948, 1952, Pennak 1953, Edmondson 1959, Hynes 1960, Macan 1963, Mackereth 1963, Ruttner 1965, Hutchinson 1957, 1967). Even in the Indian context several such general studies have been conducted in recent decades on the ponds, lakes and streams, though most of them deal with freshwater biotopes of the plains of India (Prasad 1916, Arora 1931, Pruthi 1933, Sewell 1935, Ganapati 1941, 1943, 1955, 1960, Das and Srivastava 1956, 1959, Singh 1960, Michael 1962, 1968, 1969, 1980, Sreenivasan 1963, 1964, 1969, 1976, George 1966, Moitra and Bhowmick 1968, Munawar 1970, Hussainy [illegible] 1967, Navaneethakrishnan and Michael 1971,

Jana and Sarkar 1971, Jana 1973, Nasar and Munshi 1974,1975). Comparable studies on Indian altitudinal lakes, ponds and streams are relatively few and even those available are of a preliminary nature (Vasisht 1968, Das et al 1969, 1970, Sreenivasan 1968, Mathew 1977). Among these earlier works, such investigations on the cold water systems of Eastern Himalayan ranges are conspicuously 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 the fish distribution, studies on other aquatic fauna may equally be of interest from a zoogeographic viewpoint.

With the mighty Brahmaputra sprawling through the hill ranges of the eastern Himalayas, numerous streams flow into it, some of them forming shallow lakes along their course. However, such lakes are far and few, although there are a number of artificial manmade impoundments, primarily managed by Government or private agencies for the purpose of fish culture. A detailed study of such systems with special reference to their boiota will be of great interest both from academic and applied point of view. It is for this purpose that the present investigations have been undertaken on such systems with special reference to cladocerans which are well known to be one of the dominant groups of zooplanktonic organisms. The choice of such systems was deliberate in view of our commitment to relate the researches to the development of Inland Fish Culture of the North-Eastern

hill regions.

Cladocerans are a group of Crustacea occurring mostly in freshwater systems. Their marine relatives are comparatively few and the majority of them are planktonic occurring both in the littoral and limnetic zones. They are mostly filter feeders, though there are some of predatory habit. These microcrustaceans constitute an important fraction of any aquatic biota and studies on them have been given much importance in recent years. Cladocerans also exhibit successful adaptation to different types of aquatic systems and as well present the most dominant species composition (Hutchinson 1967).

Importance of Cladocera as fish food has long been established by different investigators (Alikunhi 1952, Welch 1952, Pennak 1953, Vaas and Van-Oven 1959, Michael 1962, Green 1967, Cordone et al 1971). In recent years, other animals using Cladocera as one their food of choice have also been reported (Evi 1966, Pickavance 1971, Pellantova 1974, Kennedy and Fitzmaurice 1974). These realisations provoked investigations on the culture of these animals since the early days of limnological research (Banta 1921, Banta and Wood 1938) and these efforts continue even till today (d'Agostino and Provasoli 1970, Martin and Novotny 1975).

It is long since the cladoceran genus Daphnia attracted scientists as an ideal laboratory material for the understanding of different biological problems (Banta 1914, 1921, Anderson 1932, Korinek 1970, Navaneethakrishnan and Michael 1971,

Peters and Rigler 1973, Hebert 1974, Lei and Clifford 1974, Meijering 1975, Kring and O'Brien 1976). In the modern researches on the problem of pollution Daphnia lends itself as an excellent laboratory and field animal for various bioassay work (Zago 1976, Leeuwangh 1978, Adema 1978, Dortland 1978). This is further stressed by the recent symposium held on 17th February, 1977 on the " After effects of Pesticides on the biology and ecology of Daphnia species", organised by the Fauna group of Dutch Commission for Research at Utrecht, Netherlands.

Investigations on bioenergetics and trophic aspects of energy transfer through cladocerans as primary consumers have also gained importance in recent decades (Kersting and Leeuw 1976, 1976a, Kersting 1978). Prey-predator relationship and associated morphological changes in Cladocera has been one another aspect gaining momentum in recent years (Hrbacek 1959, Brooks and Dodson 1965, Green 1967, Lynch 1980). Further, nutrient enrichment through cladocerans in aquatic ecosystem is a new area of recent interest (Porter 1976, 1977, Jacobson and Comita 1976, Lane and Levins 1977).

These few aspects of clasoceran bionomics focus on the need for a better understanding of their ecology and biology. Since they are directly consumed by both young and adult fishes (Alikunhi 1952, Welch 1952, Michael 1962, Cordone et al 1971), artificial manipulation of different species of Cladocera and

their population may successfully meet the desired food paucity in fish cultural practices. In this context the understanding of the biology and life cycles of Cladocera is considered imperative and has, therefore, attracted the critical attention of several investigators even in India (Michael 1962, Navaneethakrishnan and Michael 1971, Murugan and Sivaramakrishnan 1973, 1976, Murugan 1975, 1975a, Murugan and Ramaseshan 1978).

Thus in the present investigation attempts have been made:

a) to construct a seasonal distribution map of Cladocera of ponds and lakes from this part of India to relate their occurrence to their respective habitats.

b) to study the biology of the available species of Cladocera in different types of lentic habitats

c) to study the life cycles of commonly occurring species of Cladocera under seminatural conditions in the laboratory.

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 the earlier literature on cladoceran research shows that information on the taxonomy and distribution of different cladoceran species have mostly accumulated over the last one and half centuries. On the other hand, studies on the biology and ecology of Cladocera are of relatively recent origin. Further, in the larger perspective of world literature, Indian works on Cladocera are of very recent times and limited as outlined in detail at the end of the present review. However, in the present investigations, emphasis has been given on the different aspects of cladoceran biology in order to fill this lacuna.

Culture of cladoceran species have been attempted by several workers even from the early decades of the present century. Banta (1921) improvised a culture medium of Cladocera which is still in use. Suginome and Baba (1963, 1963a) suggested a standard culture medium and pointed out that influence of food, temperature and population density should be taken into account for maximum yield in mass culture. Quoilin (1965) cultured Cladocera with dry mud from temporary pond containing large number of Daphnia and found that the meduum was favourable for luxurient growth of Cladocera. d'Agostino and Provasoli (1970) suggested a vitamin-rich mineral medium for the culture of Cladocera. Provasoli et al (1970) further emphasized the importance of vitamin and fats for the restoration of fertility in Daphnia . Arnold (1971) advocated the suitability of green algae over blue green

for cladoceran culture due to the toxic effect of the latter. Metteilung (1975) cultured cladocerans with modified technique and studied the effect of food and temperature. A culture method for Chydorus, Bosmina and Cyclops was suggested by Martin and Novotny (1975). In addition to these few studies laboratory cultures of Cladodera could be maintained by using algae, bacterial cultures as well as filtered pond water. However, the method of mass-culture is yet to be standardised.

The problem of food and feeding and its impact on cladoceran life cycles have been studied by several workers. Importance of food in the formation of ephippium in Cladoeera was pointed out by Wood and Banta (1933). Parker (1961) reported the ability of Daphnia to utilise inorganic phosphorus from cell-free medium while Marshall (1962) demonstrated the effect of gamma radiation on the feeding and growth of Daphnia . McMohan (1963) and McMohon and Rigler (1965) showed 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 and is independent of the size of the food particles. Parlova (1964) studied food requirement in penilia avirostris from Black Sea. Ivanova (1966) calculated filtration rates in relation to body weight and organic suspension. Levina et al (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 due to the sticky nature of the latter algae. Burns (1968, 1968a) established relationships between size of food particles and carapace length in Cladocera to predict preference of particle size by different species. He further reported that filtering rate increased with the increase in temperature. Burns et al (1967) predicted filtering rate for Daphnia populations of Heart lake based on their laboratory studies with yeast suspension and natural water. 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 temperatures while Crowley (1973) observed that filtering rate of Daphnia was inhibited by seston. Chirkova and Romanenko (1973) studied the consumption of organic matter of mud by Ilyocryptus sordidus. Semenova (1974) while working out the food composition of Bosmina coregoni also reported that $18^{\circ}-20^{\circ}C$ was the best temperature for its growth. Clark and Carter (1974) are of the opinion that food supply is the major factor in controlling population dynamics of Cladocera. Chisholm and Stross (1975) measured filtering rate as a function of temperature, food density, animal length and the time of the day. The predaceous cladoceran species, Laptodora kindtii has been reported to eliminate 50% of the total filter feeding crustaceans (Karabin 1975). Smyly and Collins (1975) recorded that bacteria associated with algae formed the major food item of Ceriodaphnia quadrangula. Vijverberg (1976)

observed that lower concentration of food affected the life cycle of Daphnia hyalina . Kring and O'Brien (1976, 1976a) reported that pH, temperature and oxygen concentration below 3 mg/l could change filtering rate in Daphnia. Lampert (1978) reported that fecundity in Daphnia is dependant on particular level of food concentration.Recently Redfield (1980) observed that Daphnia is able to respond to improved food supply with increased number of eggs/brood. De Bernardi et al (1980) reported better growth of Daphnia spp. when fed on Mocrocystis in comparison to Scenedesmus.

Although a vast amount of literature has accumulated on the population parameters of various cladoceran species conducted mostly in connection with the zooplankton fauna, a few studies on the population of different cladoceran species have been referred here. Johnson (1956) while studying the limnology of lake Taba from Sumatra, detailed out the cladoceran populations.Parker (1960,1961) observed that the daphnid species Simocephalus exspinosus seemed to obstruct feeding of Cyclops, probably due to feeding competition. Hall (1964) investigated the dynamics of a natural population of Daphnia galeata mendote and analysed frequency of moulting, duration of egg development, growth rate and life span. Elbourn (1966) reported two peaks in spring and autumn in field population of Daphnia obtusa and found 4 preadult instars requiring 5 days to complete preadult periods at

22°C. Kowalczyky (1969) reported that crustaceans in peat bogs are influenced by the age of peat bog, water table, type of banks, pH and possible connection with river. Babitsky (1970) investigated the detailed biology and productivity of Eurycercus lamellatus. Keen (1970) used a probabilistic approach for the study of the dynamics of natural populations of Chydoridae. Brandl and Fernando (1971) attributed reproductive activities to be the cause of microaggregations while studying the populations of Ceriodaphnia affinis . Carter (1971) analysed the populations of crustacean plankton. Asch and Kingsbury (1972) observed three distinct peaks in the copepod and cladoceran species of Red Rock reservoir, Iowa. Cunningham (1972) reported vertical migration of Daphnia populations in ice covered ponds and lakes. Population dynamics and productivity of Daphnia hyalina was investigated by George and Edward (1974). Taylor (1974) while studying the crustacean plankton of lake Moncove, West Virginia, recorded faunal similarity between the different stations of the lake. Kwick and Carter (1975) and Duncan (1975) studied production and population dynamics of different cladoceran species. Stross and Chisholm (1975) put forward the view that density stabilisation in Cladocera to be the property of the individual or the population, while Pejler (1975) reported remarkable stability of the zooplankton in contradiction to the hypothesis that zooplankton are an extraordinarily labile biocenose. 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. Keen (1976) observed that though population dynamics of different chydorid species followed no set pattern, they had remarkable similarity from year to year. Corni and Strainer (1976) observed that decrease in the population densities of chydorid Cladocera was due to the death of aquatic weeds. Watson (1976) investigated seasonal distribution and abundance in crustacean zooplankton in lake Erie. Allan (1977) held the view that seasonal succession in Cladocera can be predicted as different species has different rates of responses to temperature. Lynch (1978) pointed out the coexploitive interactions between cladoceran species. Ghilarov (1980) investigated the population dynamics of epilimnetic cladoceran species.

A few studies on the life cycle of different cladoceran species have been referred here. Brown (1926) studied the influence of temperature on duration of instars and pointed out occurrence and developmental rate in nature and also later suggested a mathematical model (Brown 1927). Anderson (1932) while studying the life cycle of Daphnia magna reported more than 5 preadult instars in this species. He also pointed the relative growth and variations in this species. Buikema (1968) showed that longer wavelengths increase survival of the young of Daphnia pulex. Shan (1969) studied the life cycle of the chydorid species, Pleuroxus denticulatus and held the view

that probably all chydorids have similar life cycle pattern. Korinek (1970) studied the embryonic and postembryonic development in Daphnia in relation to food and temperature. Lei and Clifford (1974) studied the detail biology of both male and female of Daphnia schødleri. Bottrell (1975) investigated 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.

Sex and reproduction in Cladocera has been studied with enough emphasis since long time when Banta (1914) reported sex to be regulated by environment which is reemphasised in recent years by Hebert and Ward (1972). Batna and Wood (1928) furnished genetic evidence of Daphnia male being deploid. Batna and Brown (1929, 1929a, 1929b, 1929d, 1930), Brown and Banta (1932), Banta (1937) and Banta and Wood (1938) performed a series of experiments in laboratory cultures and suggested that sex in Cladocera to be controlled by factors like crowding of mother, excretory metabolites, critical period, rate of mothers' development, drugs, temperature, population density and maternal influence. Hoshi (1951a) studied the hatchability of the ephippium of Simocephalus vetulus using artificial culture medium. Stross (1965, 1966, 1969)

induced sexual reproduction in Daphnia pulex and was able to germinate sexual eggs through the regulation of temperature and photoperiod. Davison (1969) activated ephippium of Daphnia by regulating wavelengths and pointed out the need of dark reaction before light treatment. Suginome (1969) worked out the standing crop of resting eggs and identified ephippium of different species. Shan (1970) could enhence the time for hatching of resting eggs by proper control of the photoperiod. Makrushin (1970, 1972) 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.

Cyclomorphosis in cladoceran species has been studied by many workers. A few of them are referred here. Brooks (1946, 1947) while experimenting with Daphnia found that temperature and turbulence controlled relative head size and cyclomorphosis. Hrbacek (1959) demonstrated the role of circulation of water in the helmet formation in cyclomorphic Daphnia . Mannilova (1963) viewed that cyclomorphosis in Cladocera to be an adaptive phenomenon related to the continual existance which is influenced by change in physical properties of water. Brooks and Dodson (1965) attributed helmet formation in Daphnia

to be due to the predation pressure exerted by vertebrate predetor like fishes. Hazelwood (1966) observed that turbulence and illumination effect helmet length/carapace length ratio. Egloff (1968) studied seasonal variability in cyclomorphic characters and correlated different structure and temperature in natural populations of Daphnia . Jacobs (1970) used a multiple regression method to establish cyclomorphosis. Kerfoot (1975) observed cyclomorphosis in Bosmina longirostris and attributed it to predation pressure though in the laboratory experiments temperature and turbulence seemed to be the major factors. Zago (1976) found that temperature, food and turbulence effect cyclomorphosis in Daphnia . Blue green algae were reported to decrease population and produced more ephippia by Zago (1976). Recently Hebert (1978) held the view that the hypothesis of predation pressure as controlling factor of cyclomorphosis does not hold good and this phenomenon is related with swimming fitness and better gas exchange.

In the recent decades, predation has been much advocated to influence the biology of Cladocera. Korinek (1965) while studying the production of female Daphnia pulex pointed out that the main loss of population was through predation. Goulden (1971) reported that the main controlling factor of chydorid population was invertebrate

predation. Keen (1973) reported that decline in chydorid population was due to predation though immigration and natural mortality are also important factors. Hirston and Pastorok (1974) studied predation effect on Daphnia by cascade model. Bosselman (1974) while investigating the plankton communities of the lake Erson, noted that predation and productivity do not change species composition. Bernardi and Canali (1975) observed that predation and migration play important role in regulating population dynamics of pelagic Cladocera. Stavn (1975) proposed predation pressure to be the major factor in controlling species composition and vertical migration in Daphnia while Kerfoot (1975a) reported changes in egg-size due to predation in Bosmina . Galbraith (1975) opined that Daphnia can be used as an index for fishing quality of rainbow trout as the later preyed upon Daphnia . Jacobs (1978) observed that predation effect was more on larger animals. Recently Lynch (1980) reviewed the evolution pattern of life histories in Cladocera in the light of both vertebrate and invertebrate predation.

In recent years a number of physiological and toxicological studies have been conducted on different cladoceran species. Hoshi (1949, 1949a, 1950a, 1950b, 1950c, 1951, 1953, 1954, 1957) conducted a series of experiments on the physiology of Simocephalus vetulus and studied the influence of oxygen, pH, fatty substances, glycogen both

in relation to embryonic and adult stages. Parker (1959) reported that Simocephalus cannot survive when kept in continuous illumination. Johnson (1952) studied the thermal tolerence and its impact on the reproductive behavior of Cladocera. Marshall (1962) studied the effect of gamma radiation on Daphnia and also found that intrinsic rate of increase was density dependant. Heart rate of cladoceran species has been shown to increase with temperature, size and during copulation by Smirnov (1965). Green (1966) recorded a green pigment in Simocephalus in addition to normal pigments. Gerals et al (1969) established that oxygen consumption is more in males of Leptodora kindtii than that of females. Peters and Rigler (1973) developed a model for phosphorus excretion by Daphnia. C^{14} O_2 output in Cladocera was studied by Lampert (1975) while Nebeker and Puglisi (1974) found out the lethal dose of aquatic toxicants for Daphnia. Peters (1975) worked out a mathemetical medel for P excretion, feeding and assimilation in cladoceran species. Kersting (1975), while studying the effect of diuron formulated a budget of energy for Daphnia magna. Ganon and Ganon (1975) reported that carbonated water, chloroform and methyl alcohol to have narcotic effect on Daphnia. Meijering (1975) observed that arotic cladoceran populations have relatively slower rates of metabolism. Lampert (1977, 1977a, 1977b, 1977c) made a series of studies on the carbon metabolism in Daphnia pulex. Leeuwangh (1978) pointed out the importance of daphnid species as ideal material for toxicological studies.

Few other aspects of cladoceran biology in addition to those mentioned above have been referred here. Smyly (1956) reported frequent occurrence of more than two eggs in the ephippium of Acantholeberis curvirostris . Proszynska (1963) reviewed the problem of differentiating Cladocera and Copepoda fauna of small water bodies and ponds in the light of present faunistic literature. Hrbacek (1966) attributed more than hundred forms of Daphnia to phenotypic and genotypic variability. Evi (1966) reported cladocerans to be the food of roach larvae of 5 to 10 cm in length. Piekavance (1971) and Cordone et al (1971) reported that cladocerans form food of Plannarians. Shan (1971) held the view that natural gamogenetic hybrids are reproductively sterile. Smyly (1974) found no difference in the day and night collections of Ceriodaphnia . Green (1974) gave a systematic account of the parasites and epibionts of Cladocera. Bogdan and McNaught (1975) observed that larger zooplankton enjoy advantage for resource competition.

Among the notable works on the taxonomy and distribution of Cladocera, only a few earlier and recent significant works have been outlined in this review. Birge's (1891, 1893, 1897, 1918) contributions on American cladoceran fauna is one of the important earlier studies. Prof. G.O.Sars of the Christina University, Norway documented

the faunistic records of Cladocera, Copepoda and Ostracoda from New Siberian Island in 1898. He also studied and discussed the Cladocera fauna of South America (1901) and Central Asia (1903). Gurney (1927) reported cladoceran species from the dried mud after culturing in the laboratory. Ueno (1932, 1933) documented 22 and 18 cladoceran species from China and Japan. Jenkins (1934) reported 18 species from the Rift valley lakes of Kenya. A key for the British species of Cladocera was presented by Johnson (1952b) while dealing the British fauna. Harding (1957) described two Alona species while in 1961 he reported 38 species of freshwater Cladocera from South Africa. Brooks (1957) monograph on the North American Daphnia species is of great significance. Frey (1959, 1967) stressed upon the taxonomic and phylogenetic significance of head pores in Chydoridae and traced the phylogenetic relationships of the family as a whole and distinguished Alona costata, A.rustica and A.bicolor based on head pores and general morphology. A review of the two cladoceran genera, Latonopsis and Pseudosida has been given by Thomas (1961a) who also reported 25 species from Uganda (1961b). Green (1962) investigated cladoceran fauna of river Sokoto, Uganda, and reported 50 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 18 species and 3 taxonomic forms of cladoceran from the microbenthos samples of Volga river. Smirnov (1966a, 1966b,

1966c) composed identification keys for Pleuroxus, reviewed the genus Alonopsis and pointed out that there are three distinct sections in family Chydoridae. Faunal contribution on the cladocerans of Nepal and the surrounding Himalayan foot hills was that of Ueno (1966). Olga (1966) held the view that subfossil studies are important in understanding the distribution, life history and ecology of various cladoceran species. Dickinson (1967) identified cladoceran species from fossil remains from Nevada while Frey (1967) emphasized the importance of cladoceran fossil remains for the understanding of their evolution. Barker (1967) identified 14 species of Cladocera from central Africa. Flossner (1967) reported Macrothrix hirsuticornis, Alona rustica and A. intermedia from Bulgaria while Barker (1967) recorded Ceriodaphnia reticulata var. serrata for the first time from Africa. A handbook for the identification of British species of Cladocera was prepared by Scourfield and Harding (1967). Smirnov (1968, 1969) discussed and contributed data on the functional morphology in some species of the chydorid Cladocera. DeCosta (1968a, 1968b) reported species diversity of chydorid cladoceran community from 45 lakes in Mississippi valley in the United States of America. Fryer (1968) discussed the evolution and adaptive radiation in Chydoridae, based on functional morphology while later on, he traced out the evolution of Macrothricidae and held the view that this

group is the oldest of all anomopods (Fryer 1974). The same author reported (1971) anal drinking in Cladocera. Frey (1971, 1975) reviewed the ecology and distribution of Eurycercus and Saycia and discussed subgeneric diffentiation in Eurycercus and also reported a new species of Eurycercus from Sweden. Smirnov's detailed studies on the world fauna of Chydoridae (1971) as well as Macrothricidae and Moinidae (1976) are valuable contributions to the taxonomy and distribution of Cladocera as a whole. Goulden (1968) reviewed the taxonomy of Moina and Moinodaphnia , and raised them to the status of the new family, Moinidae. 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. Anderson (1974) while dealing with Canadian cladoceran fauna, brought out the interespecific relationship. Fernando (1974, 1980) reported 45 species of Cladocera with 14 new records from Srilanka and pointed out the relatively lower abundance of larger cladoceran species. Meijering (1975) discussed the systematics and ecology of Daphnia pulex and reported (1975a) a species resembling both D.middendorffiana and D.pulex. He attributed this intermediate nature to environmental stress. Roeben (1975) reported 13 species of Cladocera with 5 new records from Canary Island, Africa, while Margaritoria and Ferrara (1975) made observations on the taxonomy and distribution of Daphnia spp. from Sardina. Hebert (1977)

reviewed the taxonomy of Australian Daphnia species. Kurbersky (1978) discussed the worldwide distribution of Alonopsis and described a new species.

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

First study on the cladoceran fauna was that of Baird (1859, 1860) who dealt with the Cladocera fauna of Nagpur in Central India. Gurney (1907) furnished a systematic account of the cladoceran fauna of Bengal and part of Bihar and described two new species of Macrothrix. Arora (1939) contributed to the Cladocera fauna of Lahore, now in Pakistan territory. Sewell (1935) contributed to the faunal record of Indian Cladocera in course of his studies on the plankton fauna of Indian Museum Tank and also traced their seasonal changes. Brehm's report (1936) on Yale North India Expedition is one of the important contributions to Indian cladoceran fauna. He contributed further (1950) to the freshwater cladocerans of India. Biswas (1964) recorded Latona tiwari sp. nov. from Rajasthan and dealt with their distribution. Biswas (1966) described Chydorus brehmi sp. nov. from Jaipur, India. Biswas (1971) identified 45 species of Cladocera from Rajasthan and dealt with their distribution. Nayer (1971) recorded 17 species of Cladocera

from different part of Rajasthan, India and added 9 new records. Patil (1976) contributed to the Cladocera fauna of North-Eastern India and added 7 new records for this region. Nasar (1977) recorded 11 species of Cladocera from Bhagalpur, Bihar of which 9 were new records.

Michael (1962) attempted for the first time in India to analyze the seasonal events in a 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 acutirostratus and found resemblance with the temperate species of daphnid, 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 (1975a) observed similarity between embryonic and postembryonic developments of Ceriodaphnia cornuta and those of other daphnids. Murugan and Sivaramakrishnan (1976) investigated the life cycle of Scapholeberis kingi and reported 2 preadult and 17 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 sypply and sexual egg producing mothers may or may not undergo any parthenogenetic generation during the rest of life span. They also recorded pseudosexual eggs to be more in the field than in laboratory.

PART-I

SEASONAL SURVEY OF CLADOCERA AND THEIR ENVIRONMENT

PART-I

INTRODUCTION

Taxonomy and distribution of animals both in time and space have been considered as basic requirement of any biological research. Along with the development of modern tools in biological research concepts of modern taxonomy and distribution studies have undergone simultaneous moderanisation. Such works in the Indian context have been limited and more so on Cladocera, although the first study on the taxonomy and distribution of this group has been initiated as early as 1859 by Baird. Baird's pioneering work was based on the collections made by Rev.Hislop in and around Nagpur in Central India (Baird 1859, 1860). After about five decades Gurney dealt with the entomostracous crustaceans from Bengal and Bihar in Eastern India (Gurney 1906, 1907). This was followed by Arora (1931) who gave an account of the Entomostraca from Lahore, now within the territory of Pakistan.

Faunal studies on Cladocera from different regions of India is still incomplete. Sewell (1935) listed the cladoceran species occurring in the Indian Museum Tank, Calcutta. Brehm (1936) studied the material of Yale University North India expedition from Ladakh, Kashmir valley, Punjab and also from Nilgiri Hills from South India. Subsequently he contributed further to the Indian cladoceran fauna (Brehm 1950, 1952, 1953). Biswas (1964) reported five species of Daphnidae from Simla Hills and Kameng district of NEFA, now called Arunachal Pradesh. He also investigated

the fauna of Rajasthan state of North-Western India (Biswas 1964a, 1965, 1971). Petkovski (1966) worked on the collections made from Baroda, in Gujrat state of Western India. Nayar (1971) published a paper on the taxonomy and distribution of Cladocera from Rajasthan and described a new species and added nine new records to the Indian fauna. The only important faunistic study from peninsular India is that of Michael (1973) who dealt with species occurring in and around Madurai. Patil (1976, 1977) listed the Cladocera from material collected from a survey of Assam, Meghalaya and Manipur states of Eastern India.

Though these studies are of importance from taxonomy and distribution point of view, most of them appear to be based on a few or several collections and have not taken into account any other aspects of their biology. On the other hand studies on the seasonal occurrence and distribution of Cladocera have been more than neglected. Thus the present part deals with the studies on the number of available species of Cladocera during different times of the season in relation to the various limnological parameters. For this purpose as many different system as possible have been chosen from the greater Shillong area for the study of morphometry, vegetation, phydicochemical properties along with the cladoceran fauna. This study being the first of its kind from this unexplored region of India, it is hoped that the present investigations will lay the foundations for any future investigations on Cladocera from this region.

PART-I

MATERIAL AND METHODS

The materials for the present study were obtained from a total of 29 freshwater lentic habitats from the greater Shillong area (lat. 25°N, long. 91°9'E). The various limnological parameters, namely, morphometry, physicochemical and biological features were determined as follows:

i) Morphometry: Shoreline mapping was done following the 'Enclosed rectangle method' as suggested by Welch (1948). This method essentially consists of fixing a base line around the system and measuring the distance from this to the shore line at every metre interval.

The depth contours were prepared for each system by finding out the actual depth along transects with the help of a graduated iron rod. This method was found to be convenient for use in most of the systems as majority of them were less than 1.50 m deep. For the ponds in Fish Dale, data on morphometry were obtained from the records of the Fishery Department, Government of Meghalaya. For larger systems such as Ward Lake and a few others, a plastic boat or a bamboo raft was used for the contour mapping. A weighted disc attached to a graduated plastic rope was used for the depth measurements. Readings were taken at one metre interval along several transects across the impoundment and the contour maps were prepared accordingly.

ii) Collection device: Cladocera samples were collected from all the systems between 0800 to 1200 hrs. The samples were obtained with the help of a conical plankton net fabricated out

of No.25xxx bolting silk. The net was towed through both littoral and limnetic zones in each of the system. At times, when there was too much littoral vegetation, an iron handle was attached to the net to faciliate easy collection. Samples were immediately fixed in Formalin raising slowly to a final concentration of about 5%. Such slow addition of Formalin was found to prevent distortion of body shape in Cladocera. On return to the laboratory, these organisms were sorted out under a binocular microscope. Water samples were collected at fixed stations by slowly dipping a plastic bottle of one litre capacity just below the water surface. Chemical analysis of various factors were carried out immediately on return to the laboratory.

iii) Physicochemical factors : Temperature of both air and water was measured using an ordinary Centigrade thermometer. Water temperature was recorded by dipping the thermometer just below the water surface. Air temperature was measured by holding the thermometer in air and care was taken to avoid falling of direct sunlight.

pH was measured using a portable pH meter in the field and also in the laboratory with a standard pH meter.Since the samples were brought to the laboratory almost immediately, there was not much appreciable change between the two readings. Hence in the later part of the study field determination was avoided and the pH was taken only at the laboratory.Conductivity

values were determined at the laboratory with the help of a Standard Conductivity meter. Data on humidity, rainfall and maximum and minimum temperature were collected from the Shillong Unit of Meteorological Survey of India. Analysis of dissolved oxygen, carbon dioxide, alkalinity, phosphate, nitrate and silicate were conducted employing the Standard Methods according to APHA (1967).

Dissolved oxygen was determined by the modified Winkler's method. Free carbon dioxide was measured by titrating 50 ml of water sample against N/44 NaOH using Phenolphthalein as indicator. As carbon dioxide is known to escape rapidly from the water surface analysis was made at the field itself. For analysis of both carbonate and bicarbonate alkalinity, 50 ml of sample was titrated against N/70 HCl using Phenolphthalein and Methyl Orange solutions as indicators. The dissolved inorganic phosphate content was analysed colorimetrically by the Stannous chloride reduction method. The nitrate-nitrogen was determined colorimetrically by phenol disulphonic acid method. The amount of silicate present in the water was measured using the colorimetric silicomolybdate method.

The Similarity Index for cladoceran fauna was computed following Sørensen index (QS) using the formula:

$QS = \frac{2C}{a + b}$, where 'C' represents the number of similar species between the two habitats, while 'a' and 'b' represent the number of species recorded in the two habitats.

PART-I

RESULTS

PART-I

I. HYDROGRAPHICAL SURVEY OF SYSTEMS UNDER STUDY

Before the hydrographic data are presented for individual systems, it is thought relevant to provide meteorological information of Shillong area for the total study period (Table-1, Fig.-1). It will be seen that the minimum air temperature ranged between 4.5°to 18.1°C while maximum temperature ranged between 13.4° to 24.3°C. Similarly the mean humidity values fluctuated between 57.0 to 89.00%, while the rainfall was from a minimum of o.o mm recorded during January, 1978 to a maximum of 453.40 mm in May, 1977. The following are the hydrographical features of the various systems investigated, while in a map of Shillong (Fig.2) the location of different systems has been shown in a serial order. Also the actual photographs of the investigated systems are presented serially in Plates - I to XIII .

System-I

Located behind St. Anthony's College hostel in the vicinity of the Don Bosco School. This is a shallow irregular pit with coarse sandy bottom. It is about one year old, artificial system with a total area of 22 sq m . The basin gradually slopes towards the centre having a maximum depth of 0.90 m. The average depth was 0.55 m. The vegetation was represented by shore line flora mainly belonging to the members of Family Poaceae.

System-II

This is a small artificial pond located close to System-I

Table-1 : Showing the meteorological data of Greater Shillong area.
(September, 1976 to February, 1978)

Month	Temperature (°C)		Humidity (%)	Total rainfall (mm.)
	Maximum	Minimum		
1976				
September	23.60	13.90	84.42	158.50
October	21.30	13.00	77.50	53.00
November	18.60	10.90	78.78	3.60
December	15.20	6.50	75.00	2.20
1977				
January	15.10	5.40	71.50	11.40
February	17.90	7.80	64.50	9.70
March	23.40	12.60	57.00	44.80
April	21.70	12.70	59.00	200.50
May	21.90	14.20	82.00	453.40
June	23.00	16.60	85.50	310.70
July	24.20	18.10	87.50	270.00
August	24.30	17.70	86.50	319.80
September	23.60	16.60	83.50	279.40
October	20.70	13.20	81.00	127.40
November	18.50	12.10	80.50	50.30
December	15.10	6.70	74.00	25.00
1978				
January	13.40	4.50	74.00	-
February	15.80	6.80	65.50	17.70

Fig. 1

Seasonal variation in the meteorological factors of Greater Shillong area (September, 1976 to February, 1978).

Fig.1

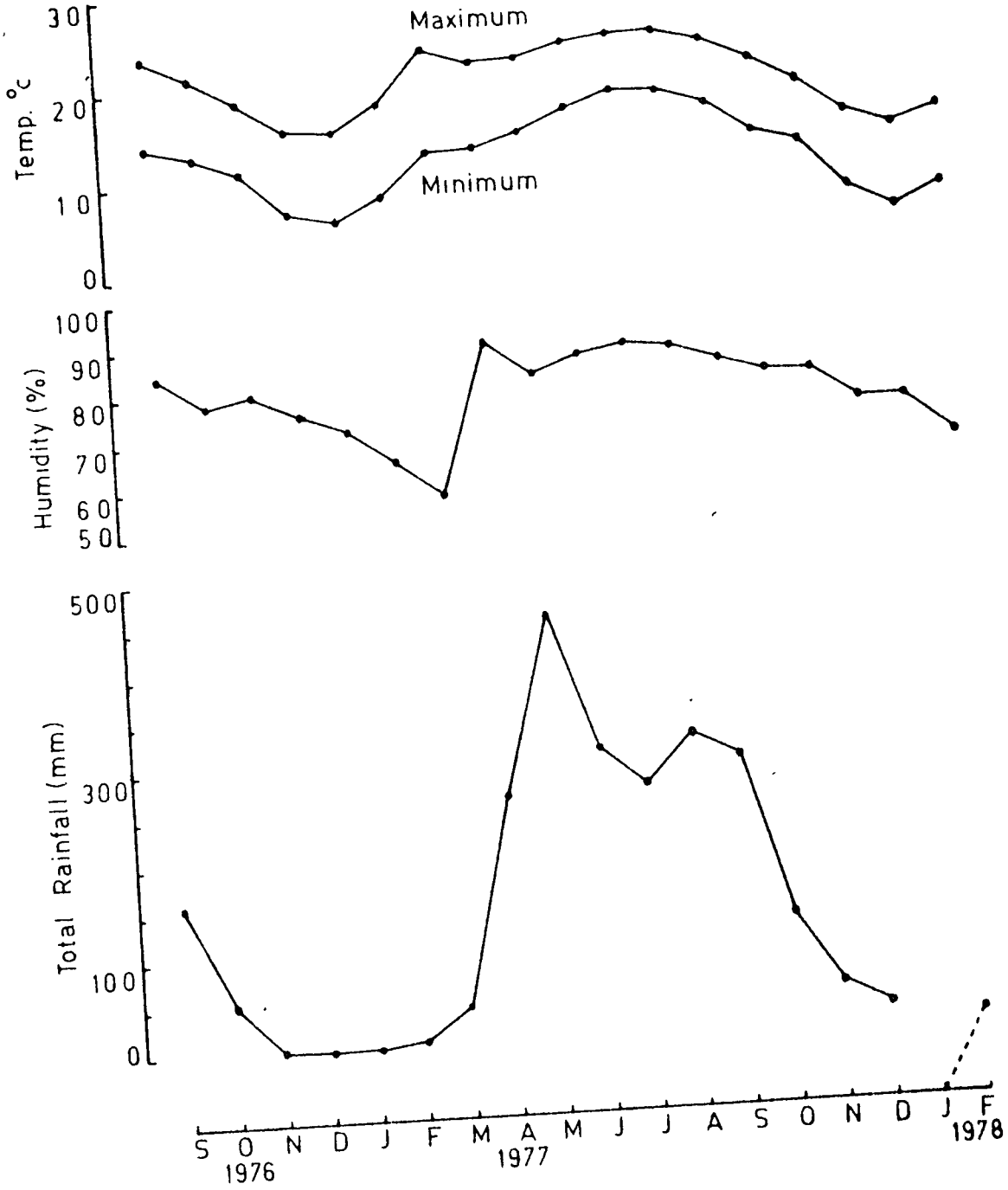
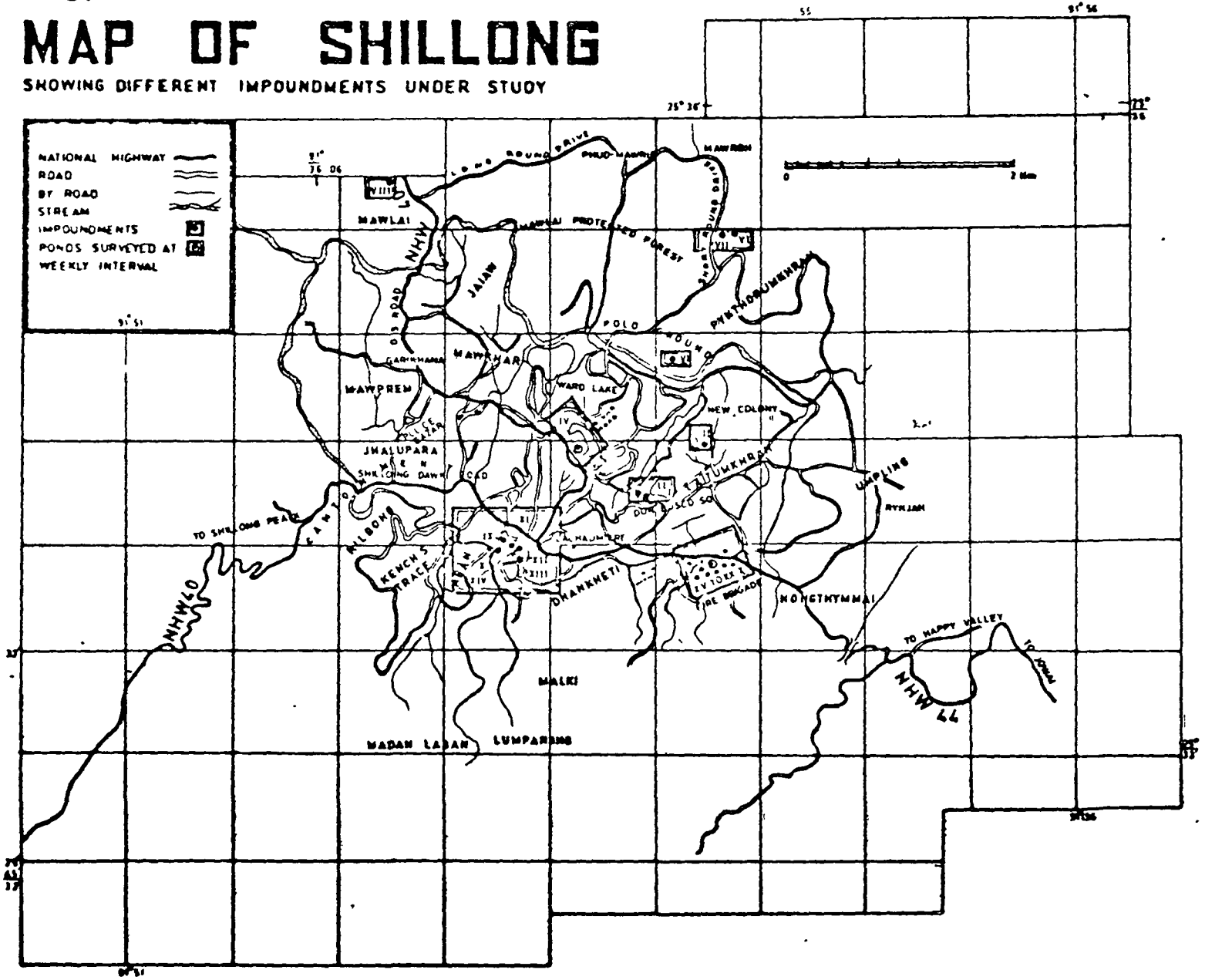

Maximum
Minimum
Temp. °c
30
20
10
0
Humidity (%)
100
90
80
70
60
50
Total Rainfall (mm)
500
300
100
0
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fig:2

MAP OF SHILLONG

SHOWING DIFFERENT IMPOUNDMENTS UNDER STUDY



in the same locality. This is a rectangular pond fed by an underground spring and used for the purpose of rearing fish. This system is of recent origin and approximately 3 years old and of perennial nature. Total area of the system is 397.72 sq m with the length and breadth being 24.40x 16.30 m . The basin shape is irregular with coarse sandy and rocky bottom. Maximum depth was found to be 2.14 m with an average of 1.53 m . The main water body was devoid of any vegetation though the aquatic plants belonging to the genera Polygonum and Bulbostylis were recorded which were usually confined to one corner of the pond.

System-III

A small pond located within the precinct of the Geological Survey of India at the New Colony locality. This pond was originally dug about 2 years ago for the purpose of collecting soil for construction works. When this pit was filled with rain water, it was fertilised with a view to grow fishes. Tap water was fed into it during winter season. The shape of the pond is more or less rectangular with the average length and breadth being 7.12 m and 4.19 m respectively. The total area was 29.84 sq m . The bottom shape was more or less flat and completely sandy with a depth of 3.85 m . No vegetation was present in this system.

System-IV (Ward Lake)

This system is located behind the Shillong Club, adjacent

to the Shillong main road. This is a permanent pond stocked with culturable fishes and extensively used for recreational purposes. It is the largest of the surveyed systems with a total area of 23800 sq m and with a maximum depth of 6.00 m while the average depth was 3.40 m . It was constructed as early as 1894 out of what was originally a swampy area. Detailed morphometry and vegetational association of this system has been dealt with in Part - II as this was one of the systems chosen for detailed biological studies on Cladocera.

System-V

This is a small perennial pond situated adjacent to the Shillong Cricket Club at the Polo Ground locality. This is a somewhat irregular impoundment, fed by a drainage from the Polo Bazar area and having an outlet at its other end. The total area of the system was 185.67 sq m with an average depth of 0.71 m. Maximum depth recorded was 1.12 m and this system had a muddy bottom. No recorded data is available either of its origin or age though the local people attribute its origin to the cutting of soil for repair work of the club house. Both the inlet and the outlet are almost defunct except during the rainy reason.

Vegetational association in this pond was quite rich and the aquatic and marginal plants recorded were; Monochoria hastata, Vallisneria sp,, Leersia hexandra, Scirpus erectus, Polygonum hydropiper, Alternanthera sessilis.

System-VI

A small pond located in the Golflink locality. This is a square shaped pond with a total area of 84.63 sq m having an inlet of 0.80 m width. Its bottom is flat and muddy with a maximum depth of 1.00 m, while the mean depth was found to be 0.67 m . Vegetational association of the pond was represented by : Brasenia peltata, Vallisneria sp., Chara sp., Carex sp., Scirpus sp. and Utricularia sp.

System-VII

This is a irregular swampy system located in the Golflink area near the Golf road. It is fed by a small canal from the direction of the Golf Club which passes through the pond and emerges on the other side. Before entering the pond the canal forms a large swamp which dries up during the winter months. The maximum length and breadth of the system was 25.00 and 14.71 m respectively. The maximum depth was 0.85 m at the centre while the mean depth was 0.59 m. The approximate total area of the system was 202.05 sq m. This pond was devoid of any vegetation in the centre although the littoral zone was inhabited by Vallisneria sp., Chara sp., Rotala rotundifolia, Cyperus sp and Eriocaulon sp.

System-VIII (Nam Ka Brin Pond)

This pond is situated close to the G.S.Road at the Mawlai locality. It is a triangular pond with a total area of 1737.37 sq m having a maximum depth of 3.35 m and the mean

was 2.02 m. The origin of this pond is reported to have been due to digging of soil for road construction; the alternative view is also held that it represents a former old perennial system. However, at present it is totally rainfed and dries up completely during the winter season. There is no inlet or outlet to this system. The depth measurement given here was measured during the monsoon season. The bottom of this pond is muddy and generally deepens at the central region. The main water body is without any vegetation though Vallisneria spp., Chara , Rotala and Ammania were recorded from the littoral region.

System-IX

This pond is located within the Lady Hyderi Park situated at the Barrik locality. It is a shallow bog formed along the course of a small stream passing through the park. It is more or less triangular in shape with a length of 20.3 m. Maximum and minimum breadth are 8.00 and 3.33 m respectively. The average breadth is 5.67 m with a total surface area of 115.10 sq m. The average recorded depth was 0.72 m. The contour of the pond shows that it is deep in the centre with a rocky bottom encrusted with periphyton. Submerged bushes of Rotala rotundifolia and Ammania multiflora were recorded.

System-X

This system is also located in the same area as that of

the previous pond. It is a small rocky permanent pond more or less oval in shape. The total surface area is 211.50 sq m. Maximum depth recorded was 1.50 m and it is deepest in the centre. Water from a tap and rain water are the two major sources of water. No inlet or outlet is present and the average depth recorded was 0.92 m. Vegetational association as found consisted of Rotala rotundifolia , Eriocaulon sp., Cyperus sp., Frimbystylis dicotoma, Juncus prismatocarpus and Polygonum sp.

System-XI

This system is located in the area of Lady Hyderi Park. It is approximately of semilunar shape, artificial in nature with a single inlet and an outlet. The bottom is flat and muddy and one of the banks is made up of concrete. The total surface area is 2537.92 sq m . The maximum depth recorded was 0.87 m and the average depth was 0.56 m . One of the sides was densely populated by macrophytic vegetation represented by Alternanthera sessilis, Nymphaea sp., Chara spp., Scirpus sp., Polygonum sp., P. hydropiper, Eriocaulon sp. and Rotala rotundifolia.

System-XII (Lady Hyderi Park pond)

It is an artificial impoundment, rectangular in shape with 2 parts - one being more shallow than the other. The water flows into it through an inlet while the outlet is almost nonfunctional for the greater part of season. A number of aquatic birds belonging to different genera and families are kept in this pond area for recreational purposes. The total

area of the pond was 1075.08 sq m, the average length, breadth and depth being 105.40 m , 10.20 m and 0.75 m respectively. This is again a study area for the population of Cladocera and hence details of vegetation and morphometry have been dealt with in Part II.

System-XIII

This is a small pond with cemented shores, rectangular in shape and heavily weeded in nature. This is connected to System-XII and has an outlet leading to a small canal. The length and breadth of the system were 29.94 m and 3.61 m respectively and the total area was 108.10 sq. m . The shape of the bottom was flat and the maximum depth recorded was only 0.50 m . The associated weeds in this pond were Alternanthera sessilis, Nymphaea sp. and Leersia hexandra.

System-XIV

Located in the Lady Hyderi Park area. This is comparatively deeper pond, with a more or less round shape. The total area of the pond was 675.33 sq m . The depth contours indicated more or less flat profile with a muddy bottom. Depth was more at the central region and the maximum value was 3.12 m. There is only one inlet which is connected to this system. It had a rich aquatic flora composed of Nymphaea, Rotala rotundifolia and Isachaemum sp.

The following systems (No.XV to XXIX) are all located

in the Fish Dale belonging to the department of fisheries, Government of Meghalaya. These ponds are of the same depth (1.50 m) and their bottom surface is flat in nature.

System-XV

This system actually consisting of two ponds is located in the Fish Dale Complex of the Government of Meghalaya, situated at the Fruits Garden locality (Fig.I, System-XV). These ponds are used for either nursery or for breeding purposes. These are artificial ponds, more or less square in shape. Since both of these ponds are interconnected they were always sampled as one unit and their total area were 89.89 sq m and 99.00 sq m respectively. The vegetation consisted of species such as Alternantheria sessilis, Ammania multiflora, Scirpus sp. Rotala rotundifolia and Vallisneria sp.

System-XVI

Located at Fish Dale. Two interconnected ponds represent this system. The size of the ponds are 61.90 sq m and 83.35 sq m , both approximately of square shape. The vegetation consists of Scirpus sp., Cyperus sp. and Bulbostylis sp.

System-XVII

Located at Fish Dale. This is an artificial stocking

pond, more or less rectangular in shape with big boulders lining the sides. Its average length and breadth are 54.24 m and 45.11 m respectively and the total area is 2447.22 sq m. The vegetation of this pond included Polygonum sp. ,Juncus sp. and Selaginella sp.

System-XVIII

Situated at Fish Dale area. It is a stocking pond, irregular in shape with an average length and breadth of 48.94 m and 38.1 m respectively. The total area calculated was 1864.61 sq m. The associated flora was represented by Polygonum sp., Juncus sp., Arundinella bengalensis and Capellipedium assamile.

System-XIX

Location, same as above. The shape of this pond was irregular. It is a stocking pond with its length and breadth being 50.90 m and 38.10 m respectively. The total area of the pond was 1939.35 sq m. Its sides are lined by big boulders and and devoid of any vegetation excepting some species of Mosses.

System-XX

Location: Fish Dale. This is an artificial nursery-cum-breeding pond of more or less square shape with a total area of 83.72 sq m and the length and breadth were 9.20 m and 9.10 m respectively. The macrophytes were represented by Galinsoga

parviflora, Lindernia sp., Rotala rotundifolia and Agaratum conizoides .

System-XXI

Location: Fish Dale. This system is artificial and rectangular in shape used as nursery and breeding pond with a total area of 526.66 sq m (length into breadth: 27.43 x 15.20 m). Vegetational association was represented by Digitaria spp. , Vallisneria sp., Cyperus sp., Ammania sp., Scirpus sp., and Rotala sp.

System-XXII

Location: Fish Dale. This is a more or less square pond which has a total area of 143.08 sq m (Length x Breadth: 13.41 x 10.67 m). The nature of vegetation was same as that of System-XXI.

System-XXIII

Location: Fish Dale. This is a nursery pond with a total area of 197.43 sq m (Length x Breadth: 25.91 x 7.62 m) with the same vegetational composition as that of the previous pond.

System- XXIV

Location: Fish Dale. This pond is rectangular in

shape with a total surface area of 327.79 sq m. (Length x Breadth: 24.30 x 14.02 m) which is used as a nursery or a breeding pond. The macrophytic complex more or less resembles that of the System-XXI.

System-XXV

Location: Fish Dale. The shape of the pond is approximately squarish (Length x Breadth: 12.80 x 10.06 m) with a total area of 128.77 sq m. This system is also used for the dual purpose of a nursery and a breeding pond. The floral association of this pond resembles that of System-XXI.

System-XXVI

Location: Fish Dale. This is a more or less square pond with a total area of 200.86 sq m (Length x Breadth : 15.24 x 13.11 m), used as a nursery as well as a breeding pond. The associated vegetation of this pond was closely similar to that of System-XXI..

System-XXVII

Location: Fish Dale. This is a breeding pond 26.21 m long and 9.14 m broad. The total area of the pond was 239.56 sq m. The pond bottom was flat and had a depth of 1.50 m with the sides formed of cemented wall. The vegetation consisted

of Leersia hexandra, Digitaria sp., Rotala rotundifolia, Scirpus erectus .

System-XXVIII

Location : Fish Dale. The shape of this system is square with a total surface area of 197.43 sq m (Length x Breadth: 14.02 x 14.33 m). This pond is also used for either nursery or breeding purposes. The floral composition consisted of Ammania multiflora, Rotala rotundifolia and Scirpus sp.

System-XXIX (Fish Dale pond)

This is a cemented pond, rectangular in shape with a total area of 102.88 sq m; the length and breadth being 12.50 and 8.23 m respectively. The detailed morphometry of this system has been given in Part-II in connection with the studies on the biology of the Cladocera.

PART-I

II. PHYSICOCHEMICAL PROPERTIES AND CLADOCERAN FAUNA

Before the Cladocera fauna of individual systems are presented, the total number of species recorded during the present investigations has been furnished. Camera lucida diagrams of different species are shown in Plates XIV to XVI. Thus during the present studies, a total of 23 species of Cladocera were recorded of which 2 belonged to Sididae, 7 to Daphnidae, 2 to Macrothricidae, 1 each in Moinidae and Bosminidae while Chydoridae was represented by 10 species as shown below:

Family : Sididae
- Sida crystallina (O.F.Muller, 1875)
- Diaphanosoma excisum Sars, 1885

Family : Daphnidae
- Daphnia lumholtzi Sars, 1885
- Daphnia sp.
- Ceriodaphnia cornuta Sars, 1885
- Scapholeberis kingi Sars, 1903
- Simocephalus vetulus (Schoedler, 1858)
- Simocephalus exspinosus (Koch, 1841)
- Simocephalus serrulatus (Koch, 1841)

Family : Moinidae
- Moina micrura Kurz, 1874

Family : Macrothricidae
- Macrothrix laticornis (Jurine, 1820)
- Ilyocryptus spinifer Herrick, 1884

Family : Bosminidae
- Bosmina longirostris (O.F.Muller, 1785)

Family : Chydoridae
- Chydorus sphaericus (O.F.Muller, 1785)
- Pseudochydorus globossus (Baird, 1893)
- Biapertura affinis (Leydig, 1860)

Alona sp.
Leydigia australis cylonica Daday, 1898
Alonella excisa (Fischer, 1854)
Alonella nana (Baird, 1850)
Pleuroxus similis (Varva, 1900)
Acroperus harpae (Baird, 1834)
Camptocercus australis Sars, 1896

Results on the seasonal fluctuations in the physico-chemical factors and the composition and seasonal distribution of cladoceran species have been presented here for individual systems.

System-I :

This temporary pond was surveyed for 6 months only, after which it completely dried up. Physicochemical properties of this pool is furnished in Table-2a. Water temperature was always less than that of air temperature and the former fluctuating between 12° to 22°C. pH ranged from 5.5 to 6.9 with highest in the month of December, 1976. Highest conductivity value was obtained in the month of August, 1976 (94.5 /umhos/cm) and the lowest recorded value was 77.7 /umhos/cm. The range of dissolved oxygen, free carbon dioxide and alkalinity varied from 7.4 - 10.4 mg/l, 3.8 - 9.0 mg/l and 10.6 - 28 mg/l respectively. Dissolved phosphate was always below 0.7 mg/l. Nitrate values ranged from 0.31 - 1.25 mg/l. The silicate concentration was found to vary between 4.33 - 6.14 mg/l.

Only 2 species of chydorid cladoceran were recorded.

Both these species occurred during all the 3 collections (Table-2b).

Table-2b : Showing species composition and seasonal distribution of Cladocera in System-1 (August, 1976 to June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.
Family Chydoridae						
Chydorus sphaericus	+	+	+	System dried		
Alonella excisa	+	+	+			

System-II :

The physicochemical properties of this system has been furnished in Table-3a. The water temperature was less or equal to the air temperature. pH remained acidic throughout the study period with the value ranging from 5.4 - 6.1. Highest conductivity value was recorded in the month of February, 1977 (78.12 /umhos/cm). Highest oxygen and carbon dioxide values were obtained in the months of August, 1976 (10.4 mg/l) and April, 1977 (15.6 mg/l) respectively. Carbonate alkalinity was never recorded while the bicarbonate values ranged from 9.2- 29.32 mg/l with the highest in the month of June, 1977. Highest values of phosphate, nitrate and silicate were recorded during the months of February, 1977 (2.5 mg/l), October, 1976 (3.5 mg/l) and February, 1977 (9.13 mg/l) respectively.

Table-2a : Showing the seasonal changes in the physicochemical factors of System-I (August, 1976 to June, 1977).

Factors	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C) Air	23.0	18.0	9.0			
Water	21.0	17.0	8.0			
pH (unit)	5.9	5.5	6.9			
Conductivity (umhos/cm)	94.5	86.2	77.7			
Dissolved oxygen (mg/l)	7.4	7.6	10.4	System dried up		
Carbon dioxide (mg/l)	9.0	5.8	3.8			
Alkalinity (mg/l)	10.6	15.8	28.0			
Phosphate (mg/l)	0.62	0.63	0.45			
Nitrate (mg/l)	0.75	1.25	0.31			
Silicate (mg/l)	5.27	4.33	6.14			

Table-3a : Showing the seasonal changes in the physicochemical factors of System-II (August, 1976 to June, 1977).

Factors	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June
Temperature (°C) Air	19.0	25.0	10.0	19.0	22.0	24.0
Water	22.0	19.0	10.0	16.0	19.0	23.0
pH (unit)	5.8	5.4	5.6	6.1	5.6	5.9
Conductivity (umhos/cm)	67.33	50.92	67.20	78.12	69.30	65.30
Dissolved oxygen (mg/l)	6.80	11.28	8.00	10.49	5.28	8.20
Carbon dioxide (mg/l)	7.2	10.4	5.2	5.2	15.6	6.8
Alkalinity (mg/l)	9.12	9.20	14.00	22.20	26.80	29.32
Phosphate (mg/l)	0.75	0.87	0.56	2.50	1.03	0.91
Nitrate (mg/l)	3.00	3.50	3.15	2.15	1.35	1.90
Silicate (mg/l)	5.27	8.78	4.39	9.13	5.79	5.27

Only one species of Cladocera was recorded in this freshly dug out pond (Table-3b).

Table-3b : Showing species composition and seasonal distribution of Cladocera in System-II (August, 1976 to June, 1977).

Species	1976		1977			
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.
Family Chydoridae						
Chydorus sphaericus	-	-	+	+	+	-

System-III :

Results of the analysis of physicochemical factors have been given in Table-4a. Water temperature was found to be less than that of the air temperature. pH was slightly alkaline except in the month of February, 1977 (6.8) and varied between 7.3 - 7.9. Highest value of conductivity was recorded in the month of October, 1976 (126 µmhos/cm) and the lowest value was found to be 52.29 µmhos/cm in the month of April, 1977. The ranges in the values of oxygen, carbon dioxide, alkalinity , phosphates, mitrates and silicates were :

Oxygen : 8.16 - 13.56 mg/l, CO_2 : 2.4 -4.8 mg/l, Alkalinity : 23.80 - 48.00 mg/l, Phosphate : 1 - 4.0 mg/l, Nitrates : 0.20 - 0.90 mg/l and Silicates : 4.87 - 15.80 mg/l.

The cladoceran fauna was represented by 3 diverse

species namely, Scapholeberis kingi, Moina micrura and Bosmina longirostris belonging to the families Daphnidae, Moinidae and Bosminidae. Their seasonal distribution have been given in Table-4b.

Table-4b : Showing species composition and seasonal distribution of Cladocera in System-III (August, 1976 to June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.
Family Daphnidae						
Scapholeberis kingi	-	+	-	-	+	-
Family Moinidae						
Moina micrura	+	+	-	+	-	-
Family Bosminidae						
Bosmina longirostris	+	+	-	+	+	-

System-IV (Ward Lake) :-

Results on the physicochemical analysis are given in Table-5a. The air and water temperatures varied within a limit of 1°C with the highest water temperature being 25°C in the month of June, 1977 and the lowest during December, 1976 and February, 1976 (16°C). The pH ranged between 6 - 7. Highest conductivity value was in the month of October, 1976 and the variation was between 66.66 - 76.19 /umhos/cm. Dissolved oxygen, carbon dioxide and alkalinity ranged between 6.58 - 10.53 mg/l, 4.25 - 9.88 mg/l and 17.70 - 30.60 mg/l respectively. The

Table-4a : Showing the seasonal changes in the physicochemical factors of System-III (August, 1976 to June, 1977).

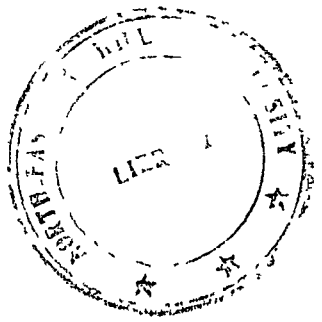
Factors		1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Temperature (°C)	Air	22.0	22.5	8.5	22.0	23.0	24.0
	Water	21.0	18.5	8.0	16.0	21.0	22.0
pH (unit)		7.6	7.9	7.5	6.8	7.4	7.3
Conductivity (umhos/cm)		112.13	126.00	97.13	54.92	52.29	87.20
Dissolved osygen (mg/l)		8.60	8.40	8.16	10.20	13.56	8.40
Carbon dioxide (mg/l)		2.60	2.40	2.40	4.80	2.80	2.60
Alkalinity (mg/l)		23.80	29.60	48.00	27.40	31.00	29.40
Phosphate (mg/l)		4.00	3.00	1.00	2.25	2.38	2.12
Nitrate (mg/l)		0.63	0.90	0.30	0.25	0.20	0.20
Silicate (mg/l)		4.87	4.92	5.27	9.13	15.80	5.27

Table-5a : Showing the seasonal changes in the physicochemical factors of System-IV (August, 1976 to June, 1977).

Factors		1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Temperature (°C)	Air	25.5	22.8	17.0	19.0	22.0	26.0
	Water	25.0	23.0	16.0	16.0	20.0	25.0
pH (unit)		6.43	6.16	6.59	6.57	6.59	6.28
Conductivity (umhos/cm)		74.94	76.19	67.59	66.66	71.57	72.14
Dissolved oxygen (mg/l)		10.53	6.58	7.34	8.83	7.66	8.38
Carbon dioxide (mg/l)		8.07	4.25	4.80	9.87	9.88	9.00
Alkalinity (mg/l)		29.93	17.70	28.05	22.40	30.60	29.45
Phosphate (mg/l)		0.56	2.05	1.59	1.13	1.68	1.00
Nitrate (mg/l)		0.30	0.65	0.79	0.85	0.74	1.52
Silicate (mg/l)		3.52	1.45	1.85	2.93	1.41	1.54

Table-5b : Showing species composition and seasonal distribution of Cladocera in System-IV (August, 1976 to June, 1977)

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Sididae						
Sida crystallina	-	-	-	-	+	+
Diaphanosoma excisum	+	-	-	-	+	-
Family Daphnidae						
Daphnia lumholtzi	-	-	-	-	+	+
Ceriodaphnia cornuta	-	-	-	-	-	+
Scapholeberis kingi	+	+	+	+	+	+
Simocephalus exspinosus	+	+	+	+	+	+
Simocephalus serrulatus	-	-	+	+	+	-
Family Macrothricidae						
Ilyocryptus spinifer	-	+	+	-	-	-
Family Moinidae						
Moina micrura	-	+	+	-	-	-
Family Bosminidae						
Bosmina longirostris	+	+	+	+	+	+
Family Chydoridae						
Chydorus sphaericus	+	+	+	+	+	+
Biapertura affinis	+	+	+	+	+	-
Alona sp.	-	+	+	-	-	-
Alonella excisa	+	+	+	+	+	+
Alonella nana	-	+	+	+	+	-
Pleuroxus similis	-	+	+	+	+	+
Acroperus harpae	+	+	+	+	+	+
Camptocercus australis	+	+	+	+	+	+



amounts of phosphates, nitrates and silicates varied between 0.56 - 2.05 mg/l, 0.8 - 1.52 mg/l and 1.41 - 3.52 mg/l.

This lake was the largest of all the systems surveyed and exhibited the maximum number of cladoceran species. There were two species of Sididae, five species of Daphnidae, one of Moinidae, one of Bosminidae, one of Macrothricidae and eight of Chydoridae with a sum total of eighteen species. The details of the species composition and their seasonal distribution have been shown in Table-5b.

System-V :

The readings recorded on physicochemical factors is furnished in Table-6a. Water temperature was found to be always lower than the air temperature. The range of pH value was 57 - 6.2. Conductivity value was highest in the month of February, 1977 and the maximum and minimum range was 79.50-173.5 /umhos/cm. Dissolved oxygen, free carbon dioxide and alkalinity ranged between 3.24 - 9.76 mg/l, 4.6 - 18.2 mg/l and 14.00 - 39.60 mg/l respectively. The inorganic phosphates, nitrate-nitrogen and silicate values were 1.23 - 3.75 mg/l, 0 - 0.45 mg/l and 3.19 - 7.02 mg/l.

Cladocera fauna has been represented by 2 species of Daphnidae, 1 species of Macrothricidae and 5 species of Chydoridae. Their seasonal occurrence are shown in Table-6b.

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Table-6a : Showing the seasonal changes in the physicochemical factors of System-V (August, 1976 to June, 1977).

Factors		1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Temperature (°C)	Air	26.0	21.0	16.0	18.0	24.0	26.0
	Water	24.0	19.0	10.0	16.0	23.0	24.0
pH (unit)		6.0	5.7	6.4	5.9	6.2	6.1
Conductivity (umhos/cm)		84.00	78.96	115.50	173.50	86.10	79.50
Dissolved oxygen (mg/l)		6.80	8.00	3.24	4.24	9.76	4.60
Carbon dioxide (mg/l)		7.80	4.60	6.60	18.20	8.40	11.20
Alkalinity (mg/l)		14.00	15.40	39.60	36.20	30.00	27.60
Phosphate (mg/l)		1.23	2.25	1.88	3.75	3.75	3.75
Nitrate (mg/l)		-	0.45	0.10	0.30	-	0.10
Silicate (mg/l)		3.19	5.27	3.51	3.51	7.02	3.51

Table-6b : Showing species composition and seasonal distribution of Cladocera in System-V (August, 1976 to June, 1977) .

Species	1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Family Daphnidae						
Simocephalus exspinosus	+	+	+	-	+	-
Family Macrothricidae						
Macrothrix laticornis	+	-	-	-	+	+
Ilyocryptus spinifer	-	+	-	-	-	-
Family Chydoridae						
Chydorus sphaericus	+	+	+	+	+	+
Biapertura affinis	+	+	+	+	+	+
Pleuroxus similis	+	-	+	+	-	-
Acroperus harpae	-	+	+	+	-	-
Camptocercus australis	-	+	+	+	+	-

System-VI :

Records of physicochemical data have been presented in Table-7a. pH and conductivity of water did not show much seasonal variations and have ranged between 5.98 - 6.70 and 19.95 to 26.57 µmhos/cm. The ranges of variation in oxygen, carbon dioxide, alkalinity phosphates, nitrates and silicates were : Oxygen - 3.20 - 10.68 mg/l, carbon dioxide - 4.8 - 9.6 mg/l, alkalinity - 14.25 -26.29 mg/l, phosphate - 0.78 - 4.12 mg/l, nitrate - 0 - 0.20 mg/l and 3.51 - 7.02 mg/l.for silicate.

Cladocera fauna was represented by one species of Daphnidae and 3 species of Chydoridae as shown in Table-7b.

System-VII :

Data on the physicochemical factors are shown in Table-8a. Except in the month of August, 1976, water temperature was always lower than that of air. pH was variable and ranged from 5.45 to 6.95 units. Conductivity value was rather low ranging between 15.75 - 22.68 µmhos/cm. Range of oxygen concentration was 6.84 to 9.72 mg/l. Carbon dioxide ranged from 4.20 - 11.80 mg/l and the range in alkalinity was 8.40 - 17.60 mg/l. Dissolved nutrient substances such as phosphates, nitrates and silicates varied as :
Phosphate - 0 - 3.63 mg/l, Nitrate- 0 - 0.12,mg/l, Silicate -2.63 - 8.43 mg/l.

Only 4 species of Chydoridae were recorded from this

Table-7a : Showing the seasonal changes in the physicochemical factors of System-VI (August, 1976 to June, 1977).

Factors		1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Temperature (°C)	Air	24.0	21.0	18.0	18.0	22.5	
	Water	22.0	20.0	10.0	16.0	23.0	
pH (unit)		6.70	5.98	6.80	6.70	6.30	
Conductivity (umhos/cm)		19.96	26.23	22.58	23.20	26.57	No analysis carried out
Dissolved oxygen (mg/l)		3.20	4.66	4.84	7.60	10.68	
Carbon dioxide (mg/l)		7.62	8.42	4.80	5.20	9.60	
Alkalinity (mg/l)		26.29	14.25	17.60	22.50	18.60	
Phosphate (mg/l)		0.78	1.04	2.25	4.12	3.13	
Nitrate (mg/l)		0.10	0.20	0.20	0.15	-	
Silicate (mg/l)		5.18	4.87	3.51	3.51	7.02	

Table-7b : Showing species composition and seasonal distribution of Cladocera in System-VI (August, 1976 to June, 1977)

Species	1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June
Family Daphnidae						
Simocephalus exspinosus	-	+	+	-	-	+
Family Chydoridae						
Chydorus sphaericus	+	+	+	+	+	+
Pseudochydorus globossus	+	+	-	-	-	+
Biapertura affinis	+	+	+	+	+	+

Table-8a : Showing the seasonal changes in the physicochemical factors of System-VII (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June
Temperature (°C)	Air	24.0	19.0	16.0	22.0	21.0	26.0
	Water	24.0	18.0	10.0	16.0	22.0	24.0
pH (unit)		6.95	5.45	6.80	5.60	5.60	6.72
Conductivity (umhos/cm)		15.75	22.58	22.58	18.38	15.96	22.68
Dissolved oxygen (mg/l)		9.72	6.84	7.74	8.96	8.48	7.92
Carbon dioxide (mg/l)		4.20	5.00	4.80	11.80	11.00	8.40
Alkalinity (mg/l)		8.40	11.20	17.60	14.20	15.60	17.20
Phosphate (mg/l)		0.87	1.38	-	1.75	3.63	2.51
Nitrate (mg/l)		0.10	-	0.20	0.10	-	0.12
Silicate (mg/l)		8.96	8.43	6.15	2.63	7.02	5.27

Table-8b : Showing species composition and seasonal distribution of Cladocera in System-VII (August, 1976 to June, 1977)

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June
Family Chydoridae						
Chydorus sphaericus	+	+	+	+	+	+
Biapertura affinis	+	+	+	+	+	+
Alona sp.	-	+	-	-	+	-
Alonella excisa	+	+	+	+	+	+

system as shown in Table-8b.

System-VIII :

This system could be sampled only from August, 1976 to December, 1976 for a total of six months period since this pond dried up. The data presented here, therefore, represents three collections made at every two months interval (Table-9a). The water temperature was found to be less than that of air temperature . The pH ranged between 6.3 to 6.78. Variations in the dissolved oxygen, carbon dioxide, alkalinity were : 5.28 - 9.66, 3.20 - 6.40 and 25.25 - 39.00 mg/l respectively.

The Cladocera founa in this system has been well represented with 3 species of Daphnidae, 1 species of Bosminidae and 5 species of Chydoridae as shown in Table-9b.

System- IX :

The various physicochemical factors (Table-19a) show that water temperature was always lower in this system than that of air. The pH values ranged between 5.55 - 6.9 whereas the conductivity value varied from 34.65 to 65.1 umhos/cm. Oxygen, Carbon dioxide and alkalinity ranged between 4.08 - 10.16 mg/l, 3.20 - 11.40 mg/l and 11.00 to 43.20 mg/l respectively whereas the variations in the contents of phosphates, nitrates and silicates were 0 - 3.78 mg/l, 0.10- 0.55 mg/l and 2.63 - 7.08 mg/l.

Table-9a : Showing the seasonal changes in the physicochemical factors of System-VIII (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C)	Air	24.0	22.5	15.0			
	Water	23.0	18.5	12.0			
pH (unit)		6.30	6.52	6.78			
Conductivity (umhos/cm)		31.0	42.2	53.0			
Dissolved oxygen (mg/l)		9.66	5.67	5.28	System dried up		
Carbon dioxide (mg/l)		3.20	5.40	6.40			
Alkalinity (mg/l)		25.25	34.73	39.00			
Phosphate (mg/l)							
Nitrate (mg/l)		Not analysed					
Silicate (mg/l)							

Table-9b : Showing species composition and seasonal distribution of Cladocera in System-VIII (August, 1976 to June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Scapholeberis kingi	+	+	+			
Simocephalus vetulus	+	+	-			
Simocephalus exspinosus	+	-	-			
Family Bosminidae				System dried up		
Bosmina longirostris	+	+	+			
Family Chydoridae						
Chydorus sphaericus	+	+	+			
Biapertura affinis	-	+	-			
Alonella excisa	+	+	+			
Alonella nana	+	+	-			
Pleuroxus similis	+	-	-			

Only 2 species of Cladocera belonging to Daphnidae and Chydoridae were recorded in this pond.(Table-10b).

Table-10b : Showing the seasonal occurrence and distribution of Cladocera in System-IX (August, 1976 to June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.
Family Daphnidae						
Simocephalus exspinosus	+	+	+	+	+	+
Family Chydoridae						
Chydorus sphaericus	+	+	+	+	+	+

System-X :

The physicochemical factors have been shown in Table-11a. Water temperature was lesst than that of the atmospheric. The pH range was found to be 5.55 - 7.1. Conductivity values ranged between 46.20 to 74.55 umhos/cm. The range of variation in oxygen, carbon dioxide, alkalinity, phosphates, nitrates and silicates were as follows : Oxygen - 7.44 - 9.48 mg/l, carbon dioxide - 4.8 - 12.4 mg/l, alkalinity - 12.40 - 36.40 mg/l, phosphate - 0.13 - 1.88 mg/l, nitrate - 0.3 - 1.40 mg/l and silicate - 4.39 - 6.14 mg/l.

Cladocera fauna was represented by 1 species of

Table-10a : Showing the seasonal changes in the physicochemical factors of System-IX (August, 1976 to June , 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C)	Air	26.0	18.0	18.0	20.0	21.0	26.0
	Water	23.0	15.0	11.0	17.0	20.0	24.0
pH (unit)		6.90	5.55	6.25	6.10	5.90	6.70
Conductivity (umhos/cm)		57.75	34.65	55.65	51.66	65.10	71.31
Dissolved oxygen (mg/l)		4.08	7.44	6.80	10.16	8.00	5.60
Carbon dioxide (mg/l)		10.60	3.20	4.80	11.00	11.40	12.00
Alkalinity (mg/l)		16.00	11.00	25.60	42.20	36.40	43.20
Phosphate (mg/l)		1.50	1.75	1.39	-	3.37	3.29
Nitrate (mg/l)		0.32	0.55	0.65	0.10	0.35	0.24
Silicate (mg/l)		5.21	4.92	4.40	2.63	5.27	7.08

Table-11a : Showing the seasonal changes in the physicochemical factors of System-X (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C)	Air	29.0	18.0	18.0	20.0	21.0	23.0
	Water	24.0	15.0	12.0	17.0	20.0	22.0
pH (unit)		7.10	5.55	6.05	6.60	5.80	5.90
Conductivity (umhos/cm)		65.10	46.10	50.35	74.55	52.08	49.35
Dissolved oxygen (mg/l)		9.32	9.00	9.48	7.44	8.16	8.44
Carbon dioxide (mg/l)		7.90	8.40	5.80	4.80	12.40	4.90
Alkalinity (mg/l)		13.40	12.40	21.00	36.40	24.40	26.50
Phosphate (mg/l)		0.87	1.00	0.12	0.87	1.87	0.56
Nitrate (mg/l)		0.59	1.40	0.70	0.40	1.00	0.30
Silicate (mg/l)		5.29	6.14	4.39	3.39	5.27	4.39

Table-11b : Showing species composition and seasonal distribution of Cladocera in System-X (August, 1976 to June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Scapholeberis kingi	+	+	+	-	+	-
Family Chydoridae						
Alonella excisa	-	+	+	+	-	-

Daphnidae and 1 species of Chydoridae.(Table-11b).

System-XI :

Data on the physicochemical factors of this pond has been furnished in Table-12a. The water temperature was found to range between 12° in December, 1976 to 24° in June, 1977. Highest pH value was 6.2 and the range was between 5.3 - 6.2. Conductivity varied between 58.80 - 73.80 /umhos/cm. The concentration of oxygen, carbon dioxide and alkalinity varied from 5 - 12.32 mg/l, 4.20 - 14.80 mg/l and 16.00 - 38.40 mg/l respectively. The nutrients such as phosphate, nitrate and silicate varied between 0 - 2.50 mg/l, 0.10 - 0.30 mg/l and 5.27 - 9.13 mg/l respectively.

In this pond 1 species of Daphnidae, species of Bosminidae and 3 species of Chydoridae were recorded during different times of the year as shown in Table-12b.

System-XII :

The physicochemical factors represented in Table-13a shows that water temperature was always lower than that of the atmosphare and ranged from 12° - 23°C. pH value fluctuated between 5.88 to 6.40. Conductivity value ranged from 55.82 to 84.87 /umhos/cm. Variations recorded in the concentrations of oxygen, carbon dioxide and alkalinity were 4.66 - 9.04 mg/l, 9.57 - 13.55 mg/l and 14.25 - 39.00 mg/l respectively.

Table-12a : Showing the seasonal changes in the physicochemical factors of System-XI (August, 1976 to June, 1977).

Factors		1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Temperature (°C)	Air	28.0	21.0	18.0	20.0	23.0	23.0
	Water	24.0	20.0	12.0	18.0	22.0	22.0
pH (unit)		6.2	5.3	5.8	6.2	6.2	6.2
Conductivity (umhos/cm)		63.00	66.15	58.80	75.60	68.78	73.80
Dissolved oxygen (mg/l)		9.12	5.00	6.80	10.16	12.32	8.48
Carbon dioxide (mg/l)		12.80	4.20	14.80	10.80	10.20	9.80
Alkalinity (mg/l)		16.00	19.20	28.60	39.60	36.20	38.40
Phosphate (mg/l)		0.82	0.65	0.31	-	2.50	0.90
Nitrate (mg/l)		0.22	0.38	0.16	0.10	0.22	0.11
Silicate (mg/l)		5.86	9.13	5.27	5.27	7.02	6.21

Table-12b : Showing species composition and seasonal distribution of Cladocera in System-XI (August, 1976 to June, 1977).

Species	1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Family Daphnidae						
Scapholeberis kingi	+	+	+	-	-	+
Family Bosminidae						
Bosmina longirostris	+	+	+	-	+	+
Family Chydoridae						
Chydorus sphaericus	+	+	+	+	+	+
Pleuroxus similis	+	+	-	+	+	-
Alonella nana	+	+	-	-	-	-

Table-13a : Showing the seasonal changes in the physicochemical factors of System-XII (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C)	Air	23.5	22.0	15.0	18.0	21.0	23.0
	Water	23.0	21.0	12.0	15.0	19.0	22.0
pH (unit)		6.00	5.88	6.03	6.17	6.40	6.03
Conductivity (umhos/cm)		55.82	59.23	73.23	74.97	84.87	70.29
Dissolved oxygen (mg/l)		9.04	4.66	5.36	7.00	6.83	4.89
Carbon dioxide (mg/l)		9.57	10.90	12.95	11.80	9.76	13.55
Alkalinity (mg/l)		29.27	14.25	32.90	32.33	39.00	36.75
Phosphate (mg/l)		0.78	1.04	1.58	1.73	2.18	1.86
Nitrate (mg/l)		0.29	0.41	0.62	0.10	0.64	0.87
Silicate (mg/l)		5.18	4.87	9.17	7.31	8.18	4.83

Table-13b : Showing species composition and seasonal distribution of Cladocera in System-XII (August, 1976 to June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Daphnia sp.	-	-	-	-	+	-
Scapholeberis Kingi	-	-	-	-	+	+
Simocephalus exspinosus	-	+	+	-	+	+
Family Bosminidae						
Bosmina longirostris	+	+	+	+	+	+
Family Chydoridae						-
Chydorus sphaericus	+	+	+	+	+	+
Biapertura affinis	+	+	+	-	+	+
Alonella excisa	+	+	-	-	+	+
Pleuroxus similis	-	-	+	-	-	-
Acroperus harpae	+	+	+	-	+	+

Phosphates, nitrates and silicates fluctuated between 0.78 - 2.18 mg/l, 0.10 - 0.64 mg/l and 4.83 - 9.17 mg/l.

A total of 9 species of Cladocera were recorded with 3 species of Daphnidae, 1 species of Bosminidae and 5 species of Chydoridae. Seasonal distribution and occurrence have been given in Table-13b.

System-XIII :

Table-14a a represents the physicochemical factors. Water temperature followed the same pattern as that of System-XII. pH ranged between 5.5 - 6.9. Other parameters followed the fluctuation pattern as given below:-

Conductivity : 51.45 - 101.22 umhos/cm, oxygen : 4.0 -9.60 mg/l, canbon dioxide : 4.20 to 9.00 mg/l, alkalinity: 16.00-50.20 mg/l, phosphates: 0.11 to 5.50 mg/l, nitrates: 0.22 to 0.38 mg/l and silicate: 2.63 to 6.62 mg/l.

A total of 4 species of Cladocera have been recorded from this system during different seasons. 1 of these belonged to Daphnidae, 1 to Bosminidae and 2 Chydoridae (Table-14b).

System-XIV :

Readings of the physicochemical analysis are given in Table-15a . Water temperature was always found to be lower than that of air. pH range was 5.30 in October, 1976 to 6.70 during August, 1976. Conductivity value ranged from

Table-14a : Showing the seasonal changes in the physicochemical factors of System-XIII (August, 1976 to June, 1977)

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C)	Air	27.0	22.0	20.0	20.0	23.0	24.0
	Water	24.0	20.0	10.0	17.0	21.0	23.0
pH (unit)		6.90	5.50	6.10	6.60	6.30	6.50
Conductivity (umhos/cm)		51.45	101.22	74.55	84.21	75.29	67.51
Dissolved oxygen (mg/l)		4.40	4.00	4.16	9.56	9.60	9.20
Carbon dioxide (mg/l)		6.70	4.20	9.00	5.60	7.80	8.00
Alkalinity (mg/l)		16.00	19.20	40.20	50.20	36.40	33.82
Phosphate (mg/l)		1.13	1.13	0.11	1.00	5.50	2.40
Nitrate (mg/l)		0.22	0.30	0.22	0.12	0.38	0.38
Silicate (mg/l)		5.27	4.92	5.09	2.63	6.62	6.62

Table-14b : Showing species composition and seasonal distribution of Cladocera in System-XIII (August, 1976 to June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Scapholeberis kingi	-	-	+	-	+	-
Family Bosminidae						
Bosmina longirostris	-	-	-	+	+	-
Family Chydoridae						
Chydorus sphaericus	+	-	+	+	+	-
Pleuroxus similis	+	-	+	+	+	-

Table-15a : Showing the seasonal changes in the physicochemical factors of System-XIV (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (oC)	Air	27.0	24.0	20.0	20.0	23.0	22.0
	Water	24.0	20.5	11.0	17.0	21.0	21.0
Ph (unit)		6.7	5.3	5.8	6.3	6.4	6.4
Conductivity (umhos/cm)		68.2	85.0	77.7	91.1	76.4	72.3
Dissolved oxygen (mg/l)		4.3	4.7	6.0	5.7	10.1	6.2
Carbon dioxide (mg/l)		8.2	5.0	5.4	4.8	6.8	6.4
Alkalinity (mg/l)		16.6	16.2	40.2	27.0	37.6	26.2
Phosphate (mg/l)		0.6	1.1	--	--	2.6	1.6
Nitrate (mg/l)		0.2	0.3	0.3	0.1	0.3	0.2
Silicate (mg/l)		5.3	5.3	5.4	4.0	7.0	6.9

Table-15b : Showing species composition and seasonal distribution of Cladocera in System-XIV (August, 1976 to June, 1977)

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Simocephalus exspinosus	+	+	-	-	-	-
Scapholeberis kingi	+	-	+	+	-	-
Family Bosminidae						
Bosmina longirostris	+	+	-	-	+	+
Family Chydoridae						
Chydorus sphaericus	-	-	+	+	+	+
Alona sp.	-	-	-	-	+	-
Leydigia australis ceylonica	-	-	-	+	+	-
Pleuroxus similis	-	-	+	-	-	-

68.25 to 91.14 /umhos/cm. Oxygen, carbon dioxide and alkalinity were found to range between 4.32 and 10.08 mg/l, 5.0 and 8.2 mg/l and 16.20 and 40.20 mg/l respectively. The fluctuations in phosphates, nitrates and silicates ranged from 0 - 2.63 mg/l, 0.10 - 0.35 mg/l and 4.04 to 7.02 mg/l.

A total of 7 species of Cladocera with 2 species belonging to Daphnidae, 1 to Bosminidae and 4 species belonging to Chydoridae were recorded. Their seasonal distribution is furnished in Table-15b.

System-XV :

The data on the physicochemical factors analysed for this pond are tabulated in Table-16a. The water temperature values ranged from 12.° to 22°C. pH did not show much fluctuations (5.3 to 6.60 units). Fluctuations in conductivity value was between 31.50 and 70.14 /umhos/cm. The range of variations in dissolved oxygen, carbon dioxide and alkalinity were 6.56 to 8.44 mg/l, 3.2 to 9.2 mg/l and 8.2 to 29.30 mg/l. Phosphate, nitrate and silicate varied from 0 - 1.75 mg/l, 0.11 - 1.55 mg/l and 1.76 - 5.83 mg/l.

Cladocera fauna was represented by 1 species of Daphnidae and 2 species of Chydoridae with a total of 3 species (Table-16b).

Table-16a : Showing the seasonal changes in the physicochemical factors of System-XV (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C)	Air	25.0	18.5	16.0	20.0	23.0	22.5
	Water	22.0	17.0	12.0	14.0	18.0	21.5
pH (unit)		5.9	5.3	6.6	5.8	6.2	6.4
Conductivity (umhos/cm)		33.60	81.50	31.50	54.92	70.14	62.50
Dissolved oxygen (mg/l)		6.60	6.80	8.44	6.96	7.76	6.56
Carbon dioxide (mg/l)		5.00	4.20	3.20	9.20	6.00	6.20
Alkalinity (mg/l)		11.60	8.20	12.40	23.60	21.00	29.30
Phosphate (mg/l)		1.62	0.37	0.37	-	1.75	0.65
Nitrate (mg/l)		0.11	1.00	0.49	0.40	2.40	1.55
Silicate (mg/l)		3.27	1.76	3.34	5.27	5.83	5.27

Table-16b : Showing species composition and seasonal distribution of Cladocera in System-XV (August, 1976 to June, 1977)

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Scapholeberis kingi	+	+	-	-	-	-
Family Chydoridae						
Chydorus sphaericus	+	+	+	-	+	-
Acroperus harpae	+	+	-	+	+	-

S System-XVI :

Table-17a represents the data on the physicochemical analysis of this pond. The water temperature varied from 12°C in December, 1976 to 22°C in August, 1976 and June, 1977 and was always lower than that of atmosphere. The pH value ranged between 5.9 to 6.5. Conductivity value showed a variation between 28.88 and 70.14 /umhos/cm. The range of variation in dissolved oxygen, carbon dioxide, alkalinity, phosphates, nitrates and silicate were respectively 5.04 to 7.32 mg/l, 3.0 - 9.2 mg/l, 7.6 - 29.60 mg/l, 0.38 - 3.00 mg/l, 0 - 0.85 mg/l and 2.56 - 7.90 mg/l.

The cladoceran species recorded from this pond were: 1 species of Daphnidae, 1 species of Bosminidae and 4 species of Chydoridae with a sum total of 6 species. Seasonal distribution record has been given in Table-17b.

System-XVII :

The range of fluctuations in the physicochemical properties (Table-18a) of this pond during different seasons were as follows:
Water temperature : 12° - 22°C, Air temperature: 16° - 23°C, pH : 5.3 - 6.4, conductivity: 26.78 - 62.90/umhos/cm, oxygen: 4.36 - 7.60 mg/l, carbon dioxide: 3.2 - 6.2 mg/l, alkalinity: 10.00 - 33.6 mg/l, phosphate : 0 - 0.88 mg/l, nitrate : 0.05 - 1.0 mg/l, silicate: 4.21 - 5.89 mg/l.

Table-17a : Showing the seasonal changes in the physicochemical factors of System-XVI (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (oC)	Air	27.0	18.5	16.0	22.0	22.0	21.0
	Water	22.0	17.0	12.0	17.0	18.0	20.0
pH (unit)		6.40	5.20	6.50	5.90	6.20	6.30
Conductivity (umhos/cm)		30.45	28.88	34.65	53.02	71.14	59.65
Dissolved oxygen (mg/l)		6.80	6.48	7.32	6.96	5.04	6.04
Carbon dioxide (mg/l)		3.00	5.60	3.80	9.20	5.20	7.20
Alkalinity (mg/l)		8.00	7.60	14.80	26.40	23.60	29.60
Phosphate (mg/l)		0.50	0.75	0.37	1.37	3.00	1.50
Nitrate (mg/l)		0.30	0.85	0.48	0.49	-	0.11
Silicate (mg/l)		2.56	3.86	7.90	3.51	5.62	5.27

Table-17b : Showing the seasonal distribution and species composition of Cladocera in System-XVI (August, 1976 to June, 1977)

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Scapholeberis kingi	-	+	-	+	+	+
Family Bosminidae						
Bosmina longirostris	+	-	-	+	+	-
Family Chydoridae						
Chydorus sphaericus	+	+	-	+	+	+
Biapertura affinis	+	-	+	-	+	+
Pleuroxus similis	-	-	-	+	+	-
Acroperus harpae	-	+	-	+	+	-

Table-18a : Showing the seasonal changes in the physicochemical factors of System-XVII (August, 1976 to June, 1977)

Factors		1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Temperature (°C)	Air	23.0	20.0	16.0	22.0	22.0	23.0
	Water	20.0	19.0	12.0	17.0	18.0	22.0
pH (unit)		6.40	5.30	6.40	6.30	6.10	6.30
Conductivity (umhos/cm)		36.22	26.78	36.75	48.09	62.90	59.60
Dissolved oxygen (mg/l)		6.40	5.44	5.92	7.60	7.36	4.36
Carbon dioxide (mg/l)		5.20	3.20	4.20	6.20	4.00	4.00
Alkalinity (mg/l)		10.00	15.80	24.00	33.60	31.40	27.60
Phosphate (mg/l)		0.77	0.40	0.37	-	0.87	0.42
Nitrate (mg/l)		0.30	0.30	0.16	0.05	1.00	0.52
Silicate (mg/l)		5.11	4.21	4.92	5.27	5.89	3.27

Table-18b : Showing species composition and seasonal distribution of Cladocera in System-XVII (August, 1976 to June, 1977

Species	1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Family Chydoridae						
Chydorus sphaericus	+	+	+	+	+	+
Alonella excisa	+	+	-	-	+	+
Acroperus harpae	+	+	+	+	+	-

Only 3 species of Chydorid Cladocera have been recorded from this pond (Table-18b).

System-XVIII :

The data on the analysis of physicochemical factor have been recorded in Table-19a. The water temperature was found to vary between 12°- 22°C and was always less than that recorded for air. pH showed very little fluctuations (6.00-6.40) while conductivity value varied between 24.68 to 63.21 umhos/cm. The range of variations in the values of dissolved oxygen, carbon dioxide, alkalinity, phosphates, nitrates and silicates were 4.68 - 8.20 mg/l, 3.40 - 7.80 mg/l, 10.00 - 36.20 mg/l, 0.25 - 1.75 mg/l, 0.10 - 0.70 mg/l and 4.27 - 7.02 mg/l respectively.

A total of 3 species belonging to Daphnidae, Bosminidae and Chydoridae were recorded during different seasons as shown in Table-19b.

System-XIX :

Results of the analysis of physicochemical factors have been given in Table-20a. The seasonal ranges of variation in the water temperature, pH and conductivity values were 12°- 24°C, 5.80 - 7.00 and 30.98 - 67.30 umhos/cm. The values of dissolved oxygen, carbon dioxide and alkalinity varied between 5.6 - 9.12 mg/l, 2.80 - 12.20 mg/l and 10.00-39-20 mg/l

Table-19a : Showing the seasonal changes in the physicochemical factors of System-XVIII (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (^{o}C)	Air	22.0	19.0	16.0	22.0	21.5	23.0
	Water	21.0	17.5	12.0	17.0	20.0	22.0
pH (unit)		6.30	6.10	6.20	6.40	6.00	6.20
Conductivity (umhos/cm)		36.23	24.68	38.85	48.41	63.21	61.21
Dissolved oxygen (mg/l)		8.20	5.68	6.12	6.88	7.68	4.68
Carbon dioxide (mg/l)		5.20	3.40	4.60	7.20	6.60	7.80
Alkalinity (mg/l)		12.00	10.00	19.60	31.00	32.80	36.20
Phosphate (mg/l)		0.37	0.45	0.25	0.87	2.87	1.76
Nitrate (mg/l)		0.22	0.19	0.19	0.10	0.70	0.52
Silicate (mg/l)		4.27	5.09	5.27	4.39	7.02	5.27

Table-19b : Showing species composition and seasonal distribution of Cladocera in System-XVIII (August, 1976- June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Scapholeberis kingi	-	-	+	+	+	-
Family Bosminidae						
Bosmina longirostris	-	-	-	-	+	+
Family Chydoridae						
Chydorus sphaericus	-	-	-	+	+	+

Table-20a : Showing the seasonal changes in the physicochemical factors of System-XIX (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C)	Air	22.0	17.5	16.0	19.0	24.0	24.0
	Water	24.0	15.0	12.0	15.0	21.0	22.0
pH (unit)		6.7	5.8	8.1	7.0	6.4	6.6
Conductivity (umhos/cm)		35.18	30.98	60.90	65.20	67.20	67.30
Dissolved oxygen (mg/l)		6.80	5.60	9.12	8.20	6.32	6.40
Carbon dioxide (mg/l)		3.20	2.80	4.00	4.00	12.20	9.30
Alkalinity (mg/l)		10.00	14.00	39.20	37.60	30.20	27.20
Phosphate (mg/l)		0.81	0.64	-	0.36	0.75	0.42
Nitrate (mg/l)		0.05	0.31	0.11	0.21	0.43	0.39
Silicate (mg/l)		5.27	3.51	3.51	3.51	5.27	6.87

Table-20b : Showing species composition and seasonal distributior of Cladocera in System-XIX (August, 1976 - June, 1977)

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Bosminidae						
Bosmina longirostris	+	-	-	+	+	-
Family Chydoridae						
Chydorus sphaericus	+	+	-	+	+	-
Biapertura affinis	-	+	-	-	-	-
Pleuroxus similis	-	-	-	+	+	-

while the seasonal variations in the concentrations of phosphates, nitrates and silicates were 0 - 0.81 mg/l, 0.05 - 0.43 mg/l and 3.51 - 6.87 mg/l respectively.

Total number of cladoceran species recorded were 4, of which 3 belonged to Chydoridae and 1 to Bosminidae (Table-20b).

It may be pointed out here that Systems-XX to XXVIII were drained off for preparing them for fish culture in the month of December, 1976 and were refilled during the last week of March, 1977. Hence no observations could be made in these systems during those months.

System-XX :

Results of the analysis of physicochemical factors have been tabulated in Table-21a. The range of variations obtained during different seasons were as follows : Water temperature : 15 - 20°C, pH : 6.1 - 7.3, conductivity: 38.28 - 70.25 µmhos/cm, dissolved oxygen : 7.12 - 13.20 mg/l, carbon dioxide : 4.0 - 12.2 mg/l, alkalinity :12.00 -35.20 mg/l, phosphates : 0.88 - 3.25 mg/l, nitrates : 0.18 - 0.90 mg/l and silicates : 1.75 - 5.27 mg/l.

The Cladocera fauna was represented by a single member of Daphnidae and one member of Bosminidae, Chydoridae were not recorded (Table-21b).

Table-21a : Showing the seasonal changes in the physicochemical factors of System-XX (August, 1976 to June, 1977).

Factors		1976 Aug.	1976 Oct.	Dec.	1977 Feb.	1977 Apl.	1977 June.
Temperature (oC)	Air	24.0	17.0		20.0	24.0	
	Water	22.0	15.0		21.0	22.0	
pH (unit)		7.3	6.6		6.1	6.4	
Conductivity (umhos/cm)		47.25	38.28	System	70.25	49.90	
Dissolved oxygen (mg/l)		13.20	7.12	dry	7.44	8.20	
Carbon dioxide (mg/l)		4.00	4.40		9.60	12.20	
Alkalinity (mg/l)		15.20	12.00		35.20	30.12	
Phosphate (mg/l)		0.87	0.87		3.25	2.87	
Nitrate (mg/l)		0.39	0.90		0.18	0.30	
Silicate (mg/l)		1.75	1.75		5.27	5.27	

Table-21b : Showing species composition and seasonal distribution of Cladocera in System-XX (August, 1976- June, 1978)

Species	1976 Aug.	1976 Oct.	Dec.	1977 Feb.	1977 Apl.	1977 June
Family Daphnidae						
Scapholeberis kingi	+	-	System	-	-	
Family Bosminidae			dry			
Bosmina longirostris	+	+		+	+	

System-XXI :

The results of physicochemical analysis for this pond have been furnished in Table-22a. Water temperature was found to be less than that of air and ranged between 16.5° to 22°C. pH ranged between 5.40 to 6.50. Conductivity value fluctuated between 38.85 - 67-31 /umhos/cm while variations in the concentrations of dissolved oxygen, carbon dioxide, alkalinity, phosphates, nitrates and silicates were 3.36 to 9.40 mg/l, 3.20 - 8.40 mg/l, 17.6 - 58.00 mg/l, 0.40 -2.50 mg/l, 0.10 - 0.22 mg/l and 3.16 - 6.85 mg/l respectively.

A total of 5 species of Cladocera were recorded of which 1 belonged to Daphnidae, 1 to Bosminidae and 3 to Chydoridae as shown in Table-22b.

System-XXII :

Data on the physicochemical factors are shown in Table-23a. Water temperature, pH and conductivity values differed in different seasons and thus the range of variations were 16.50 - 22°C, 5.60 - 7.10 and 54.71 -108.15 /umhos/cm respectively. The variations in the value of dissolved osygen, carbon dioxide and alkalinity were found to be 7.60 - 8.40 mg/l, 2.60 - 3.60 mg/l and 15.20 - 52.40 mg/l. The dissolved nutrient substances such as phosphates, mitrates and silicates varied from 0.20 - 0.50 mg/l, 0.11 - 0.23 mg/l

Table-22a :Showing the seasonal changes in the physicochemical factors of System-XXI (August, 1976 to June, 1977).

Factors		1976 Aug.	1976 Oct.	Dec.	1977 Feb.	1977 Apl.	1977 June.
Temperature (°C)	Air	24.0	18.0			21.0	23.0
	Water	22.0	16.5			20.0	21.0
pH (unit)		6.5	5.4			6.4	6.4
Conductivity (umhos/cm)		46.99	38.85	System		67.31	65.31
Dissolved oxygen (mg/l)		9.40	5.08	dry		3.36	4.48
Carbon dioxide (mg/l)		5.00	3.20			8.40	8.20
Alkalinity (mg/l)		17.60	17.30			58.00	39.20
Phosphate (mg/l)		0.40	0.60			2.50	1.50
Nitrate (mg/l)		0.18	0.22			0.10	0.20
Silicate (mg/l)		3.27	3.16			6.85	5.27

Table-22b:Showing species composition and seasonal distribution of Cladocera in System-XXI (August, 1976 to June, 1977).

Species	1976 Aug.	1976 Oct.	Dec.	1977 Feb.	1977 Apl.	1977 June.
Family Daphnidae						
Simocephalus exspinosus	+	+			+	-
Family Bosminidae						
Bosmina longirostris	+	+	System		-	-
Family Chydoridae			dry			
Chydorus sphaericus	+	+			+	+
Biapertura affinis	+	+			-	-
Pleuroxus similis	+	+			+	-

Table-23a:Showing the seasonal changes in the physicochemical factors of System-XXII (August, 1976 to June, 1977).

Factors		1976			1977		
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (oC)	Air	20.0	18.5			21.0	23.0
	Water	22.0	16.5			20.0	22.0
pH (unit)		7.1	5.6			7.1	6.9
Conductivity (umhos/cm)		54.71	42.00			108.15	97.58
Dissolved oxygen (mg/l)		8.80	7.60			8.40	8.48
Carbon dioxide (mg/l)		3.20	3.00			3.60	2.60
Alkalinity (mg/l)		16.40	15.20			80.40	52.40
Phosphate (mg/l)		0.50	0.32			0.50	0.20
Nitrate (mg/l)		0.11	0.11			0.16	0.23
Silicate (mg/l)		3.76	3.51			5.27	3.87

Table-23b : Showing species composition and seasonal distribution of Cladocera in System-XXII (August, 1976 to June, 1977)

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Bosminidae						
Bosmina longirostris	-	+	System dry		+	+
Family Chydoridae						
Chydorus sphaericus	+	+			+	+

and 3.51 - 5.27 mg/l respectively.

Only 2 species of Cladocera belonging one each to Bosminidae and Chydoridae were recorded (Table-23b).

System-XXIII :

The physicochemical data have been furnished in Table-24a. Water temperature range during different seasons was 17°- 24°C. pH and conductivity varied between 5.40-7.35 and 38.33 - 78.96 /umhos/cm. Values of dissolved oxygen, carbon dioxide and alkalinity fluctuated within the range of 3.32 - 12.00 mg/l, 2.40 - 8.80 mg/l and 16.80 - 33.42 mg/l respectively. The concentrations of phosphates, nitrates and silicates varied from 0 - 5.00 mg/l, 0.2 - 0.25 mg/l and 3.51 - 6.85 mg/l respectively.

2 species of Daphnidae, 1 species Bosminidae and 1 species of Chydoridae were recorded from this pond (Table-24b).

System-XXIV :

Physicochemical data recorded in Table-25a shows that water temperature of this pond varied within the range of 15.5°- 23.00°C. pH and conductivity value ranged from 6.2 - 7.9 and 42.53 - 87.17 /umhos/cm respectively. The variations in the values of the rest of the factors were

Table-24a : Showing the seasonal changes in the physicochemical factors of System-XXIII (August, 1976 to June, 1977).

Factors		1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Temperature (°C)	Air	20.0	17.0			22.0	24.0
	Water	23.0	15.5			21.0	22.5
pH (unit)		7.35	5.40			6.20	6.40
Conductivity (umhos/cm)		67.53	38.33	System		78.96	59.96
Dissolved oxygen (mg/l)		12.00	7.32	dry		3.32	7.68
Carbon dioxide (mg/l)		2.40	4.20			8.80	7.56
Alkalinity (mg/l)		20.20	16.80			48.40	33.42
Phosphate (mg/l)		-	0.50			5.00	4.50
Nitrate (mg/l)		0.20	0.15			0.25	0.22
Silicate (mg/l)		3.87	3.51			6.85	5.27

Table-24b : Showing species composition and seasonal distribution of Cladocera in System-XXIII (August, 1976-June, 1977).

Species	1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June
Family Daphnidae						
Scapholeberis bingi	-	+		+	-	
Simocephalus exspinosus	+	+	System	-	-	
Family Bosminidae						
Bosmina longirostris	-	+	dry	+	+	
Family Chydoridae						
Chydorus sphaericus	+	+		+	+	

Table-25a : Showing the seasonal changes in the physicochemical factors of System-XXIV (August, 1976 to June, 1977).

Factors		1976			1977	
		Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C)	Air	21.0	17.5		23.0	26.0
	Water	22.0	15.5		22.5	23.5
pH (unit)		7.90	6.20		6.40	6.50
Conductivity (umhos/cm)		55.22	42.53	System	87.15	76.60
Dissolved oxygen (mg/l)		14.80	4.80	dry	6.72	8.60
Carbon dioxide (mg/l)		1.00	2.40		5.60	4.20
Alkalinity (mg/l)		17.60	17.20		47.80	29.20
Phosphate (mg/l)		0.34	0.18		1.63	0.92
Nitrate (mg/l)		0.15	0.16		0.40	0.39
Silicate (mg/l)		3.21	4.56		5.27	5.25

Table-25b : Showing species composition and seasonal distribution of Cladocera in System-XXIV (August, 1976 - June, 1977)

Species	1976			1977	
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Chydoridae						
Chydorus sphaericus	+	+	System	-	+
Biapertura affinis	+	-		-	-
Pleuroxus similis	+	+	dry	+	+

as follows :

Dissolved oxygen : 4.80 - 14.80 mg/l, carbon dioxide: 1.00-5.60 mg/l, alkalinity : 17.20 - 47.80 mg/l, phosphates: 0.18-1.63 mg/l, nitrates : 0.15 - 0.40 mg/l and silicates: 3.21-5.27 mg/l.

3 species of Chydoridae represented in cladoceran fauna (Table-25b).

System-XXV :

Data on the analysis of physicochemical factors have been given in Table-26a. With the exception of August, 1976, water temperature was always lower than that of air and varied from 17^{o}- 22.5^{o}C. pH and conductivity values were 5.70 - 7.60 and 58.28- 96.60 umhos/cm. While the range of dissolved oxygen, carbon dioxide and alkalinity were 6.48 to 9.20 mg/l, 2.80 - 4.40 mg/l and 20.00 - 54.20 mg/l respectively, the data on the dissolved phosphates, nitrates and silicates varied within their respective ranges of 0.66 - 2.75 mg/l, 0.10 - 0.15 mg/l and 3.87 - 7.37 mg/l.

2 species of Chydoridae belonging to the genera Chydorus and Pleuroxus were recorded from this pond (Table-26b).

System-XXVI :

Physicochemical data is given in Table-27a and the range in the fluctuations during different seasons have been

Table-26a : Showing the seasonal changes in the physicochemical factors of System-XXV (August, 1976 to June, 1977).

Factors		1976			1977	
		Aug.	Oct.	Dec.	Feb.	Apl. June.
Temperature (oC)	Air	21.0	22.0		21.0	23.0
	Water	22.0	17.0		20.5	22.5
pH (unit)		7.60	5.70		6.60	6.60
Conductivity (umhos/cm)		72.98	58.28	System	96.60	78.98
Dissolved oxygen (mg/l)		6.80	8.96	dry	6.48	9.20
Carbon dioxide (mg/l)		3.60	2.80		4.40	2.80
Alkalinity (mg/l)		28.00	20.00		54.20	35.24
Phosphate (mg/l)		0.63	0.66		2.75	0.97
Nitrate (mg/l)		0.15	0.10		0.10	-
Silicate (mg/l)		3.87	4.74		7.37	5.27

Table-26b : Showing species composition and seasonal distribution of Cladocera in System-XXV (August, 1976-June, 1977)

Species	1976			1977	
	Aug.	Oct.	Dec.	Feb.	Apl. June.
Family Chydoridae					
Chydorus sphaericus	+	+	System	+	+
Pleuroxus similis	+	+	dry	+	-

Table-27a : Showing the seasonal changes in the physicochemical factors of System-XXVI (August, 1976 to June, 1977).

Factors		1976 Aug.	1976 Oct.	1976 Dec.	1977 Feb.	1977 Apl.	1977 June.
Temperature (°C)	Air	22.0	22.0			21.0	23.0
	Water	23.0	20.0			22.0	23.0
pH (unit)		6.90	5.60			6.30	6.50
Conductivity (umhos/cm)		57.75	41.48			87.05	59.60
Dissolved oxygen (mg/l)		9.40	6.48		System	5.60	8.40
Carbon dioxide (mg/l)		3.00	3.40		dry	6.00	4.80
Alkalinity (mg/l)		16.40	17.60			44.80	22.80
Phosphate (mg/l)		0.75	0.25			1.88	0.92
Nitrate (mg/l)		0.35	0.37			0.39	0.32
Silicate (mg/l)		1.41	1.41			8.78	5.62

Table-27b : Showing species composition and seasonal distribution of Cladocera in System-XXVI (August, 1976- June, 1977).

Species	1976 Aug.	1976 Oct.	1976 Dec.	1977 Feb.	1977 Apl.	1977 June.
Family Daphnidae						
Scapholeberis kingi	-	+			+	-
Family Chydoridae				System		
Chydorus sphaericus	+	+		dry	+	+
Pleuroxus similis	+	+			-	-
Acroperus harpae	-	+			-	-
Camptocercus australis	-	-			+	+

as follows :

Water temperature : 17 - 23°C, pH : 5.60 - 6.90, conductivity: 41.48 - 87.05 /umhos/cm, dissolved oxygen : 5.60 - 9.40 mg/l, carbon dioxide : 3.00 - 6.00 mg/l, alkalinity :17.60-44.80 mg/l, phosphates : 0.25 - 1.88 mg/l, nitrates: 0.32-0.39 mg/l, and silicates : 1.41 - 8.78 mg/l.

Cladocera fauna of this pond has been represented by 4 species of Chydoridae and 1 species of Daphnidae (Table-27b).

System-XXVII :

Data on the physicochemical factors as given in Table-28a shows that the water temperature, pH and conductivity fluctuated within the range of 17°- 23°C, 5.60 - 8.10 and 14.70 - 112.15 /umhos/cm respectively. The seasonal fluctuations of other factors were as follows :
Dissolved oxygen : 6.88 - 10.40 mg/l, carbon dioxide: 2.20 to 3.80 mg/l, alkalinity : 27.20 - 115.20 mg/l, phosphates : 0.63 - 1.38 mg/l, nitrates : 0.05 - 0.32 mg/l and silicates : 2.11 - 5.62 mg/l.

2 species of Chydoridae, 1 species of Daphnidae and 1 species of Bosminidae were recorded from this pond as shown in Table-28b.

System-XXVIII :

The data on the analysis of physicochemical factors

Table-28a : Showing the seasonal changes in the physicochemical factors of System-XXVII (August, 1976 to June, 1977).

Factors	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Temperature (°C) Air	22.0	20.0		20.0	23.0	
Temperature (°C) Water	23.0	20.0		22.0	22.0	
pH (unit)	6.80	5.60	System	8.10	7.20	
Conductivity (umhos/cm)	100.38	86.10		147.00	112.15	
Dissolved oxygen (mg/l)	8.80	6.88	dry	8.40	10.40	
Carbon dioxide (mg/l)	3.80	3.80		-	2.20	
Alkalinity (mg/l)	28.40	27.20		115.20	86.60	
Phosphate (mg/l)	0.63	1.88		1.38	1.22	
Nitrate (mg/l)	0.15	0.05		0.30	0.30	
Silicate (mg/l)	3.87	2.11		4.21	5.62	

Table-28b : Showing species composition and seasonal distribution of Cladocera in System-XXVII (August, 1976-June, 1977).

Species	1976			1977		
	Aug.	Oct.	Dec.	Feb.	Apl.	June.
Family Daphnidae						
Simocephalus exspinosus	+	+		-	-	
Family Bosminidae			System			
Bosmina longirostris	+	+		+	-	
Family Chydoridae			dry			
Chydorus sphaericus	+	+		+	+	
Biapertura affinis	+	+		-	+	

Table-29a : Showing the seasonal changes in the physicochemical factors of System-XXVIII (August, 1976 to June, 1977).

Factors		1976 Aug.	1976 Oct.	1976 Dec.	1977 Feb.	1977 Apl.	1977 June.
Temperature (°C)	Air	22.0	22.0			22.0	24.0
	Water	22.0	20.0			21.5	22.0
pH (unit)		7.35	5.60			6.90	6.50
Conductivity (umhos/cm)		115.00	90.83	System		72.02	70.02
Dissolved oxygen (mg/l)		15.60	9.04	dry		8.88	10.00
Carbon dioxide (mg/l)		3.00	4.80			6.40	2.80
Alkalinity (mg/l)		22.00	21.20			39.20	35.12
Phosphate (mg/l)		0.65	0.86			2.75	1.92
Nitrate (mg/l)		0.25	1.15			0.22	0.28
Silicate (mg/l)		3.27	2.28			7.90	6.28

Table-29b : Showing species composition and seasonal distribution of Cladocera in System-XXVIII (August, 1976-June, 1977).

Species	1976 Aug.	1976 Oct.	1976 Dec.	1977 Feb.	1977 Apl.	1977 June.
Family Bosminidae						
Bosmina longirostris	+	+	System		+	-
Family Chydoridae						
Chydorus sphaericus	+	+	dry		+	-
Biapertura affinis	-	+			-	-

have been furnished in Table-29a. Water temperature varied between 17°- 22°C. pH and conductivity values ranged from 5.60 - 7.35 and 70.02 - 115.00 µmhos/cm. Concentration of dissolved oxygen, carbon dioxide and alkalinity ranged from 8.04 - 15.60 mg/l, 2.80 - 6.40 mg/l and 21.20 - 39.20 mg/l respectively. The range of variations in the nutrients such as phosphates, nitrates and silicates were 0.65 - 2.75 mg/l, 0.25 - 1.15 mg/l and 2.28 - 7.90 mg/l.

Cladocera fauna was found to be represented by 1 member of Bosminidae and 2 species of Chydoridae (Table-29b).

System-XXIX :

The data on the analysis of physicochemical factors are presented in Table-30a. The winter temperature was always more than that of air and ranged between 11.58- 24°C. pH and conductivity value were found to range between 6.16 - 6.87 and 32.35 - 80.34 µmhos/cm. Values of dissolved oxygen, carbon dioxide and alkalinity varied from 5.83 - 10.11 mg/l, 3.35 to 7.45 mg/l and 11.10 - 32.64 mg/l respectively. The range of variation in the nutrients such as phosphate, nitrate and silicates varied between 0.58 - 2.86 mg/l, 0.15 - 0.99 mg/l and 2.33 - 7.24 mg/l.

7 species of cladoceran species were recorded from this pond of which 2 species belonged to Daphnidae, 1 to Bosminidae and 4 to Chydoridae (Table-30b).

Table-30a : Showing the seasonal changes in the physicochemical factors of System-XXIX (August, 1976 to June, 1977).

Factors		1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Temperature (°C)	Air	24.0	22.0	14.5	19.0	21.0	22.5
	Water	24.0	20.0	11.5	15.0	18.5	21.5
pH (unit)		6.30	6.18	6.16	6.40	6.87	6.41
Conductivity (umhos/cm)		40.04	32.35	39.95	64.23	80.34	39.06
Dissolved oxygen (mg/l)		10.11	7.89	8.37	5.83	6.09	8.23
Carbon dioxide (mg/l)		7.13	3.35	7.45	5.00	5.40	5.40
Alkalinity (mg/l)		29.87	11.10	14.20	21.20	32.64	23.35
Phosphate (mg/l)		0.58	1.46	0.73	0.63	2.86	1.78
Nitrate (mg/l)		0.15	0.38	0.79	0.25	0.99	0.70
Silicate (mg/l)		3.95	3.43	7.24	3.22	3.62	2.33

Table-30b : Showing species composition and seasonal distribution of Cladocera in System-XXIX (August, 1976- June, 1977).

Species	1976 Aug.	Oct.	Dec.	1977 Feb.	Apl.	June.
Family Daphnidae						
Scapholeberis kingi	+	+	+	-	-	-
Simocephalus exspinosus	-	-	-	-	-	+
Family Bosminidae						
Bosmina longirostris	+	+	-	+	+	+
Family Chydoridae						
Chydorus sphaericus	+	+	+	+	+	+
Alonella excisa	-	-	-	+	+	-
Pleuroxus similis	-	+	+	-	-	-
Acroperus harpae	-	+	-	-	-	-

PLATE-XIV

Camera lucida diagrams of :

a. Daphnia lumholtzi (parthenogenetfc female)
b. Daphnia lumholtzi (male)
c. Daphnia sp.
d. Ceriodaphnia cornuta
e. Scapholeberis kingi
f. Simocephalus serrulatus
g. Simocephalus vetulus
h. Simocephalus exspinosus

PLATE - XIV

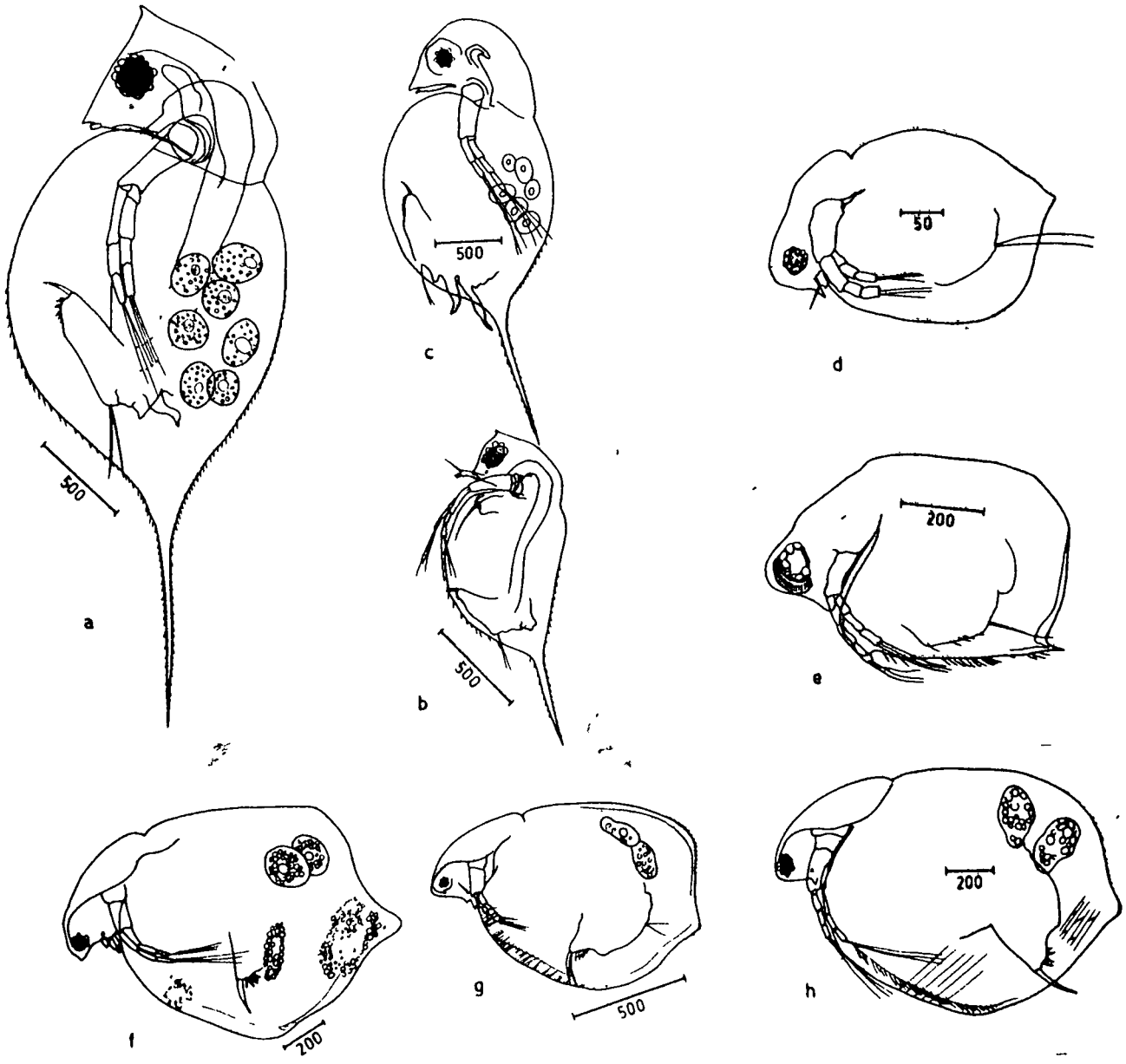


PLATE-XV

Camera lucida diagrams of :

a. Sida crystallina
b. Diaphanosoma excisum
c. Moina micrura (parthenogenetic female)
d. Moina micrura (male)
e. Macrothrix laticornis
f. Ilycryptus spinifer
g. Bosmina longirostris

PLATE - XV

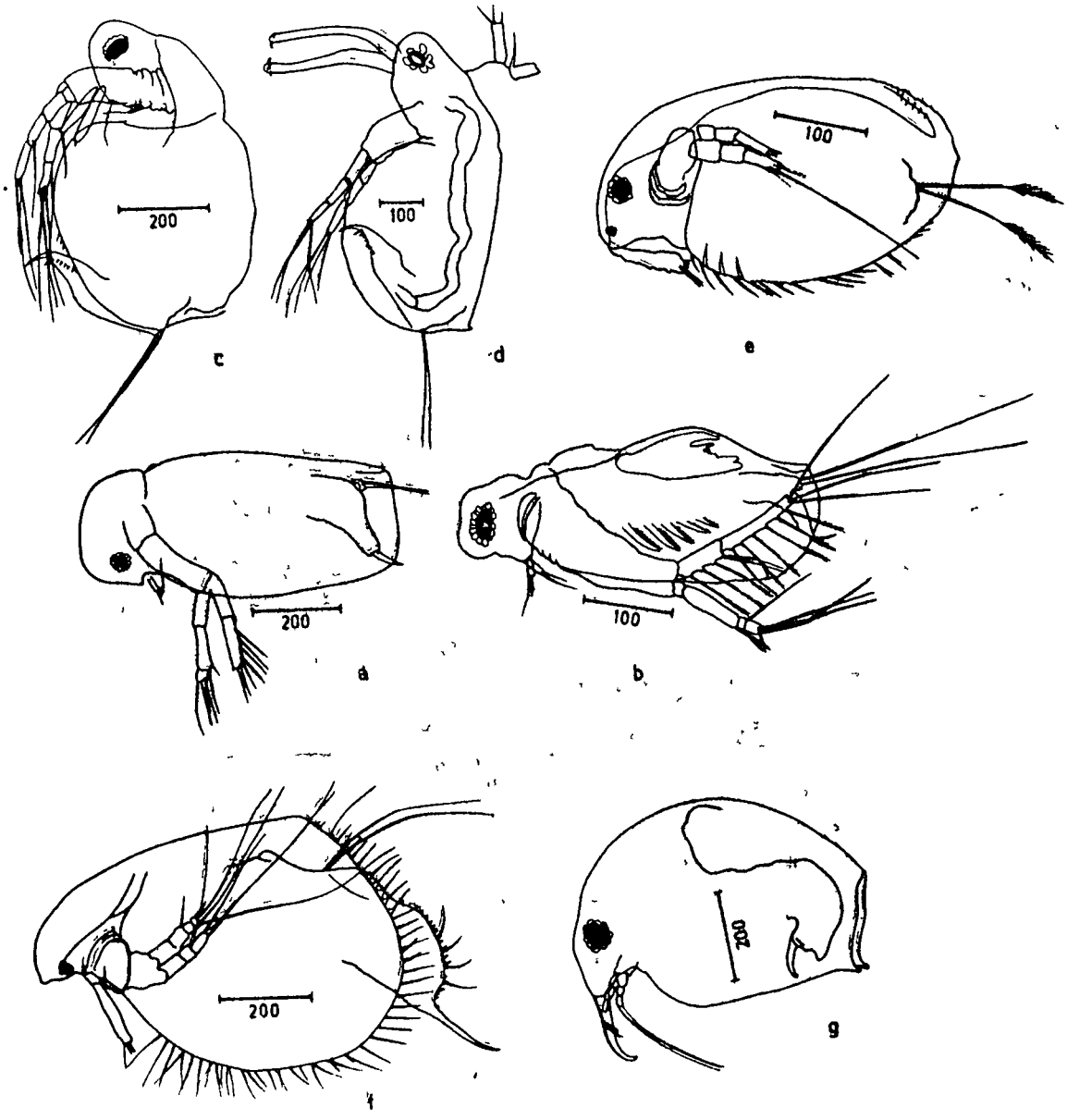


PLATE-XVI

Camera lucida diagrams of :

a. Chydorus sphaericus
b. Pseudochydorus globossus
c. Biapertura affinis
d. Camptocercus australis
e. Pleuroxus similis
f. Acroperus harpae
g. Alonella excisa
h. Alonella nana
i. Alona sp.
j. Leydigia australis ceylonica

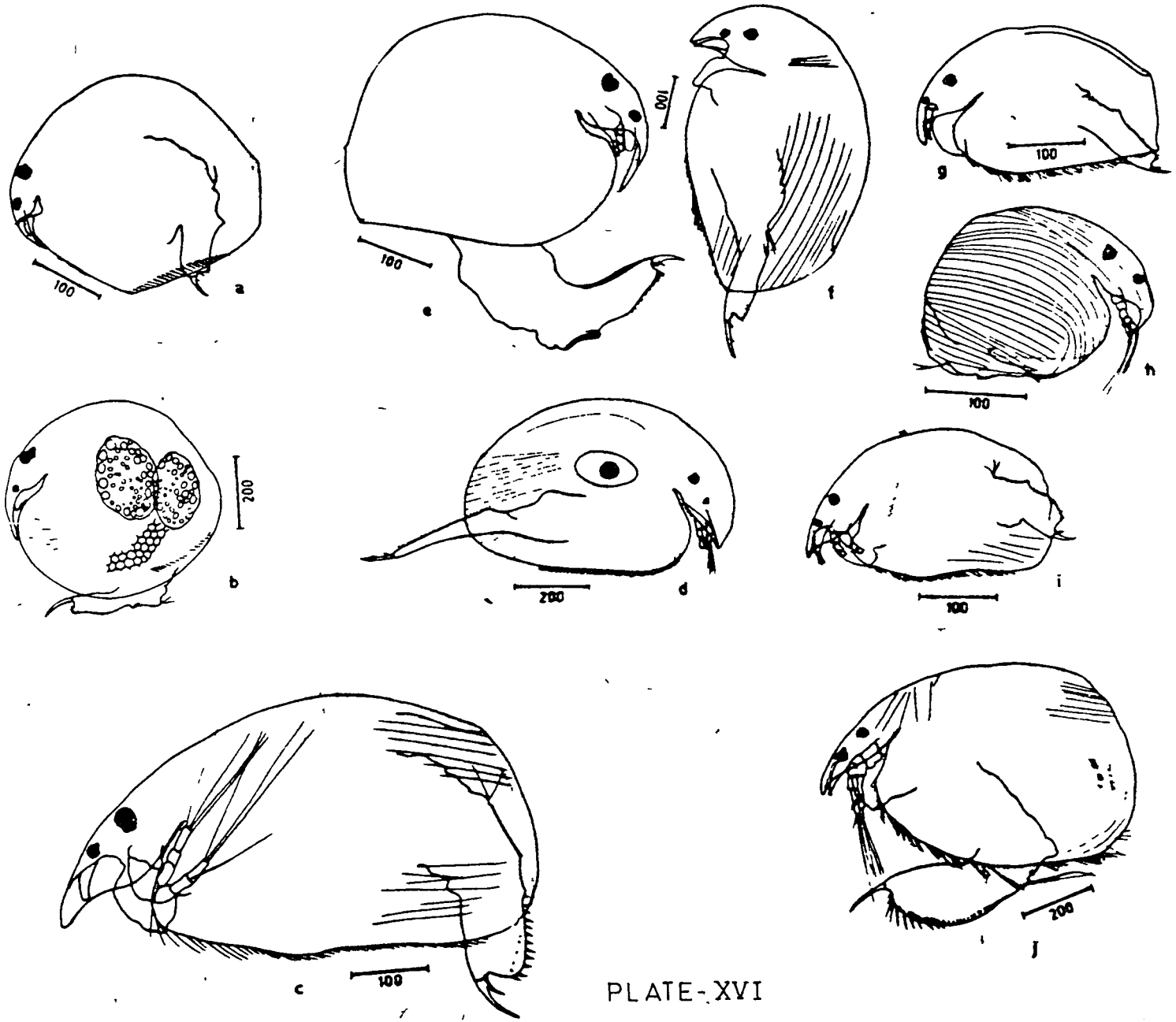


PLATE-XVI

PLATE - XVI

PART-I

D I S C U S S I O N

During the present investigations a total of 29 aquatic habitats have been surveyed and the results are presented herewith. The main objective of this survey is to understand the physicochemical milieu of these systems with special reference to the cladoceran fauna. As shown earlier, these systems are of varying size, origin and depth. Nevertheless, all these habitats are located within a radius of about 10 Km and most of them are shallow artificial impoundments but for a few. The different physicochemical factors studied during this investigation are size and depth of ponds, temperature, pH, electrical conductivity, dissolved oxygen, free carbon dioxide, alkalinity, phosphate, nitrate and silicate as summarised in Table-31.

In view of their proximity to each other and as evidenced by somewhat similar physicochemical properties as seen during this study (Table-31), it was thought appropriate to discuss the results together for all the systems. The size of the ponds under present investigations varied from a minimum of 22.00 to a maximum of 23800.00 sq m. Inspite of this wide range of diversity of size, no definite size-dependent variation in physicochemical properties of the systems could be recorded. The depth, on the other hand, varied between 0.50 -3.85 m which also apparently did not change the physicochemical properties of the surface waters. In the present context, all the systems thus being of more or less same nature and origin, effects of

depth and size was probably better reflected in the cladoceran fauna than in the quality of water.

The water temperature generally ranged between 8^{o}- 12^{o}C in December/February to a maximum of 22^{o} - 24^{o}C during June/August (Table-31), thereby showing an extensive range of about 16^{o}C during the annual cycle. This range of temperature coupled with rainfall and humidity makes it possible to divide the annual cycle into more or less four seasons namely, Spring (March - April), Summer - Rainy (May - August), Autumn (September - November) and Winter (December - February). However, due to the variations in the exact onset of monsoon, there is slight overlap in the range of different seasons. The present conditions observed in these altitudinal ponds are unlike those of Indian plains where only minimum seasonal variations in temperature are noted as in other tropical situations (Ruttner 1965, Michael 1968, 1969, Vijayaraghavan 1971, Nasar and Dutta-Munshi 1974). A lack of wide temperature difference was also noted in the altitudinal reservoirs of Nilgiri Hills in South India (Sreenivasan 1968). However, the range of temperature was lower in Nilgiri Hills reservoirs when compared to adjacent water bodies of the surrounding plains (Vijaya-raghavan 1971). Such a trend of narrow temperature range was also reported for Brazilian tropics as seen from the data of Zago (1976). The altitudinal lakes and ponds of Kashmir in North India (Das 1970), exhibit similar trend as that of the

present studies although still lower minimum temperatures were always noted. Recently Prabhavathi and Sreenivasan (1977) while dealing with the ecology of warm water zooplankton in 28 ponds and lakes from South India did not record much seasonal fluctuations in water temperature, although the highland ponds showed comparatively lower temperature than those situated in lowlands. Thus the seasonal fluctuations of temperature observed in the present study seem to resemble more, the low and highland aquatic biotopes of the temperate regions (Reid and Squibb 1971, Anderson 1971, Forsyth and McColl 1975), than most habitats of the tropical plains as discuss earlier. It must, however, be stated that the temperature regimes in these altitudinal ponds are somewhat intermediate between the truly tropical and temperate regions. It is most likely that the location of these ponds at moderately higher altitude (1600 m) on a plateau probably determine this pattern of seasonal fluctuation.

With a single exception, all the systems studied were of acidic nature for a major part of the investigations, the pH value falling within a range of 5.50 - 6.90. There were occasional shifts towards the alkaline range in some systems which can be attributed to the artificial application of lime for fishery practices. Responses to such treatments were short-lived due to dilution through constant seepage and heavy rainfall. In most of other Indian works (Loc. cit.) a general pattern of alkanine pH with moderate to higher alkalinity is noted as classified by Prabhavathi and Sreenivasan (1977). The Shillong

ponds, on the other hand, appear to fall under the slightly acidic category characteristic of low productive waterbodies (Hutchinson 1957). Electrical conductivity values of these impoundments were again low ranged between 14.70 -126.00 /umhos/cm with a single exception. It is well known that in any aquatic habitat , the conductivity is dependant upon the geological conditions of the substratum and the incoming dissolved electrolytes from the surrounding watershed. These ponds being located in heavy rainfall area (Table-1,Fig.-1) lose their organically rich upper strata of soil and are left with only the coarse sandy or rocky substrata. As a result of this constant erosion year after year, these systems have probably reached a significantly low level of conductivity values. A similar situation has been reported from Nilgiri Hills of South India (Sreenivasan 1968) where out of the two reservoirs one always showed a low conductivity range. The recent origin of the present systems also appears to influence the conductivity values since older systems seem to show comparatively high conductivity values. As an example, in System-V which is relatively older, the conductivity value ranged from 79.50 to 173.00 /umhos/cm which has also a thick muddy bottom with heavy macrophytic growth showing a shift towards eutrophication.

Dissolved oxygen ranged between 3.20 - 15.60 mg/l in the different ponds. This variation is in part due to difference in sampling time since diurnal variation in oxygen concentration due to photosynthetic utilisation is a well known phenomenon.

The range of values of dissolved oxygen recorded here is found to be similar to the reports for other systems in India. The carbon dioxide concentration in the surveyed ponds ranged between 1.00 - 18.00 mg/l and was recorded on all occasions suggesting a low utilisation of this compound for algal production, whereas in other parts of India complete absence of carbon dioxide is often recorded suggestive of higher algal production (Michael 1968, 1969, Vijayaraghavan 1971, Nasar and Dutta-Munshi 1974, Prabhavathi and Sreenivasan 1977). Anderson (1971 , 1974) on the other hand, recorded from few alpine, subalpine and mountain lakes and ponds from Canada, the presence of carbon dioxide throughout the season. However, a detailed diurnal study of the carbon dioxide dynamics may reveal a better picture of its utilisation in these systems. With one exception, the total alkalinity values ranged between 7'60 - 58'00 mg/l with the total absence of carbonate alkalinity and only bicarbonate contributing to these values. These low values of total alkalinity due to bicarbonate only, are indicative of a high free carbon dioxide - low pH - low alkalinity buffer system prevalent in these waterbodies. But in System-XXVIII, which is a fish pond, a maximum alkalinity of 115.20 mg/l was noted following the addition of lime. In the light of the above findings with low alkalinity values and acidic pH, these systems could be classified among 'low alkalinity' systems as suggested by Prabhavathi and Sreenivasan (1977). Such system with low alkalinity values,

though not commonly found in the plains of India (Michael 1968, 1969, Vijayaraghavan 1971, Nasar and Dutta-Munshi 1974), they are not altogether uncommon from the hill areas (Sreenivasan 1968).

The phosphate concentration in these ponds was generally high and ranged from 0 to 2.0 mg/l in majority of the surveyed systems though the highest value recorded was 5.5 mg/l. This is unlike those of other Indian situations where phosphate was usually recorded in very low concentrations (loc. cit.). With few exceptions, these ponds being much shallow in nature retain on an average a water level of 0.50 -0.70 m during the winter season (December - February). This shallow depth combined with a higher rate of evapotranspiration can be one of the plausible reasons for the enhanced phosphate concentrations. Moreover, in some of these impoundments phosphate concentration could have remained high due to yearly fertilisation with Superphosphates and occasional addition of cowdung. Further, Shillong planteau is situated adjacent to lime mines where lime stone containing pebbles of phosphate can occur as shown in Florida waters by Reid and Squibb (1971). This might result in higher concentration of phosphate in these neighbouring staguant water bodies. However, direct geochemical evidences are needed to establish this relationship. Phosphate being one of the important ingredients of algal metabolism, its higher concentrations in these waters is also suggestive of low utilisation by algae. Nitrate concentration was 0.00 -1.00 mg/l

in majority of the ponds though still higher values were recorded at certain instances. System-II showed a range of 1.35 - 3.50 mg/l which is the highest value recorded. This pond was regularly fertilized by cowdung. Ricebran and Oil-cake were also added at intervals as supplementary feed for the stocked fishes. It is thought that the addition of these fertilizers is undoubtedly responsible for this high value. A comparison with other Indian waters shows that the nitrate values recorded in the present studies seem to be higher than that of most systems in the plains of India (loc.cit.). Silicate content in the present studies ranged between 1.41 - 15.80 mg/l. Though 15.80 mg/l was the maximum value, 28 out of 29 surveyed ponds had an upper limit of less than 10.00 mg/l. In general, other Indian habitats show a comparatively higher value of silicate concentration (loc.cit.). The single system mentioned above with 15.80 mg/l is fed by an underground spring which may be responsible for the higher concentration. As silica content is known to be mainly dependant on the geology of the watershed and the substratum, the differences between these systems and those of other parts of India can be attributed to corresponding substrate differences. Further, such variations in silicate content in aquatic systems may also be due to biotic activities such as the presence of diatoms within a given water body (Ruttner 1965; Hutchinson 1957).

In conclusion it may be said, that the Shillong ponds are characterized in general by acidic pH, low conductivity, alkalinity and silicates with moderately high phosphates and nitrates. This is in contrast to the alkaline pH, high conductivity, alkalinity and silicates and low concentrations of nitrates and phosphates typical of impoundments of Indian plains. Once again, it may be pointed out that all the ponds in the present study are of recent origin varying from a few months to a maximum of 15 years with a single exception, the Ward Lake, known to have been constructed in 1895 from a marshy swamp with two main underground springs. Further, all these systems are also under the influence of human interference and are very shallow in nature with a few exceptions, Nevertheless, as discussed above, the geological, meteorological and altitudinal factors also make them different from the impoundments from other parts of India. As such, they can be categorized, in general, as 'cold polymictic' type of lakes, a term coined by Hutchinson and Löffler (1956) which includes tropical mountain lakes that have almost a continuous thermal circulation. This terminology, though broadly applicable to these shallow ponds, it is basically to define large, deep lake systems and hence it seems more appropriate to include them under the category of 'subtropical' type of aquatic systems as generalized by Ruttner (1963) for habitats in the neighbourhood of tropics. Such a view point also justifies the the intermediate nature of these systems in terms of moderate

temperature regimes and their location at an equally moderate altitude.

In the present studies Brook's (1959) classification of the order Cladocera has been broadly followed who divided this group into two suborders, Haplopoda and Eucladocera with a total of 8 families. Recently the genera Moina and Moinodaphnia have been grouped under a separate family Moinidae by Goulden (1968). For the present purpose this new family has been included with Brook's classification thereby bringing the total to 9 families. In Indian a total number of 8 families have been reported so far with approximately 90 species (Michael, unpublished). In the present study a total of 23 species belonging to 6 families have been recorded (vide Species list). Of these, 10 species belonged to Chydoridae, 7 to Daphnidae, 2 each in Macrothricidae and Sididae while Bosminidae and Moinidae were represented by one species each. Such a preponderance of members of the family Chydoridae was also observed in Andhra Pradesh in South-Eastern India where 15 out of the total of 23 species belonged to Chydoridae (Michel, unpublished). Eight species of Chydoridae and 8 species of Daphnidae were recorded from Nainital in Northern India (Michael, unpublished). Biswas (1971) reported 14 species of Chydoridae from the state of Rajasthan in the North-Western India. Brehm's (1936) studies from Northern India and Niligiri Hills of South India revealed a good representation of

Chydoridae, though Daphnidae was most dominant. Recent works of Das et al (1969, 1970) from Lake Alpather and other Kashmir lakes situated at an altitude of more than 12,000 ft showed a fair representation of chydorid fauna. However, the Dal Lake of Kashmir (Das and Akhtar 1970) is reported to have only 7 species of Cladocera belonging to the suborder Eucladocera of which only 2 belonged to Chydoridae. The chydorid dominance was also reported in the recent faunal list of Cladocera from Shillong (Patil 1976). When Quotient of Similarity (QS) (Sørensen 1948) was worked out between the earlier species lists and the present study, no strong resemblance emerges (QS: Ca 0.40) (Table-32), although Kashmir fauna as reported by Brehm (1936) shows relatively higher similarity index with present findings (QS: 0.44). The higher similarity index of Kashmir fauna with the present species composition may be due to the high altitude location of both these areas. That faunal composition could be influenced by altitude or latitude has already been suggested in the works of Carl (1940), Reid and Olive (1958) and Decosta (1964).

It is well known that the zooplankton as a whole, are causally related to the limnological parameters in any aquatic ecosystem (Michael 1969). In the present study it has been seen that practically no significant difference is met with in the faunal composition of different systems as they have more or less the same physicochemical characteristics but for a few exceptions (Table-31). Moreover, their location within a total

Table-32 : Showing Sørensen Index values (QS) for cladoceran fauna between Shillong (present study) and other parts of India.

Study area	Total No. of species	No. of similar species with present record	SQ value	Source
Kashmir (Northern India)	22	10	0.44	Brehm (1936)
Punjab (Northern India)	7	2	0.13	Brehm (1936)
Ladakh and Rapshu (North-Eastern India)	10	3	0.20	Brehm (1936)
Nainital (North-Western India)	17	8	0.40	Michael (unpublished)
Rajasthan (Western India)	45	6	0.14	Biswas (1971)
Nilgiri Hills (South India)	10	3	0.20	Brehm (1936)
Andhra Pradesh (South-Eastern India)	22	6	0.27	Michael (unpublished)
Shillong (North-Eastern India)	23	-	-	Present study

area of 5 - 10 Km makes it unlikely to have any significant effect on the species composition as seen from the lists of Cladocera.

Temperature has been suggested as an important factor in the regulation of phyto and zooplankton populations (Patalas 1965, Asch and Kingsbury 1972, Taylor 1972). However, the slight variations in temperature (1^{o}- 2^{o}C) between the different systems during the present study is unlikely to change faunal composition though temperature has its own influence on these cladoceran populations. The pH ranges differed very little between the systems and is of little consequence to the cladoceran species composition, although Carter (1971) found a relationship of pH to the occurrence of three species of Crustacea. DeCosta (1975), on the other hand, did not observe any such relationship between the hydrogen iron concentration and the Cladocera in Cheat Lake, USA. Studies of Kring and O'Brien (1972) showed that under prolonged exposure to altered pH levels Daphnia adapt themselves efficiently under experimental conditions. The continued occurrence of certain species in some of the systems probably reflect such adaptation to changing pH values in different seasons even under natural conditions. During the present survey, oxygen values were found always to be more than 3 mg/l in all the systems and hence could not bhave had a limiting effect on the cladoceran species, although laboratory studies of Corni and Strainer (1976) have revealed that a concentration below 3 mg/l influence the feeding rate

in Daphnia . It has been pointed out that carbon dioxide is seldom of value to evalute the limiting effects in aquatic habitats (Schindler 1971). However, both carbon dioxide and alkalinity are well known to influence the phytoplankton bloom which in turn could affect the zooplanktonic microcrastacea (Michael 1965, 1968), since minute phytoplankton and epiphyton from the food of these organisms (Vaas and Van-Oven 1959, Michael 1968). As mentioned earlier, the present systems showed low alkalinity values with carbon dioxide always present in varying concentrations. While these factors could have influenced the phytoplankton dynamics, the precise role of these factors on the cladoceran species composition cannot be ascertained. Phosphates, mitrates and silicates are important nutrient known to influence the growth and reproduction of algae (Rigler 1956, Michael 1969, Lannergren 1975) although the concept of absolute limiting effect of any of these nutrients is probably not easy to assess on any group of organisms (Lannergren 1975). However, Asch and Kingsbury (1972) established an inverse correlation of nitrate-nitrogen and phosphate to the cladoceran and copepod populations. It seems evident that while these various physicochemical factors could influence the physiology and metabolism of Cladocera, their role on the species diversity and distribution cannot be established for certain from the present studies.

Among the 23 cladoceran species listed here, Chydoridae was the numerically dominant group. Of the 10 chydorid species

Chydorus sphaericus was recorded in 26 out of the 29 ponds. This shows that they are evidently the most adaptive species to a variety of habitats, inspite of each lake or reservoir being unique with its own chemical, physical and planktonic characteristics as pointed out by Ruttner (1963). Chydorus sphaericus is also one of the most widely distributed species (Carl 1940, Patalas 1964, 1971) though it is often reported to occur at low densities (Anderson 1971). In the present studies it was noted that this species often occurred in ponds which were devoid of vegetation although many a times were found among the littoral vegetation in other ponds. This was also noted by Anderson (1971) who, therefore, placed it as a limnetic species without differentiating it as a littoral or planktonic form. Further, in view of the small and shallow nature of most of these ponds Chydorus sphaericus could well be categorised as a 'heleoplankton', a terminology used for species inhabiting ponds (Hutchinson 1967). Occurrence of C.sphaericus in System-II which was only a few months old raises an interesting question about its entry as a sole cladoceran species which could be accidentally seeded by agencies such as mammals or birds as suggested by Maguire (1963), Proctor (1964) and Anderson (1971). Distribution and occurrence of other species of Chydoridae like Alonella nana, Alonella excisa, Pleuroxus similis, Acroperus harpae, Camptocercus australis, Biapertura affinis and Alona sp. were always confined to the littoral vegetation which they apparently use both for food and shelter. Absence of Chydoridae

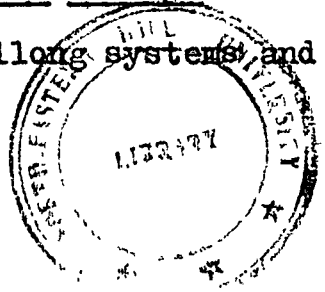
from System-III which was completely devoid of any vegetation adds additional support pointing towards their littoral habit. It is likely that the negligibly low number of weed fishes in these ponds could have also favoured their successful growth as the former are known to prey ypon the Cladocera (Korinek 1959, Brooks and Dodson 1965).

Among the Bosminidae, Bosmina longirostris is an widespread species (Brandlova et al 1972, Carter 1971, Anderson 1974) which appeared in majority of the ponds under study. Its appearence generally coincided with the fertilisation of the ponds suggesting its preference to eutrophicated waters as was observed by Edmondson et al (1956) and Zago (1976) who considered this species to be an indicator of trophic status. Moina micrura, on the other hand appeared in System-III and IV. Both these systems have greater limnetic regions and depth which could have been responsible for the occurrence of this truly planktonic form. However, their bried period of occurrence needs to be explained. It is likely that the fish fauna in these ponds was largely responsible for their disappearence (Brooks and Dodson 1965), though one another factor could explain the absence of Moina is the high phosphate content which is known to have a limiting effect (Asch and Kingbury 1972). The members of the Macrothricidae are generally believed to be benthic in their habit. In the present study Macrothrix laticornis appeared in a shallow weedy pond where there was practically no limnetic zone. Ilyocryptus spinifer was another macrothricid species which appeared in two ponds

whose bottom were of a muddy nature. It, therefore, seems that the distribution of both these species appears to be regulated by the nature of the bottom. These two ponds with comparatively turbid waters and being older than those of other systems evidently served as ideal habitats for these creeping forms (Fryer 1974).

Family Daphnidae was the second dominant group which was represented by Daphnia lumholtzi, Daphnia sp., Scapholeberis kingi, Ceriodaphnia cornuta and 3 species of Simocephalus namely S. exspinosus, S. vetulus and S. serrulalus. The two species of Daphnia appeared one each in System IV and XII. It is of interest to note that, though both these systems were sampled at weekly intervals, these species were recorded for only a very short duration. Daphnia lumholtzi developed significant numbers in the month of April 1977 and their morphology showed considerable variations suggestive of cyclomorphosis (Green 1967). The lake in which Daphnia lumholtzi occurred, being the largest with open water seems to have served as a suitable habitat for this species. It may also be said that this lake has a dense population of the common carps (Cyprinus carpis carpio L) along with other indigenous species of carp. While the alteration in the helmet length (vide infra , Part-II) could be attributed to the rise in temperature in keeping with the classical buoyancy theory (Wesenburg-Lund 1926, Wolterect 1913), it is equally tempting to hazard the predation theory of Brooks and Dodson (1965) to

explain the phenomenon in view of these dense carp populations. However, more work is needed in this direction in view of the differing opinions put forth to explain helmet formation (Wesenburg-Lund 1926, Brooks and Dodson 1965, Hebert 1975). Appearence of Daphnia sp. in System-XII only for a brief period is also of considerable interest. Aquatic birds were introduced into this ponds for recreational purposes and hence the appearence of this species seems to be a chance occurrence having been seeded by these migratory birds which are known to carry resting eggs or ephippia of Cladocera (Proctor 1964, Anderson 1971). This view is further strengthened by the fact that though this system was investigated at weekly intervals for a period of 18 months, this Daphnia sp., was never recorded for a second time except during April 1977. Furthermore, this species does not resemble the two species of Daphnia appearing commonly in India, Daphnia lumholtzi Sars and Daphnia carinata King. Again, their sudden disappearence may be due to their failure to build a substantial population in this environment probably not conducive to their continued survival and propagation. Scapholeberis kingi, a littoral species (Anderson 1971) appeared in 13 out of the 29 systems. This may be due to their remarkable adaptation of hanging from the surface film of water (Fryer 1956) and occupying the epineustic zone as a result of which they face the least competition for existance at the air-water interface. Ceriodaphnia cornuta also appears to have a limited distribution in Shillong systems and was



recorded in only System-IV (Ward Lake). On the other hand, in the plains of India, this species is well represented forming successful populations (Michael 1962, Murugan 1975). It is possible that the large size of System-IV could have offered a suitable environment for this species. Among the 3 species of Simocephalus, S.exspinosus which occured in 11 ponds was invariably found to inhabit the thick submerged weed beds of Rotala rotundifolia and Ammania multiflora. The other two species, S. serrulatus and S. vetulus were also found to occupy the same niches. These species are thus strictly littoral in habit and it is certain that the distribution of these weeds largely controlled their presence or absence in a given pond. However, further detailed study is required to establish this association more accurately.

Results of the present study also reveal the nonoccurrence of more than one species of the same genus in a particular habitat, though not without exceptions which find a parallel in the works of Pennak (1957) in Americana reservoir. Even, in cases where two or more species of the same genus appeared, one of them always seems to dominate in population density as already observed by Zago (1976).

It is apparent from Table-31 that when these systems are arranged in an ascending order of size, the highest number of Cladocera is found to occur in the largest system namely, Ward Lame. A similar size-dependant species diversity was

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Table-31 : Showing the annual ranges of the physicochemical factors in the 29 systems along with the number of species recorded under different cladoceran families.

(Systems arranged in ascending order of size)

System	Size (Sq.)	Depth (m)	Water temperature	pH (Unit)	Conductivity (Umhos/cm)	Dissolved oxygen (mg/l)	Free carbon dioxide (mg/l)	Alkalinity (mg/l)	Phosphate (mg/l)	Nitrate (mg/l)	Silicate	Cladoceran families						Total Cladoceran sp.
												*Sid. 1 (No.)	*Dap. 2 (No.)	*Mon 3 (No.)	*Bos. 4 (No.)	*Mac 5 (No.)	*Chy. 6 (No.)	
I	22	0.5	8.0 -21.0	5.5-6.90	77.7- 94.5	7.4-10.4	3.8- 9.0	10.6-28.0	0.4-0.6	1.2-5.0	4.3- 6.1	-	-	-	-	-	2	2
III	30	3.8	8.0 -22.0	6.8-7.9	52.3-126.0	8.2-13.6	2.4- 4.8	23.8-48.0	1.0-4.0	0.2-3.6	4.9-15.8	-	1	1	1	-	-	3
XVI	62	1.5	12.0 -22.0	5.9-6.5	28.9- 70.1	5.0- 7.3	3.0- 9.2	7.6-29.6	0.4-3.0	0-3.4	2.6- 7.9	-	1	-	1	-	4	6
*XX	84	1.5	15.0 -20.0	6.1-7.3	38.3- 70.2	7.1-13.2	4.0-12.2	12.0-35.2	0.9-3.2	0.7-3.6	1.7- 5.3	-	1	-	1	-	-	2
VI	85	0.7	10.0- 23.0	6.0-6.7	20.0- 26.6	3.2-10.7	4.8- 9.6	14.2-26.3	0.8-4.1	0.0-0.4	3.5- 7.0	-	1	-	-	-	3	4
XV	90	1.5	12.0- 22.0	5.3-6.6	31.5- 70.1	6.6- 8.4	3.2- 9.2	8.2-29.3	.0-1.7	0.1-6.2	1.8- 5.8	-	1	-	-	-	2	3
XXIX	102	1.5	11.5- 24.0	6.2-6.9	32.3- 80.3	5.8-10.1	3.3- 7.4	11.1-32.6	0.6-2.9	0.6-3.1	2.3- 7.2	-	2	-	1	-	4	7
XIII	108	0.5	10.0- 24.0	5.5-6.9	51.4-101.2	4.0- 9.6	4.2- 9.0	16.0-50.2	1.0-5.5	0.5-1.5	2.6- 6.6	-	1	-	1	-	2	4
IX	115	0.7	11.0- 24.0	5.5-6.9	34.6- 65.1	4.1-10.2	3.2-11.4	11.0-43.2	0-3.8	0.1-2.6	2.6- 7.9	-	1	-	-	-	1	2
*XXV	129	1.5	17.0- 22.5	5.7-7.6	58.3- 96.6	6.5- 9.2	2.8- 4.4	20.0-54.2	0.7-2.7	0.1-0.1	3.9- 7.4	-	-	-	-	-	2	2
*XXII	143	1.5	16.5- 22.0	5.6-7.1	54.7-108.1	7.6- 8.4	2.6- 3.6	15.2-52.4	0.2-0.5	0.1-0.9	3.5- 5.3	-	-	-	1	-	1	2
V	186	0.7	10.0- 24.0	5.7-6.2	79.5-173.5	8.2- 9.8	4.6-18.2	14.0-39.6	1.2-3.7	0-1.8	3.2- 7.0	-	2	-	-	1	5	8
*XXIII	197	1.5	17.0- 24.0	5.4-7.3	38.3- 79.0	8.3-12.0	2.4- 8.8	16.8-32.4	0.0-5.0	0.2-1.0	3.5- 6.8	-	2	-	1	-	1	4
*XXVIII	198	1.5	17.0- 22.0	5.6-7.3	70.0-115.0	8.0-15.6	2.8- 6.4	21.2-39.2	0.6-2.7	0.2-4.6	2.3- 7.9	-	-	-	1	-	2	3
*XXVI	201	1.5	17.0- 23.0	5.6-6.9	41.5- 87.0	5.6- 9.4	3.0- 6.0	17.6-44.8	0.2-1.8	0.3-1.5	1.4- 8.8	-	1	-	-	-	4	5
VII	202	0.6	10.0- 24.0	5.4-6.9	15.7- 22.7	6.8- 9.7	4.2-11.8	8.4-17.6	0-3.6	0-0.5	2.6- 8.4	-	-	-	-	-	4	4
X	212	0.9	12.0- 24.0	5.5-7.1	46.2- 74.5	7.4- 9.5	4.8-12.4	12.4-36.4	0.1-3.9	1.2-5.6	4.4- 6.1	-	1	-	-	-	1	2
*XXVII	240	1.5	17.0- 23.0	5.6-8.1	14.7-112.1	6.9-10.4	2.28 3.8	27.2-41.2	0.6-1.4	0.0-1.3	2.1- 5.6	-	1	-	-	-	2	3
*XXIV	328	1.5	15.5- 23.0	6.2-7.9	42.5- 87.1	4.8-14.8	1.0- 5.6	17.2- 47.8	0.2-1.6	0.1-1.6	3.2- 5.3	-	-	-	-	-	3	3
II	393	1.5	10.0- 23.0	5.4-6.1	50.9- 78.1	5.3-11.3	5.2-15.6	9.2- 29.3	0.6-1.0	5.4-140	4.4- 9.1	-	-	-	-	-	1	1
*XXI	527	1.5	16.5- 22.0	5.4-6.5	38.8- 67.3	3.4- 9.4	3.2- 8.4	17.6- 58.0	0.4-2.5	0.2- 07	3.2- 6.8	-	1	-	1	-	3	5
XIV	675	3.0	11.0- 24.0	5.3-6.7	68.2- 91.1	4.3-10.1	5.0- 8.2	16.2- 40.2	0.0-2.6	0.4-1.4	4.0- 7.0	-	2	-	1	-	4	7
XII	1075	0.7	12.0- 23.0	5.9-6.4	55.8- 84.9	4.7- 9.0	9.6-13.5	14.2- 39.0	0.8-2.2	0.4-3.5	4.8- 9.2	-	3	-	1	-	5	9
**VIII	1737	2.0	12.0- 23.0	6.3-6.8	31.0- 53.0	5.3- 9.7	3.2- 6.4	25.2- 39.0	-	-	-	-	3	-	1	-	5	9
XVIII	1865	1.5	12.0- 22.0	6.0-6.4	24.7- 63.2	4.7- 8.2	3.4- 7.8	10.0- 36.2	0.2-1.8	0.1-2.7	4.3- 7.0	-	1	-	1	-	1	3
XIX	1939	1.5	12.0- 24.0	5.8-7.0	31.0- 67.3	6.6- 9.1	2.8-12.2	10.0- 39.2	0-0.8	0.1-1.7	3.5- 6.9	-	-	-	1	-	3	4
XVII	2447	1.5	12.0- 22.0	5.3-6.4	26.8- 62.9	4.4- 7.6	3.2- 6.2	10.0- 33.6	0-0.8	0.1-4.0	4.2- 5.8	-	-	-	-	-	3	3
XI	2538	0.6	12.0- 24.0	5.3-6.2	58.8- 73.8	5.0-12.3	4.2-14.8	16.0- 38.4	0-2.5	0.4-1.5	5.3- 9.1	-	1	-	1	-	3	5
IV	2380	3.4	16.0- 25.0	6.2-6.6	66.7- 76.2	6.6-10.5	4.2- 9.9	17.7- 30.6	0.6-2.0	1.2-6.1	1.4- 3.5	2	6	1	1	1	8	19

* Studied for 8 months only. ** Studied for 6 months only.

[1]*Sididae [2]*Daphnidae [3]*Moinidae
[4]*Bosminidae [5]*Macrothricidae
[6]*Chydoridae

reported by Pennak (1957) while studying the mountain lakes of Colorado. Moreover, the Ward Lake being the oldest, probably provides a relatively stable environment for the growth of Cladocera. It must, however, be added that two ponds of relatively small size (Systems-V and XXIX) also showed a greater species diversity as compared to a few larger ponds. This suggests that the species number, while to a certain extent dependant on the size of the habitat, the total complexity of an aquatic biotope offering the largest number of ecological niches will untimately decide the species composition (Anderson 1974). One of the smaller systems mentioned above was a shallow cemented pond whose high diversity of species can only be explained as being brought in form surrounding water sources through diverted inflow.

The dominance of littoral species in almost all the present systems is likely to be due to the abundant littoral vegetation in most of the habitats. The decrease or absence of such vegetation has been shown to effect, particularly the chydorid populations (Corni and Strainer 1976). In the present investigations also littoral populations were found to be affected by the removal of marginal weeds in Ward Lake where most of the species declined in number while some of them even totally disappeared (Vide infra, Part-II).

PART-I

S U M M A R Y

A survey was conducted of 29 altitudinal aquatic ecosystems in and around Shillong area in order to understand their physicochemical milieu with special reference to the cladoceran fauna. These systems were man-made in origin with varied size, shape, depth, contour, age and as well as vegetation. Further, some of these systems were astatic while one of them was a newly dug pond.

The results obtained on these different impoundments have revealed similarity in their physicochemical properties and hence discussed together. Their sizes varied between 22.00 to 23800.00 sq m while the variation in depth ranged from 0.50 to 3.85 m. A wide temperature range of about 16°C was noted during the annual cycle. The temperature regime seemed somewhat intermediate between the truly tropical and temperate situations. Four seasons could be delimited based on temperature and humidity though with certain degree of overlappling brought about by the onset of monsoon.

With a single exception, all the rest of the systems were acidic in nature with the pH varying between 5.50 to 6.90. Occasional shifts towards alkaline range as a result of heavy fertilisation were evident though shortlived. Low conductivity values could be attributed to the general geology of this region as well as the recent origin of these impoundments. Dissolved oxygen concentration fluctuated depending upon differences in sampling time while presence and the amount of carbon dioxide

at all seasons seemed to be related to low algal productivity. The low alkalinity values observed apparently reflect a high carbon dioxide-low pH-low alkalinity buffer system. Higher concentrations of phosphates and nitrates recorded during the present study were likely to be brought about by artificial fertilisation, shallow nature and close proximity to lime mines as well as low utilisation by indwelling biota. Similarly the lower silicate level in contrast to aquatic biotopes of Indian plains probably indicate low utilisation through algae and due to associated geological conditions.

Based on the present survey, it may be concluded that in general, these aquatic biotopes of Shillong are characterised by low levels of pH, conductivity, alkalinity and silicates. On the other hand, these systems are characterised by moderately high phosphate and nitrate values. In view of the observed physicochemical characteristics, these impoundments are assigned to " subtropical type of aquatic systems" following the classification of Ruttner (1963).

A total of 23 species of Cladocera belonging to 6 families were recorded in the present study. Of these 10 belonged to the family Chydoridae, 7 to Daphnidae and 2 each in Sididae and Macrothricidae while Bosminidae and Moinidae contained one species each. This preponderence of chydorid Cladocera was similar to the recent records from other parts of Indian plains.

No strong resemblance in terms of QS (Sørensen index) was

seen between the Shillong fauna and other Indian reports though the Kashmir fauna showed a comparatively higher index value when compared with the present findings. Further, no significant difference in the faunal composition has been met within different systems. Continued occurrence of certain species through the season were apparently due to the suitability of the habitat. Concentration of oxygen in any of the systems never reached the critical value reported to have any limiting significance.

Chydorus sphaericus was the most widely distributed species appearing in 26 out of the 29 systems surveyed. It made its appearence even in ponds completely devoid of any vegetation. Possibilities of the accidental seeding of C . sphaericus . through agencies like mammals and birds were also speculated to explain its presence in one of the systems. Other chydorid species were restricted to weed beds.

The only bosminid species, Bosmina longirostris was present in majority of the systems and its appearence coincided with the fertilisation of the ponds. Moina micrura was confined to ponds with relatively deeper limnetic zones. Members of Macrothricidae were recorded in ponds with rich vegetation and thick muddy bottom, while species of Simocephalus were strictly confined to littoral vegetation, although other daphnid genera like Daphnia and Ceriodaphnia appeared in impoundments with larger limnetic zones. Appearence of a Daphnia sp. which differed from other species of this genus recorded from India

has been discussed in the context of their occurrence for a very brief period. Scapholeberis kingi was the most widely distributed daphnid in Shillong ponds.

Effect of manual removal of weeds on cladoceran fauna was observed. Further, usually nonoccurrence of more than one species of the same genus was noted, through when present, one of them always doninated. The different study ponds, when arranged in the ascending order of size, the largest harboured the maximum number of species. However, the age of the impoundment also seemed to influence the species composition. Causes for the relatively higher species diversity in a few small ponds have been discussed. Lastly, appearence of larger number of littoral species has been discussed in the light of their vegetational associations.

PLATE-I



SYSTEM-I



SYSTEM-II

LIBRARY

PLATE-II



SYSTEM-V



SYSTEM-VI

PLATE-III



SYSTEM-VII



SYSTEM-VIII

PLATE-IV



SYSTEM-IX



SYSTEM-X

PLATE-V



SYSTEM-XI



SYSTEM-XIII

PLATE-VI



SYSTEM-XIV



SYSTEM-XV

PLATE-VII



SYSTEM-XVI



SYSTEM-XVII

PLATE-VIII



SYSTEM-XVIII

18



SYSTEM - XIX SYSTEM - XX

PLATE-IX



SYSTEM - XXI & XXII



SYSTEM - XXIII SYSTEM - XXIV

PLATE-X



SYSTEM-XXV



SYSTEM-XXVI

PLATE-XI



SYSTEM-XXVII



SYSTEM-XXVIII

PART-II

ECOLOGY AND BIOLOGY OF THE NATURAL POPULATIONS OF CLADOCERA

PART-II

INTRODUCTION

The status of cladoceran research in India is yet largely confined to their taxonomy and regional distribution as shown earlier in the review of literature. Detailed studies relating to the biology of different species of Cladocera are still lacking in India. The importance of such studies need not be overemphasised as basic understanding of the biology is not only of academic value but also of applied importance as these organisms constitute important food items for culturable fishes. However, Michael (1962) attempted for the first time in India to relate different field parameters to the laboratory observations in Cladocera. Subsequently laboratory studies on the development and life cycles of Cladocera have been undertaken in different parts of India (Michael 1962, Murugan and Sivaramakrishnan 1973, 1976, Murugan 1975, 1975a, Murugan and Venketaraman 1977, Bhattacharya *et al* 1979). While the above investigations were mostly confined to individual cladoceran species observed under laboratory conditions, a holistic approach of relating the laboratory observations to actual field situations is still a much felt lacuna. Keeping this in view, the present work has been designed to study the cladoceran species in three systems with varying hydrography as well as with different vertebrate inhabitants. These systems were : (i) Ward Lake, the largest among Shillong lentic habitats with a relatively stable environment, stocked mostly with common carp (*Cyprinus carpio*); (ii) a small cemented nursery pond totally devoid of any vegetation and

(iii) a pond with limited marginal vegetation and turbid water into which both residential and migratory aauatic birds have been introduced.

This this Part of the present study deals with the morphometry, vegetational associations, physicochemical and biological properties of these systems along with biological aspects of the natural populations of Cladocera such as seasonal occurrence and distribution, population structure, size group composition, sex ratio and fecundity studies (eggs/brood). These parameters have been studied at weekly intervals for a total period of 18 months and were aimed to gain insight into the structure and dynamics of natural populations of Cladecera as obtained under different habitat conditions.

PART-II

MATERIAL AND METHODS

The materials for the present study have been collected from 3 freshwater impoundments within the town limits of Shillong. The three systems chosen were (i) Ward Lake, a permanent system stocked with large number of fishes mainly the carps (ii) a small cemented nursery pond and (iii) a pond within the Lady Hyderi Park. The last mentioned pond is situated in the precincts of a local zoo where a variety of aquatic birds have been kept for recreational purposes. All these three systems were sampled every Saturday between 08.00 and 10.00 hours. Methods employed for the study of merphomentry of these systems and the physicochemical properties namely, temperature, pH , conductivity , dissolved oxygen, free carbon dioxide, alkalinity, phosphates, nitrates and silicates have been detailed in Part-I.

Plankton samples were collected with the help of a conical plankton net fabricated out of No.25 xxx bolting silk. Fifty litres of water collected with the help of a plastic bucket of 5 litre capacity was filtered through the net equipped with a receiving test tube of 50 ml capacity. Now the tube with the plankton collected was removed gently from the net and Formalin was added slowly to obtain a final concentration of about 5% . The sample was then lebelled, and stoppered with a rubber stopper and carried to the laboratory for further analysis. A qualitative sample was collected and fixed in Lugol's Iodine solution for the indetification of phytoplankton. This gross qualitative analysis facilitated

easy indetification of phytoplankton during the study of quantitative samples. Counting of plankton was done with the help of a counting cell of 1 ml capacity (Sedgwick-Rafter model).

The preserved plankton sample in the test tube was poared into a round bottom glass crucible. Organic debris when present, were slowly lifted with the help of a pair of forceps and washed in distilled water to dislodge adhering organism. Using a wide monthed glass dropper, the sample was thoroughly mixed up and a portion of this was pipetted into the counting cell. A coverslip was placed diagonally so that with the addition of sample it rotates slowly due to surface tension and seals off the cell. A filter paper was used to remove excess water and now the cell was ready for counting. Since 1 ml of the sample represented 1 litre of pond water filtered, counting of total number of organisms in the cell directly gave the count per litre. For larger zooplankton the entire cell was scanned, while for the ennumeration of smaller forms like rotifers, protozoans and phytoplankton, only 100 out of the 1000 squares were counted. These squares were, however, selected at random. Whenever an organism was in low numbers, counting was done in the entire cell. On certain occasions, due to heavy bloom of phytoplankton, the sample had to be diluted suitably to facilitate counting. The results thus obtained were multiplied by the dilution factor to arrive at the number of units/litre as shown below:

(No. of organisms/100 squares) x 10 x a = No. of

organis/litre were 'a' denotes times of dilution. In case of filamentous and colonial algae, the entire or part of filament/ colony was treated as one unit.

Size measurements of 100 animals selected at random were made using a binocular microscape and an oculometer graduated into 100 divisions of 10 u each. These size measurements when arranged in an ascending order fell into size clusters somewhat indicative of instars. Such groupings are not altogether unknown and had been used for instar analysis in Cladocera (Frey 1973). For categorising different size groups in the present study, such size clusters were used wherever possible.

Fecundity study was made by counting actual number of eggs in each female under the microscope. For calculating regression correlations a small computer (DCM, Microsystem 1120 model) was used. Similarity index was calculated following Sørensen index as detailed in Part-I.

PART-II

GENERAL DESCRIPTION AND PHYSIOGRAPHY OF SYSTEMS UNDER STUDY

The impoundments selected for the study of the different biological parameters of cladoceran species were:

(1) WARD LAKE : This recreational lake is situated in the heart of Shillong town, adjacent to the Shillong Club complex on the one side and the Raj Bhawan on the other (Fig.2, System-IV). This is an artificial lake, more or less semicircular in shape (Fig.3). It was consttucted out of a marshy place with two main underground springs by Sir William Ward, the then Chief Commissioner of Assam, in the year 1894. A dam has been erected on one side to store the inflowing water in addition to that of the underground spring water. Total area of this lake was 23800 sq m with a maximum depth of 6.0 m. The average depth was found to be 3.40 m. The maximum length and breath were 333 m and 75 m respectively. The average total volume of water was 80920 m^3. Three inlets lead into this system while a single outlet carries constantly the excess water from the lake. However, the dam has a switch-gate, mainly for the purpose of draining off of the lake. The main inlet (Fig.3) carries the sewage water from the surrounding habitation to an isolated part of the lake located on the south-eastern 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 and it courses from the esatern side. The third inlet joins from the north-eastern side carrying the

sewage water. This inlet is functional only during the rainy seasons. The outlet, on the other hand, is situated on the western side of the lake (Fig.3) near the dam (Iron bridge).

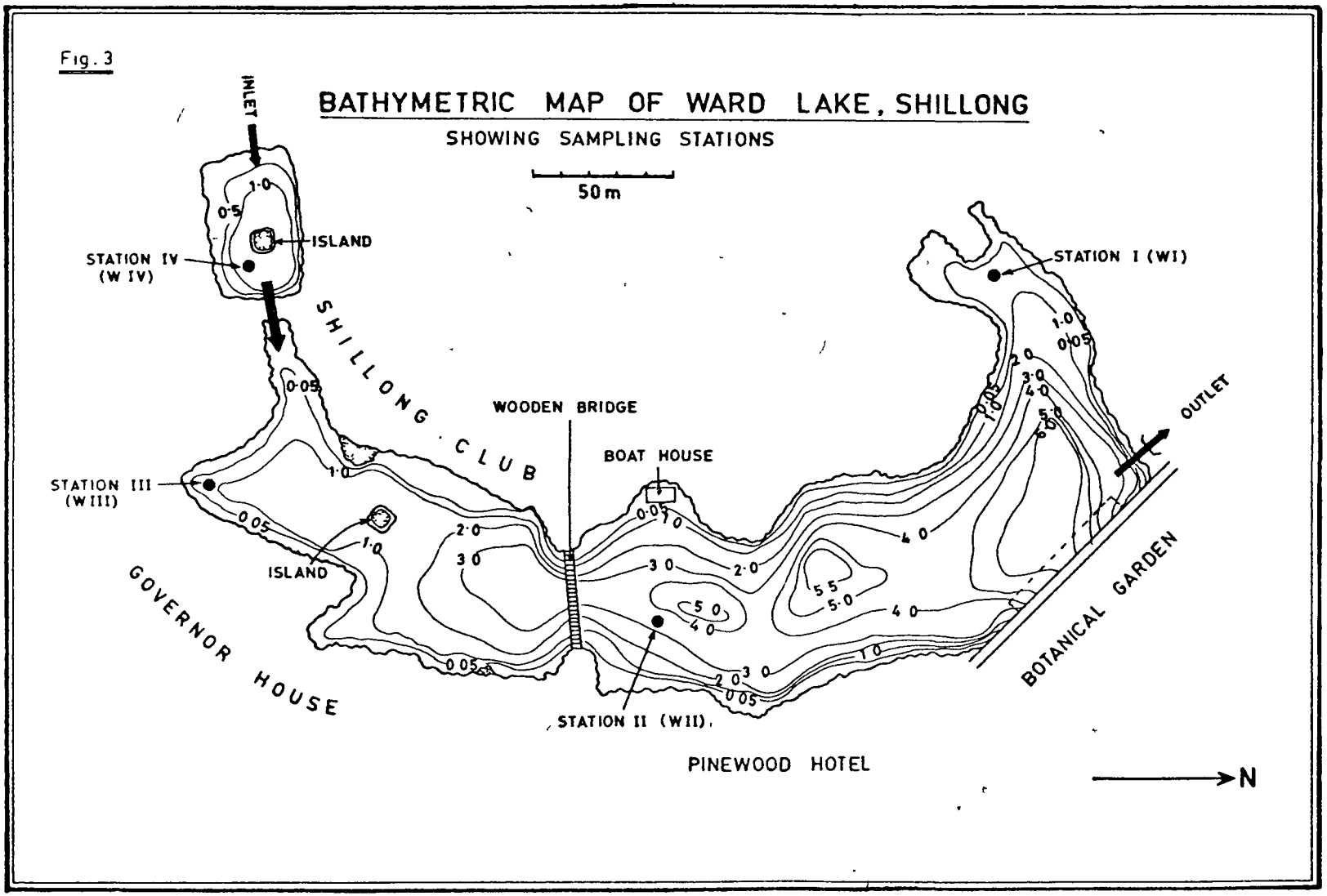
This lake has been extensively and successfully used for fish culture by the Department of Fisheries, Government of Meghalaya, and the stocked fishes mainly belong to the common carp (Cyprinus carpio) and a few other Indian species of carps. At times species of Channa has also been observed near the margins.

This lake being the largest among the lentic systems of Shillong (Table-31), it has been divided into four study sites (Stations) based on the availability of maximum variety of Cladocera species. Care was also taken to select stations so that they cover the entire area of the lake. Thus Station-I was located at the south-western corner of the lake; Station-II was located almost at the middle of the lake; Station-III on the north-eastern corner while Station-IV was located on the south-eastern corner of the lake.

Station-I was approximately 1.0 m in depth and was somewhat weedly. The vegetation associated with this station were: Rotala rotundifolia, Nymphaea sp., Lindernia sp., Polygonum sp., Polygonum hydropiper, Oxalis corymbosa, Alternanthera sessilis, Galinsoga parviflora and species of Utricularia.

Station-II being located on the open water zone, was devoid of any vegetation and the depth recorded was 5.50 m.

Fig. 3


BATHYMETRIC MAP OF WARD LAKE, SHILLONG
SHOWING SAMPLING STATIONS
50 m
INLET
ISLAND
STATION IV
(W IV)
SHILLONG CLUB
WOODEN BRIDGE
BOAT HOUSE
STATION I (WI)
OUTLET
STATION III
(W III)
ISLAND
GOVERNOR HOUSE
BOTANICAL GARDEN
STATION II (WII)
PINEWOOD HOTEL
N

Station-III another weedy station was approximately 0.80 m deep with the associated vegetation such as Ageratum conyzoides, Polygonum sp., Erigeron sp., Nymphaea sp., Rotala rotundifolia, Ischaemum rugosum, Polygonum hydropiper and Ammania sp.

Station-IV was located on the isolated portion resembling a somewhat rectangular shaped pond. This pond was 53 m in length and 35 m in breath 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. Inspite of frequest deweeding of this portion, the vegetation could hardly be checked from encroachment into the main water body. The following plants could be identified from this pond:
Rotala rotundifolia, Nymphaea sp., Lindernia sp., Polygonum hydropiper, Oxalis corymbosa, Alternanthera sessilis, Galinosoga parviflora and species of Utricularia.

(II) FISH DALE POND : This is a small nursery pond located in the Fish Dale complex of the Fishery Department, Government of Meghalaya, at the Fruit's Garden locality (Fig.2, System-XXIX). This is an artificial cemented pond with a flat bottom. The shape of the pond is approximately square with the length and breath being 12.50 m and 8.23 m respectively. Though the actual depth is 1.50 m, the pond retained a water level of about 0.95 m during the study period. Thus the approximate volume of water

was 97.74 m^3 while the total area was 102.88 sq m. During the winter months water from a surrounding stream was drained into this pond. The fish frys included mainly those of the common carp (Cyprinus carpio). Before commencement of the present envestigations, the pond was processed by liming and addition of fertilisers like superphates and nitrates. It was not refertilized during the 18 months study period. This system was totally devoid of any vegetation.

(III) LADY HYDERI PARK POND: This is an artificial impoundment situated inside the campus of Lady Hyderi Park located at the Barrik locality (Fig.2, System-XII). This pond is rectangular in shape with a flat bottom having 2 parts, one being shallower than that of the other. Water flows into it through an inlet. While the outlet is almost nonfunctional throughout greater part of the year. The total area of the pond was 1075.08 sq m , the average length and breath being 105.40 m and 10.20 m respectively. The average depth recorded was found to be 0.90 m. Thus the total volume of water in the pond was 967.57 m^3.

This pond had a limited vegetation and the water was extremely turbid throughout the study period. The aquatic vegetation recorded from this pond was:
Rotala rotundifolia, Eragrostis gangetica, Ischaemum rugosum, species of Digitaria and Agaretum conyzoides.

This pond is utilized by the park authorities to maintain aquatic birds for recreational purposes. This pond was never used for fish culture purposes.

PLATE-XII



WARD LAKE (SYSTEM-IV OF PART-I)

PLATE-XIII



FISH DALE POND (SYSTEM-XXIX OF PART-I)



LADY HYDERI PARK POND (SYSTEM-XII OF PART-I)

PART-II

RESULTS

I. THE ENVIRONMENT

WARD LAKE

Physicochemical properties

Biological properties

FISH DALE POND

Physicochemical properties

Biological properties

LADY HYDERI PARK POND

Physicochemical properties

Biological properties

The following account deals with the physicochemical and biological parameters of the lake and ponds investigated for a period of 18 months at weekly intervals. However, the weekly data have been compiled and represented as mean monthly values. This present study commenced from the month of September, 1976 and continued till February, 1978 extending over a total period of 18 months. The information thus gathered has been presented as the physicochemical and biological characteristics. The biological properties have been dealt under the broad categories of phytoplankton and zooplankton and exeept for Cladocera most of the other organisms recorded in this study have been dealt with upto family/group level.

I. WARD LAKE :

A. PHYSICOCHEMICAL PARAMETERS :

In this system, four sampling stations have been chosen and are referred to as WI, WII, WIII and WIV. The data obtained from each station have been dealt with separately. The different physicochemical properties included in this study were air and water temperature, pH, ionic conductivity, dissolved oxygen, free carbon dioxide, alkalinity, phosphates, nitrates and silicates. The results on the analysis of the above physicochemical properties of the four stations of Ward Lake have been presented in Tables-33, 34, 35 and 36 and depicted in Figs.4, 5, 6 and 7.

Temperature :

Air : The seasonal fluctuations of the air temperation in

Station XI have been graphically represented in Table-33. The atmospheric temperature showed a decline from September to December, 1976 from 22.85°C to 17.25°C. From January, 1977 the air temperature slowly rose from 17.75°C to 25.75°C in the month of March, 1977. In the month of April, 1977 air temperature reached 21.9°C and increased further to reach the maximum value of 26.50°C in the month of October, 1977. From November, 1977 onwards, there was a steady decline in air temperature reaching the value of 12°C in the month of February, 1978 which marked the end of the study period. January and February, 1977 showed higher values of temperature than that of succeeding year (17.75°C, 19.0°C and 13.00°C and 12.0°C respectively). The seasonality of atmospheric temperature in Station-II (WII), III(WIII) and IV(WIV) have been graphically shown in Tables-34, 35 and 36 respectively. It is seen that these values did not show much difference from that of Station-I.

Water : Surface water temperature followed the same trend as that of air and the highest value recorded in Station-I(WI) was 25.76°C in the month of July, 1977. Lowest value of surface water temperature in WI was 12°C, recorded in the month of January, 1978. In September, 1976, water temperature was slightly more than that of air and the two readings were 23°C and 22.85°C respectively.

Surface water temperature in WII, WIII and WIV showed the same nature of fluctuation and highest and lowest values in

all cases were in the month of July.1977 and January, 1978 respectively. However, in all these stations the lowest value was 11°C in contrast to 12°C in Station-I. The surface water temperature was never more than that of the air in these stations. Water temperature of the four stations have been shown in Figs. 4, 5, 6 and 7.

Hydrogen-ion-concentration (pH) :

pH value of water of Station-I showed very little fluctuations during the study period and was always acidic in nature. The highest value recorded was 6.84, in the month of March, 1977 and lowest value was 6.16 observed during October, 1976. Seasonal fluctuations have been represented in Fig.4.

Station-II(WII) pH showed almost the same type of seasonality and in this station also highest value was recorded in March, 1977 (6.88) as seen in Station-I. But the lowest value was observed in the month of October, 1977 with 6.30. However, September, 1976 also showed higher pH value of 6.43 (Fig.5).

Station-III of Ward Lake, on the other hand, showed the highest value of 6.70 in the month of December, 1977 while a comparatively lower value was observed in March, 1977 (6.59). The lowest pH value was 6.13 recorded in the month of May, 1977 (Fig.6).

Station-IV of Ward Lake showed (Fig.7) the highest pH value of 6.75 in the month of December, 1977 like that of Station-III, while lowest value recorded was in January, 1978 with the value of 6.01.

Conductivity :

The conductivity values showed a tendency for greater fluctuation than the pH. Seasonal fluctuations in conductivity of Station-I has been shown graphically in Fig.4. The pupper and lower limits of conductivity values were 88.20 /umhos/cm and 55.55 /umhos/cm recorded during the months of December, 1977 and November, 1977 respectively. Excepting on these two occasions the conductivity values ranged between 59 - 76 /umhos/cm.

WII, an open water station, showed two distinct maxima (Fig. 5) in conductivity and the highest value was recorded in the month of August, 1977 (103.47 /umhos/cm). The other higher value was 88.41 /umhos/cm recorded in December, 1977 while the lowest value was 59.40 /umhos/cm in November, 1977.

In Station-III the trend of conductivity values followed the pattern as that of Station-I. The highest and lowest values observed during November, 1977 and December, 1977 were 89.15 and 60.50 /umhos/cm respectively.

These values showed the maximum fluctuations in Station-IV (Fig.6) with two distinct maxima. The first higher value was 122.43 /umhos/cm recorded in April, 1977. From February, 1977 onwards the conductivity value showed an increasing trend to reach the first maxima of 96.73 /umhos/cm in April, 1977. From May, 1977 the conductivity readings showed a steady decline to reach the lowest value of 74.94 /umhos/cm in July, 1977 and rose again showing another maxima in December, 1977 (104.16 /umhos/cm).

Like other stations the value during November, 1977 was comparatively lower with 75.44 umhos/cm.

Dessolved oxygen (D.O.) :

In Station-I the highest dissolved oxygen concentration was recorded in the month of July, 1977 (10.7 mg/l), while the lowest value was in October, 1977 when the concentration was 5.25 mg/l (Fig.4). Oxygen concentration increased from September, 1976 onwards and reached a maxima in March, 1977 (9.34 mg/l), only to become low in April, 1977 (7.66 mg/l) and rose again to reach the peak in July, 1977 with a record of 10.70 mg/l. January, 1978 showed a comparatively higher value (9.32 mg/l) of dissolved oxygen.

In Station-II, the same seasonal trend was maintained (Fig.5) although the peak in July, 1977 was comparatively low (9.46/l). The lowest dissolved oxygen concentration was recorded during the month of September, 1976 (5.06 mg/l). In January, 1978 oxygen value rose to 9.20 mg/l showing a second maxima.

Station-III also followed the same trend of fluctuation in dissolved oxygen and the lowest value was recorded in September, 1976 (4.52 mg/l), while the highest value was in July, 1977 with 9.89 mg/l (Fig. 6).

Among all the stations of Ward Lake, Station-IV showed the highest maxima value of 17.76 mg/l recorded in the month of July, 1977. The general trend of oxygen curve (Fig.7) was

similar to those of other stations and the lowest amount of oxygen recorded was 4.60 mg/l during September 1976. As in other stations the value of D.O. was comperatively low in the month of March, 1977, but November, 1977 showed a comparatively higher value of 10.64 mg/l.

Free carbon dioxide :

In Station-I of Ward Lake, maximum amount of free carbon dioxide was recorded in May, 1977 with a value of 10.90 mg/l, the lowest being 2.40 mg/l recorded in January, 1978. This was in contrast to that of the values in January, 1977 when 10.25 mg/l carbon dioxide was recorded. Again in February, 1978 there was an upward trend in contrast to the lowering tendency observed during February, 1977.

Station-II, the open water station, did not show any major difference in the concentration of free carbon dioxide (Fib.5). The highest was found in August, 1977 (7.16 mg/l) and the lowest value of 2.20 mg/l was seen in January, 1978. In May, 1977 a moderately higher value of 6.60 mg/l was again recorded.

Station-III exhibited the same trend in carbon dioxide fluctuations having two maxima, the highest concerntration was observed in May, 1977 (11.10 mg/l), while the other maxima of 10.00 mg/l was witnessed in August, 1977. The lowest concentration was observed in January, 1978 with the value of 2.60 mg/l.

In Station IV (Fig.7) March and August, 1977 showed the two maxima and of these the highest value was that of August, 1977 (15.93 mg/l). There was a third maxima observed in the month of March, 1977 exhibiting a concentration of 8.95 mg/l. In contrast to all other preceeding stations the lowest value was in December, 1976 with 3.25 mg/l. Both January, 1977 and 1978 showed distinct rising tendency in the amount of free carbon dioxide.

Alkalinity :

Alkalinity readings presented in Tables- 33, 34, 35 and 36 was entirely due to the presence of bicarbonates only. No phenolphthalein alkalinity was recorded in any of the stations in this system, indicating the absence of carbonates and hydroxides.

In Station-I, alkalinity was always more or less constant with only slight fluctuations. But during September, October and November, 1976 comparatively lower values were seen with the lowest in the month of September, 1976 with 15.30 mg/l. The highest value of bicarbonate alkalinity were recorded in the months of July and November, 1977, values being 32.05 and 32.30 mg/l respectively.

The alkaline curve in Station-II has been shown in Fig. 5. As in Station-I, the alkalinity date showed a gradual increase since September, 1976 to reach the peak value of 52.60 mg/l in August, 1977, while the lower limit was 15.60 mg/l

recorded in the month of September, 1976. During the rest of the study period alkalinity curve showed slight fluctuations. However, in the month of February during both 1977 and 1978 a decline in the alkalinity value was seen.

Station-III of Ward Lake also exhibited more or less a similar nature of alkalinity trend with the highest of 37.80 mg/l being recorded in June, 1977. The lowest value was 16.13 mg/l as seen in September, 1976. During the annual cycle (January - December, 1977) two lower values recorded were in February and December. The higher alkalinity value recorded in the month of January, 1977 (Fig. 6).

The alkalinity curve of Station-IV (Fig. 7) showed a fluctuating nature with the highest value being 58.85 mg/l recorded in the month of March, 1977. The lowest record was 17.90 mg/l in September, 1976. During the year 1977 (January to December), it was observed that as in Station-III, February and December months showed lower value of bicarbonate alkalinity. In January, 1977 an upward trend in bicarbonate alkalinity was found which was similar to that of January, 1978. In this station, from July, 1977 onward alkalinity value declined steadily till November, 1977 which showed the lowest value during the annual cycle of 1977.

Phosphate :

Phosphate data for Station- I has been given in Table-33 and represented graphically in Fig.4 . The highest concentration of phosphate was found to be 1.88 mg/l in the

month of May, 1977 and the lowest value recorded was 0.28 mg/l during August, 1977. During the annual cycle starting from January to December, 1977 the phosphate value was always less than 0.84 mg/l except in the month of May. The month of November, 1977 showed slight increase in phosphate value which was also observed in November, 1976. The value during February, 1978, on the other hand, showed a decreasing trend unlike that of February, 1978 when an increasing trend was noted. However, the values recorded in both years were almost same with 0.57 mg/l (1977) and 0.56 mg/l in 1978.

Station-II exhibited greater seasonal fluctuation in the phosphate content. Here also May, 1977 showed the highest value of 1.67 mg/l and the lowest recorded was 0.21 mg/l in July, 1977. From August, 1977 the phosphate concentration increased again and reached 0.94 mg/l in November, 1977.

Station-III showed a comparatively stable picture of phosphate concentration (Fig. 6). The highest recorded was in the month of January, 1977 (0.98 mg/l) with the lowest of 0.33 mg/l in November, 1976. From March till September, 1977 a period of decreasing values was reported which increased again in October, 1977. During the rest of the months phosphate curve did not show any marked variation.

Station-IV of Ward Lake showed a highly fluctuating trend in the phosphate content. As in Station-I and II, May, 1977 marked the highest phosphate concentration (2.97 mg/l) which gradully decreased to 0.13 mg/l in the month of July, 1977.

From August, 1977, phosphate values once again increased to reach 1.11 mg/l in November, 1977 followed by subsequent decrease to 0.66 mg/l in January, 1978 (Fig.7).

Nitrate :

Nitrate as shown in Table-33 and Fig. 4, exhibited a fluctuating trend in Station-I. The maximum concentration of nitrates was recorded in the month of May, 1977, the value being 1.58 mg/l. The lowest value was 0.30 mg/l recorded in August, 1977. During the period of four months in 1976 (September -December) the value in December exhibited was higher which continued to increase to reach the maximum in the month of May, 1977. From June, 1977 onwards the nitrate content decreased gradually till August, 1977 (0.30 mg/l) only to increase again in September, 1977. February, 1978 showed a higher nitrate value than that of February, 1977.

In Station-II the nitrate values showed a comparatively stable nature with no distinct peak. January, 1977 showed the highest concentration of nitrate and was 1.03 mg/l while the lowest value was in August, 1977 with the concentration of 0.15 mg/l. From September, 1977, the nitrate level increased again to reach the value of 0.86 mg/l. The seasonal fluctuations in nitrate value has been shown in Fig. 5.

Station-III showed four distinct maxima in nitrate values (Fig.6). September, 1976 presented the lowest concentration of 0.11 mg/l which increased gradually till the first maxima was reached in January, 1977 (1.05 mg/l). From

February ,1977, the nitrate concentration gradully decreased till March, 1977 (0.49 mg/l) and increased again to reach the maximum in June, 1977 (1.24 mg/l). The other two maxima were in the months of November, 1977 (1.21 mg/l) and January, 1978 (1.22 mg/l).

Station-IV also exhibited four distinct maxima during the whole study period (Fig. 7). The first high value was 1.03 mg/l recorded in October, 1976, followed by a second maxima in the month of January, 1977 (1.28 mg/l). This maxima was followed by a sharp decline in nitrate content which suddenly increased to 2.21 mg/l, in the month of May, 1977 marking the peak. The last maxima was observed in the month of November, 1977 (1.82 mg/l) while the lowest was 0.30 mg/l observed in the month of August, 1977.

Silicate :

In Station-I, the highest silicate value was 5.27 mg/l recorded in the month of January, 1978 while the lowest value being 1.32 mg/l, as seen in October, 1977. From September, 1976, an increase in the silicate content was observed which continued to a maxima in March, 1977, only to decrease subsequently in April, 1977 and increased again in May, 1977. This trend continued till August, 1977. September, 1976 and 1977 exhibited almost similar values (Fig.4).

In Station-III silicates showed a somewhat different picture in its seasonality (Table-35, Fig. 6). There were two

distinct maxima with third mederately higher value. From September, 1976 onwards, an increasing trend in silicate has been observed till the first maxima was reached in the month of May, 1977 (5.27 mg/l). June, 1977 showed decrease in silicate content only to increase again to reach the peak in August, 1977 when the concentration was 6.23 mg/l. From September, 1977 onwards there was a sharp decline in the values till it reached the lowest of 1.76 mg/l in November, 1977. This was followed by a by a moderately higher value in January, 1978 (3.51 mg/l) which decreased to 2.72 mg/l in February, 1978.

Station-IV on the other hand, followed a somewhat different trend. Thus from September, 1976 (3.59 mg/l) onwards there was a tendency of silicate content to increase with minor fluctuations to reach the concentration of 5.40 mg/l (July, 1977). This was followed by a steady and gradual decrease till October, 1978 (4.71 mg/l) which rose again to reach the highest value in the month of January, 1978 (10.53 mg/l). The lowest value was seen in December, 1978 (1.84 mg/l). Generally, the silicate content at this station was always higher than those in the other stations (Table-36, Fib. 7).

B. BIOLOGICAL CHARACTERISTICS :

The study of biological characteristics were confined to plankton as well as to other forms associated with vegetations.

Table-33 : Showing seasonal changes in the physicochemical factors of Station-I(WI) of Ward Lake (September, 1976 to February, 1978).

Month	Temperature °C Air	Temperature °C Water	pH	Conductivity (umhos/cm)	Dissolved oxygen (mg/l)	Carbon dioxide (mg/l)	Alkalinity (mg/l)	Phosphate (mg/l)	Nitrate (mg/l)	Silicate (mg/l)
1976										
September	22.85	23.0	6.4	65.89	5.92	5.60	15.30	0.95	0.51	1.65
October	23.75	22.38	6.16	76.19	6.58	4.25	17.70	1.02	0.65	1.45
November	19.17	19.00	6.38	66.25	6.85	4.33	18.67	0.67	0.59	2.05
December	17.25	15.75	6.59	67.59	7.34	4.80	28.05	0.79	0.79	1.85
1977										
January	17.75	14.0	6.70	64.21	7.96	10.25	28.35	0.74	0.90	2.64
February	19.0	16.33	6.57	66.66	8.83	9.87	22.40	0.56	0.85	2.93
March	25.75	21.13	6.84	71.56	9.34	6.35	29.25	0.75	0.85	3.29
April	21.90	20.10	6.59	71.57	7.66	9.88	30.60	0.84	0.74	1.41
May	24.50	20.75	6.23	71.66	7.67	10.90	27.30	1.87	1.58	3.51
June	25.63	24.25	6.28	72.14	8.38	9.0	29.45	0.50	1.53	1.54
July	27.17	25.67	6.46	69.08	10.70	6.45	32.05	0.56	0.76	1.89
August	25.67	24.83	6.43	74.94	10.53	8.07	29.93	0.28	0.30	3.52
September	25.79	24.80	6.38	71.02	8.93	7.02	31.12	0.46	0.44	1.76
October	26.50	20.50	6.20	60.90	5.52	4.10	30.80	0.35	0.80	1.32
November	23.50	19.50	6.50	55.55	7.48	4.90	32.30	0.75	0.95	1.76
December	18.00	15.00	6.65	88.20	6.84	5.40	27.80	0.67	0.83	1.88
1978										
January	13.00	12.00	6.35	59.22	9.32	2.40	27.60	0.46	0.69	5.27
February	12.00	14.00	6.51	62.66	8.93	4.20	28.20	0.56	1.03	2.28

Fig.4

Seasonal variation in the physicochemical factors of Station-I (WI) of Ward Lake during September, 1976 to February, 1978.

Fig. 4

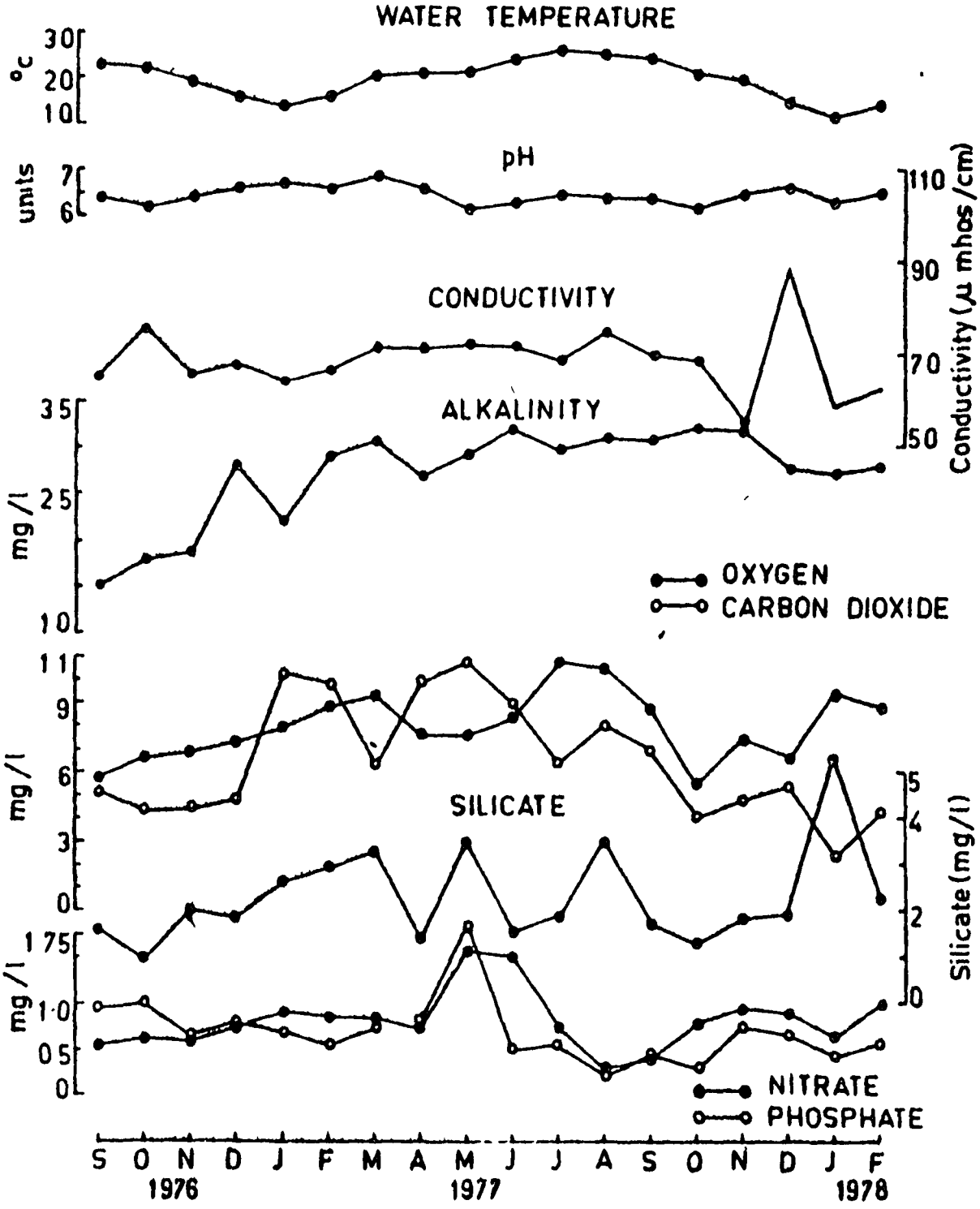

WATER TEMPERATURE
°c
30
20
10
pH
units
7
6
110
90
70
50
Conductivity (μ mhos/cm)
CONDUCTIVITY
ALKALINITY
35
25
10
mg/l
OXYGEN
CARBON DIOXIDE
11
9
6
3
0
mg/l
SILICATE
5
4
2
0
Silicate (mg/l)
1·75
1·0
0·5
0
mg/l
NITRATE
PHOSPHATE
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fig.5

Seasonal variation in the physicochemical factors of Station-II (WII) of Ward Lake during September, 1976 to February, 1978.

Fig.5

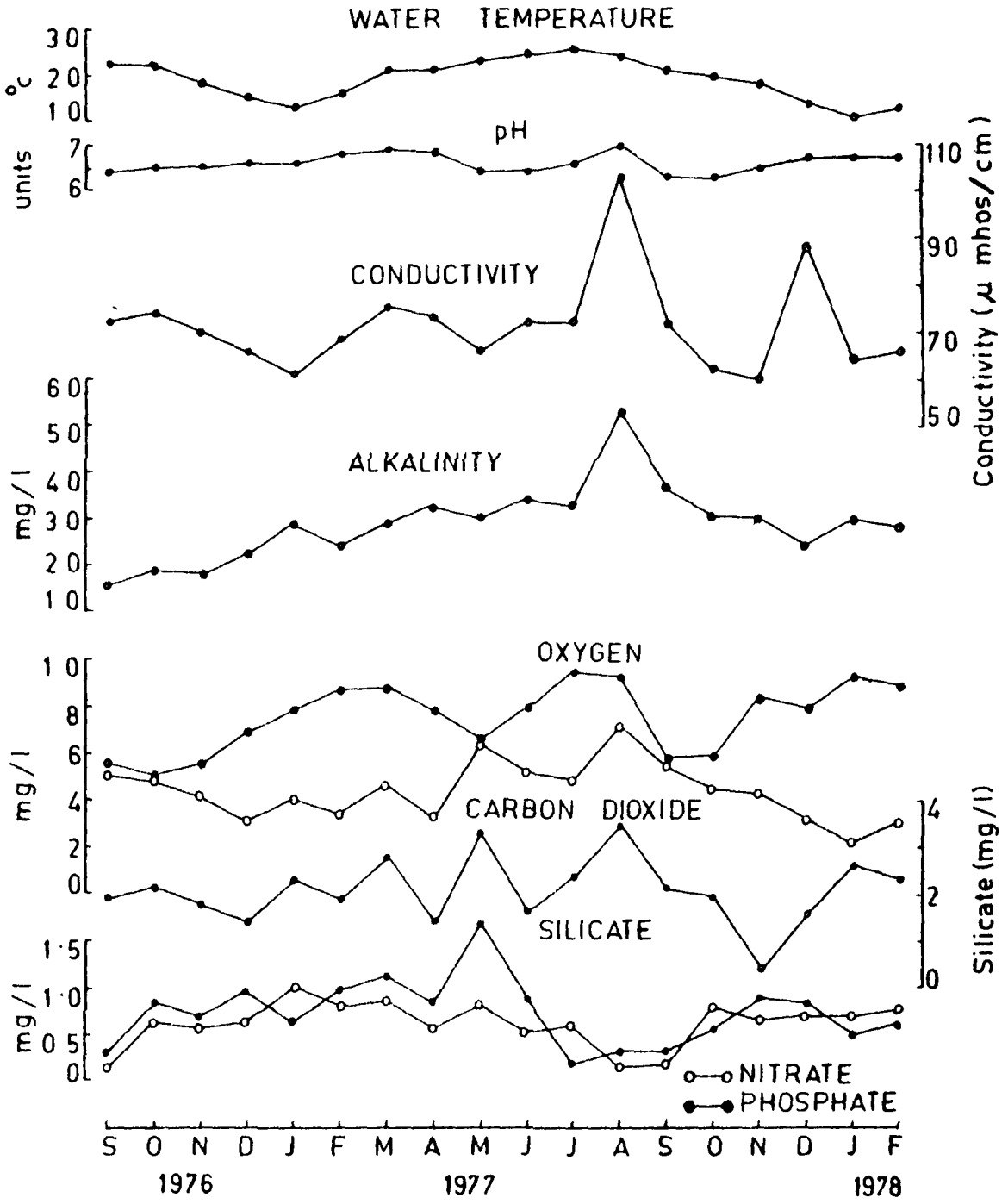

WATER TEMPERATURE
°c
30
20
10
pH
units
7
6
110
90
70
50
Conductivity (μ mhos/cm)
CONDUCTIVITY
60
50
40
30
20
10
mg/l
ALKALINITY
OXYGEN
10
8
6
4
2
0
mg/l
CARBON DIOXIDE
4
2
0
SILICATE
Silicate (mg/l)
1·5
1·0
0·5
0
mg/l
NITRATE
PHOSPHATE
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Table-35 : Showing seasonal changes in the physicochemical factors of Station-III (WIII) of Ward Lake (September, 1976 to February, 1978).

Month	Temperature °C		pH	Conductivity (umhos/cm)	Dissolved oxygen (mg/l)	Carbon dioxide (mg/l)	Alkalinity (mg/l)	Phosphate (mg/l)	Nitrate (mg/l)	Silicate (mg/l)
	Air	Water								
1976										
September	24.25	22.50	6.34	77.20	4.52	6.73	16.60	0.84	0.11	2.11
October	24.25	21.75	6.41	77.80	5.99	4.25	18.60	0.65	0.45	2.72
November	19.67	18.67	6.27	69.17	6.65	7.13	16.13	0.33	0.85	2.34
December	16.00	14.38	6.51	66.95	7.13	2.93	22.90	0.61	1.27	2.85
1977										
January	17.00	14.00	6.43	64.50	7.68	5.65	29.80	0.97	1.05	3.24
February	18.67	17.50	6.45	68.74	7.97	6.27	22.73	0.69	0.64	2.34
March	22.75	20.00	6.59	77.39	7.08	6.60	33.45	0.83	0.49	3.38
April	23.80	21.00	6.44	74.83	7.20	6.88	33.20	0.87	0.63	4.32
May	22.50	20.75	6.13	79.59	6.20	11.10	31.40	0.56	0.77	5.27
June	25.25	23.13	6.36	76.37	6.86	7.80	37.30	0.61	1.24	2.68
July	26.33	25.00	6.50	65.84	9.89	7.25	35.75	0.37	0.68	3.78
August	24.33	25.33	6.32	69.76	7.97	10.00	33.07	0.59	0.34	6.23
September	25.00	21.00	6.24	67.78	6.80	6.70	33.70	0.56	0.74	2.34
October	25.00	21.00	6.24	64.88	5.80	5.10	33.20	0.81	0.83	2.64
November	19.50	18.50	6.48	60.50	7.18	4.50	32.20	0.86	1.21	1.76
December	18.00	14.00	6.70	89.15	7.20	3.60	25.20	0.75	1.09	3.28
1978										
January	12.00	11.00	6.20	63.68	8.00	2.60	28.40	0.44	1.20	3.51
February	13.25	10.50	6.35	67.10	7.98	5.60	26.28	0.75	0.94	2.72

Fig.6

Seasonal variation in the physicochemical factors of Station-III (WIII) of Ward Lake during September, 1976 to February, 1978.

Fig. 6

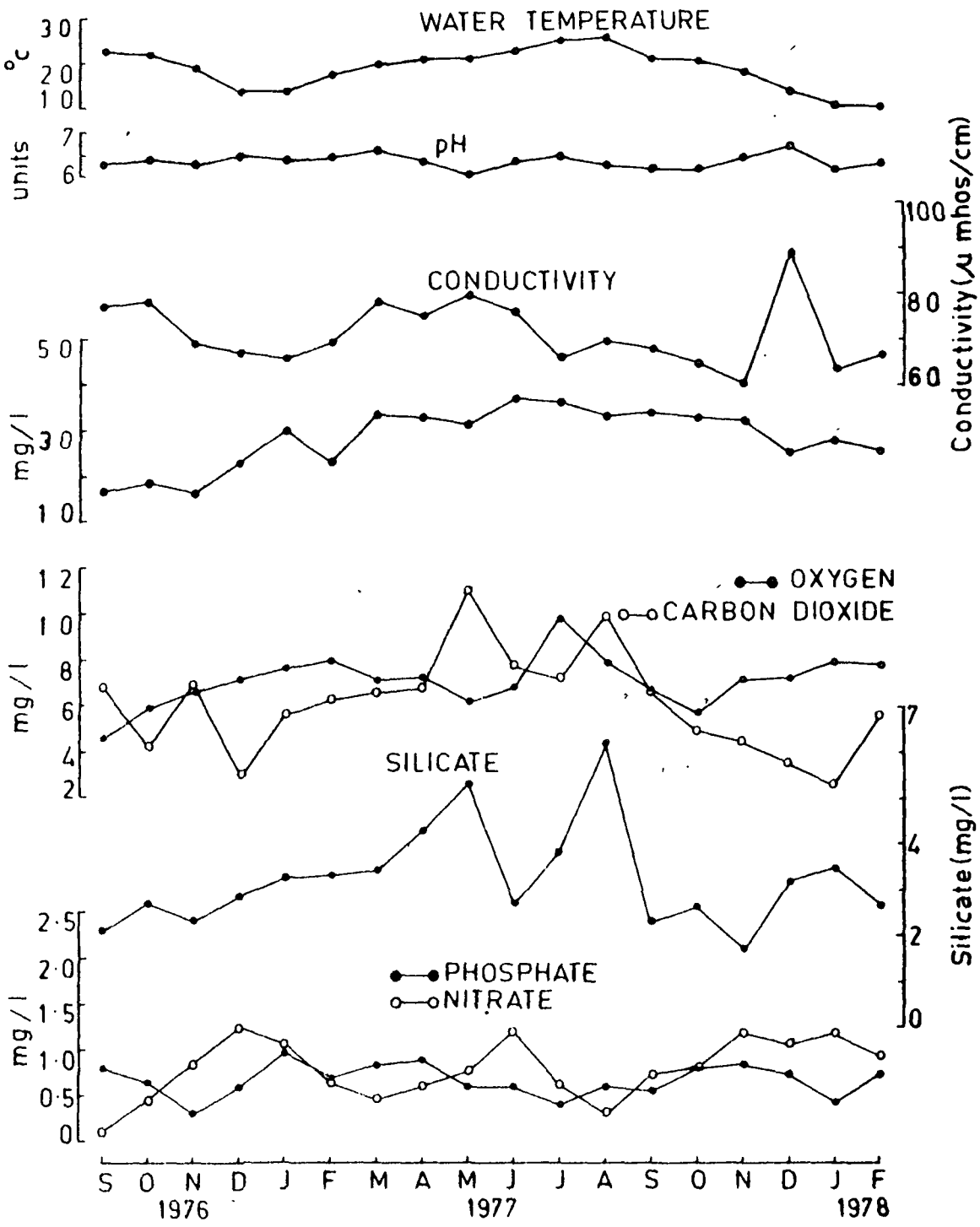

WATER TEMPERATURE
°c
30
20
10
pH
units
7
6
CONDUCTIVITY
Conductivity (μ mhos/cm)
100
80
60
mg/l
50
30
10
OXYGEN
CARBON DIOXIDE
12
10
8
6
4
2
SILICATE
Silicate (mg/l)
7
4
2
0
PHOSPHATE
NITRATE
2·5
2·0
1·5
1·0
0·5
0
S O N D J F M A M J J A S O N D J F
1976
1977
1978

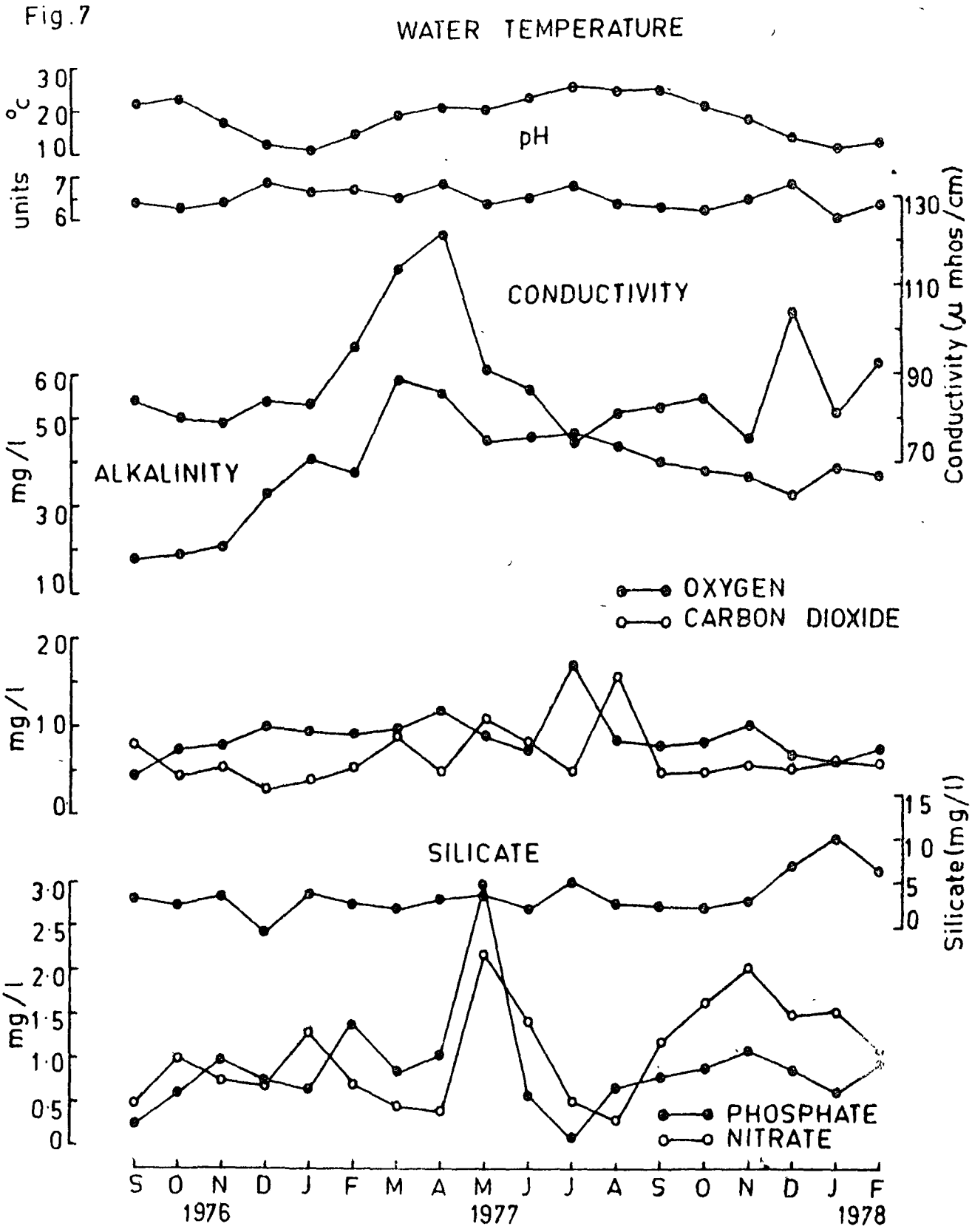
Table-36 : Showing seasonal changes in the physicochemical factors of Station-IV (WIV) of Ward Lake (September, 1976 to February, 1978)

Month	Temperature °C		pH	Conductivity (umhos/cm)	Dissolved oxygen (mg/l)	Carbon dioxide (mg/l)	Alkalinity (mg/l)	Phosphate (mg/l)	Nitrate (mg/l)	Silicate (mg/l)
	Air	Water								
1976										
September	22.00	21.50	6.38	84.05	4.60	8.30	17.90	0.26	0.51	3.51
October	24.25	20.63	6.34	79.85	7.70	4.60	19.00	0.61	1.03	2.59
November	20.17	17.17	6.41	78.93	7.97	5.07	20.67	1.00	0.75	3.63
December	14.75	11.63	6.85	83.62	10.13	3.25	33.10	0.75	0.73	1.84
1977										
January	15.50	11.00	6.65	82.52	9.80	4.35	41.40	0.68	1.28	3.78
February	20.50	14.67	6.69	96.73	9.55	5.07	37.47	1.38	0.73	2.87
March	25.50	18.75	6.53	114.43	5.92	8.95	58.85	0.85	0.49	2.20
April	22.40	20.40	6.82	122.43	7.36	5.20	55.88	1.08	0.40	3.12
May	21.50	20.00	6.35	91.14	9.04	11.40	45.20	2.97	2.21	3.51
June	24.88	22.50	6.48	86.69	7.61	8.05	46.25	0.57	1.27	4.04
July	25.83	24.67	6.75	74.94	17.76	5.35	46.50	0.13	0.53	5.40
August	24.25	24.25	6.35	81.53	8.61	15.93	43.87	0.69	0.30	5.27
September	25.00	24.25	6.30	82.05	7.69	5.30	40.05	0.83	1.18	5.11
October	23.50	20.50	6.25	83.84	8.44	5.40	38.20	0.91	1.65	4.71
November	19.50	17.50	6.44	75.44	10.64	5.90	37.10	1.11	1.82	5.27
December	17.50	13.00	6.75	104.16	7.36	5.60	33.20	0.88	1.53	7.11
1978										
January	12.00	11.00	6.01	81.06	6.52	6.40	39.60	0.65	1.55	10.53
February	14.50	12.00	6.29	92.43	7.78	6.25	37.41	0.96	1.11	6.67

Fig.7

Seasonal variation in the physicochemical factors of Station-IV (WIV) of Ward Lake during September, 1976 to February, 1978.

Fig.7


WATER TEMPERATURE
°C
30
20
10
pH
units
7
6
CONDUCTIVITY
130
110
90
70
Conductivity (μ mhos/cm)
mg/l
60
50
30
10
ALKALINITY
OXYGEN
CARBON DIOXIDE
mg/l
20
10
0
SILICATE
15
10
5
0
Silicate (mg/l)
mg/l
3·0
2·5
2·0
1·5
1·0
0·5
0
PHOSPHATE
NITRATE
S O N D J F M A M J J A S O N D J F
1976
1977
1978

(a) Phytoplankton :

Total phytoplankton recorded in WI during the 18 months study duration has been presented in Table-37 and Fig.8a. In this station, October, 1977 presented the highest numerical abundance with 78978 units/l, while the lowest density was 1877 units/l in October, 1976. Both December, 1976 and November, 1977 also showed comparatively higher values than the rest of the months.

In WII (Fig. 9a) total phytoplankton contributed always above 90% of the total plankton except in the month of September, 1976 when it formed only 86.09%. The maximum numerical density was 89751.98 units/l in November, 1976 while the lowest density was recorded in the month of February, 1978 with only 3804 units/l.

Maximum total phytoplankton recorded in WIII (Table-39, Fig. 10a) was in the month of November, 1976 when the density was 26320 units/l, which the least numerical contribution was 1353.75 units/l in October, 1976. Phytoplankton alone contributed to more than 90% of the total plankton but for the months of September and October, 1976.

In WIV (Table-40, Fig.11a), the highest number of phytoplankton was recorded in the month of February, 1977 and was 66377.00 units/l while the lowest number recorded was 1225.00 units/l (November, 1977). Phytoplankton formed more than 90% of the total plankton throughout the study except in

September, 1976 (74.52%) and November, 1977 (52.43%).

The five major groups of phytoplankton contributed in different proportions in different stations of Ward Lake as shown in Tables -37 , 38 , 39 and 40.

Myxophyceae : In WI, contribution of family myxophyceae varied during different seasons (Table-37). September, 1976 had low values which reached the minimum number in October, 1976 (377 units/l). The highest number, on the other hand, was recordcd in October, 1977 with 76450.00 units/l. In terms of percentage composition, myxophyceae formed 96.81% of the total phytoplankton in the month of September, 1977, while the lowest contribution was 9.33% in the month of May, 1977 (Fig.8b).

WII (Table-38) showed lesser density of myxophyta than in that of WI and the maximum value was 5257.25 units/l as seen in September, 1976, contributing 82.76% of total phytoplankton. The lowest number recorded was 118 units/1 in February, 1978. But in terms of percentage, they formed only 0.94% of total phytoplankton in the month of March, 1977(Fig.9b). Highest numerical abundance in WIII (Table-39) was recorded in October, 1977 with 33125 units/litre while the lowest record was in November, 1976 (110/l). Highest contribution in terms of percentage (Fig.10b) was in October, 1977 (85.24%) and lowest in November, 1976 (0.42%).

The data on myxophyceae count for WIV has been presented in Table-40. In this station the maximum abudance was in December, 1976 (15810 units/l) while the lowest being

60.00 units/l as seen in November, 1977. Contribution of myxophyceae was comparatively low with their highest contribution forming 49.33% in March, 1977. Their lowest percentage was only 1.46% during October, 1976 to the total phytoplankton (Fig.11b).

Chlorophyceae : Contribution of chlorophyceae in WI was generally much lower than that of myxophyceae (Table-37,Fib.8b). They formed 20.90% of the total phytoplankton in January,1977 when the maximum number was also recorded (3853.60 units/l). Lowest number per litre was recorded in the month of January, 1976 (87.50 units/l). On the other hand, in July,1977 these algae formed only 0.58% of the total phytoplankton.

The lowest and highest numerical densities of chlorophyceae in WII (Table-38, Fig.9b) were 90.0 and 8535.33 units/l, recorded in the months of November, 1976 and September, 1976 respectively. Their numerical density was also less than a thousand during October, 1976, March - May, 1977, July,1977 and February, 1978. During the rest of the months the population was more than thousand units/l. They formed 36.53% of total phyloplankton in September, 1977 being the highest contribution while the lowest was 1.41% during September, 1976.

In WIII (Table-39, Fig.10b) chlorophyceae count was les than thousand/l during September - November,1976, April and May, 1977, July, August and October, 1977 and February,1978.

In the remaining months units per litre count was more than a thousand units. Highest number was recorded in March, 1977 (9625.50 units/l) forming 59.04% of the total phytoplankton. Lowest count/litre was observed in October, 1976 (112.25 units/l), however, the lowest percentage occurrence was in November, 1976 (0.96%).

In WIV (Table-40, Fig.11b) the maximum abundance of chlorophyceae was in February, 1977 with 18877.00 units/l. On the other hand, their maximum number was 121.00 units/l in February, 1978. Except on four occasions namely October, 1976, November, 1976, November, 1977 and February, 1978, their number per litre was more than thousand. Their highest contribution to phytoplankton was in the month of November, 1977 (80.41%) whole the least was in October, 1976 (0.54%).

Dinophyceae : Seasonal distribution of dinophyceae was marked by the complete absence from plankton in WI during September, October and November, 1976 and August, 1977 (Table-37, Fig.8b). During the remaining 14 months of the study period, highest number was recorded in May, 1977 (4496.67/l) which also formed the largest fraction in terms of percentage (49.37%). Lowest density was noted in September, 1977 (15.50/l) forming only 0.07% of the total phytoplankton.

In WII dinophyceae was totally absent only in the month of September, 1977 (Table-38, Fig.9b). During September, 1976 and August, 1977, their number were less than 31 units/l

with the lowest in August, 1977 (3.25/l). In October, 1976 also their number was negligible (263.50 units/l), which during rest of the period they were more than 2000 units/litre. April, 1977 marked the highest number with 18164 units/l. The lowest and highest percentage composition was observed during August, 1977 (0.04%) and March, 1977 (82.28%) respectively.

The highest recorded number of dinophyceae in WIII was 2530 units/l in the month of June, 1977 (Table-39, Fig.10b), whereas the lowest abundance was observed in November, 1976 with 30.00 units/l. They were represented in the plankton samples throughout the study period with abundance in the months of May, June, July, October and December, 1977 when the numerical density was more than thousand units per litre. Dinophyceae formed 43.14% of the total plankton in April, 1977 and only 0.11% in November, 1976.

In WIV (Table-40, Fig.11b) dinophyceae was very poorly represented. Out of the 18 months study period they appeared in plankton only during the months of January, April, and July, 1977. They formed 200 units/l in January, 1977 (0.24%), 5.00 units/l in April, 1977 (0.07%) and 10.00 units/l in July, 1977 (0.12%).

Chrysophyceae : In WI (Table-37, Fig.8b) this family was found to be most abundant in the month of February, 1977 (4870.00 units/l) and the lowest was observed in August, 1977 with 26.67 units/l. In terms of percentage occurrence, April, 1977 showed

the maximum with 41.98% whereas only 0.21% was found in the month of September, 1976. During October, 1976, November, 1976, August, 1977, September, 1977 and December, 1977, the count was less than 100/l, while in September, 1976 they were totally absent.

In WII (Table-38, Fig.9b), they were always present excepting the month of September, 1977. Highest abundance was noted during November, 1976 with 65530/l while the lowest being 10.00/l, recorded in September, 1976. Chrysophyceae contributed the maximum to phytoplankton in October, 1976 when they formed 83.42% and minimum in the month of September, 1976 forming only 0.16%. Except in the month of September, 1976, 1977 and February, 1978, their numerical density was always more than 1000 units per litre.

In WIII (Table-39, Fib.10b) the highest occurrence was in December, 1976 (3600/l) and the lowest was in October, 1976 (10.00/l). They formed 18.50% during December, 1976 and only 0.11% in November, 1976. They were not recorded in the samples of September, 1976, February, 1977, July, 1977 and February, 1978.

In WAIV (Table-40, Fib.11b) chrysophyceae was recorded only on five occasions namely, November, 1976 (20/l; 0.32%), January, 1977 (4.0/l; 0.01%), June, 1977 (30.00/l; 0.26%), October, 1977 (120.0/l; 2.03%) and January, 1978 (10.00/l; 0.15%). The percentage of 2.03% recorded in October, 1977 was the highest contribution of this group to the total phytoplankton.

Bacillariophyceae : In WI (Table-37,Fig.8b), this family was most dominant numerically in the month of December, 1976 (3044/l) and lowest in number in November, 1977 with 361.50/l. They formed 73.13% of total phytoplankton in October,1976 while 0.22% was recorded in November,1977. Their number was less than a thousand per litre during February, April, May and July,1977, September, October and November of 1976.

In WII of Ward Lake (Table-38,Fig.9b) in 15 out of 18 months number of the bacillariophyceae were represented. Highest number of diatoms were recorded in November,1976 (4976.64/l) while the lowest was in April,1977 with 18 units/l. 15.19% was their highest contribution to phytoplankton (September,1976). They were absent from plankton samples during February, March and October,1977.

In WIII (Table-39, Fig.10b) minimum number of diatoms were 320/l and 25910/l, recorded in the months of April,1977 and November, 1976 respectively. They occurred throughout the 18 months study period and minimum and maximum percentage composition were 98.44% and 4.12% during October,1977 and November,1976 respectively. The diatoms were always more than thousand units/l except in March, 1977 (730/l) and April,1977 (320/l).

In WIV (Table-40, Fig.11b) bacillariophyceae was dominant among all other groups of phytoplankton. They contributed to 98.00% of total phytoplankton in October, 1976 while the lowest was 14.96% recorded in November, 1977. Highest numerical

Table-37 : Showing the seasonal fluctuations of different phytoplanktonic groups and their percentage composition in Station-I (WI) of Ward Lake. (September, 1976 to February, 1978)

Month	Myxophyceae (unit/l)	(%)	Chlorophyceae (unit/l)	(%)	Dinophyceae (unit/l)	(%)	Chrysophyceae (unit/l)	(%)	Bacillario-phyceae (unit)	(%)	Total phytoplan-kton(unit/l)
1976											
September	1797	53.40	101	2.99	-	-	-	-	1467	43.60	3364
October	377	20.08	87	4.66	-	-	40	2.13	1373	73.13	1877
November	2825	54.61	288	5.57	-	-	93	1.80	1967	38.02	5173
December	35854	87.73	9931	2.28	420	1.03	617	1.51	3044	7.45	40857
1977											
January	11294	61.24	3854	20.90	279	1.50	840	4.55	2175	11.79	18442
February	10900	54.85	884	4.45	2728	13.73	4870	24.52	490	2.47	19873
March	1166	15.25	775	10.14	2025	26.46	2111	27.61	1570	20.53	7648
April	1400	13.55	598	5.79	3355	32.48	4336	41.98	640	6.20	10329
May	850	9.33	1455	15.98	4497	49.37	1787	19.62	516	5.67	9106
June	4022	56.22	127	2.78	684	9.56	1100	15.37	1221	17.07	7154
July	19227	92.06	122	0.58	520	2.49	507	2.43	510	2.44	20885
August	11157	89.17	173	1.38	-	-	27	0.21	1153	9.22	12509
September	22562	94.81	389	1.63	15	0.07	60	0.25	770	3.24	23797
October	76450	96.80	977	1.24	356	0.45	833	1.06	361	0.46	78978
November	52700	96.19	845	1.54	580	1.06	540	0.99	120	0.22	54786
December	1670	29.65	680	12.08	530	9.41	95	1.69	2657	47.18	5633
1978											
January	1905	30.53	772	12.37	180	2.89	1935	31.01	1446	23.18	6239
February	10801	57.45	572	3.04	2262	12.03	4770	25.37	395	2.10	18800

(Counts/l given are rounded off to the nearest whole number).

Fig.8a

Seasonal fluctuation in the numerical density (unit/l) of total phytoplankton in Station-I (WI) of Ward Lake. (September, 1976 to February, 1978)

Fig.8b

Seasonal variation in the percentage composition of phytoplankton in Station-I (WI) of Ward Lake. (September, 1976 to February, 1978)

Fig.8a

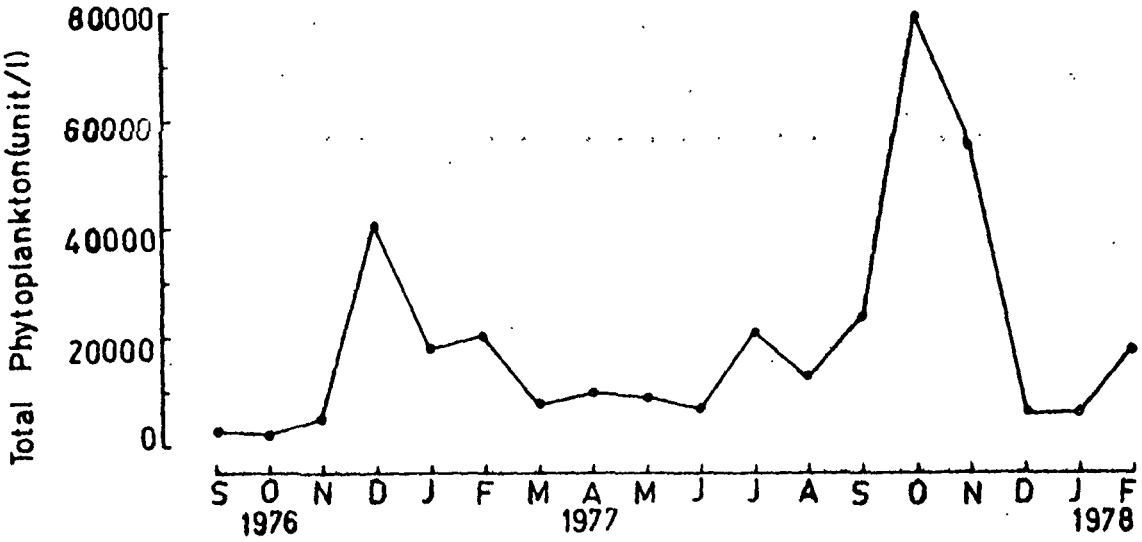

Total Phytoplankton(unit/l)
80000
60000
40000
20000
0
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fig.8b

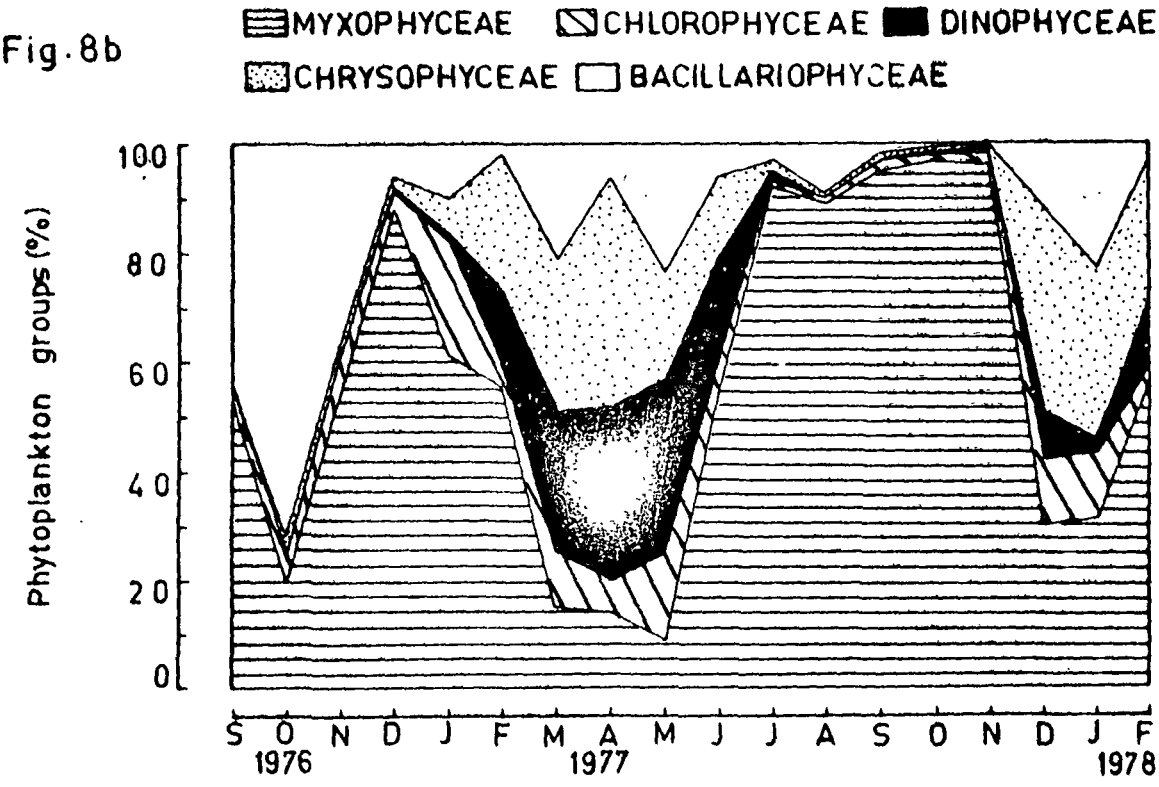

MYXOPHYCEAE
CHLOROPHYCEAE
DINOPHYCEAE
CHRYSOPHYCEAE
BACILLARIOPHYCEAE
Phytoplankton groups (%)
100
80
60
40
20
0
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Table-38 : Showing the seasonal fluctuations of different phytoplanktonic groups and their percentage composition in Station-II (WII) of Ward Lake. (September, 1976 to February, 1978)

Month	Myxophyceae (unit/l)	(%)	Chlorophyceae (unit/l)	(%)	Dinophyceae (unit/l)	(%)	Chrysophyceae (unit/l)	(%)	Bacillario-phyceae (unit/l)	(%)	Total phytoplankton (unit/l)
1976											
September	5257	82.76	90	1.41	30	0.47	10.	0.16	965	15.19	6352
October	3665	12.20	644	2.15	263	0.88	25070	83.42	410	1.36	30053
November	3710	4.13	8535	9.51	7000	7.79	65530	73.02	4977	5.55	89752
December	4464	16.81	3309	9.38	3667	13.81	15271	57.49	667	2.51	26563
1977											
January	2055	7.75	2242	8.45	12450	46.96	9655	36.42	110	0.41	26512
February	127	0.48	360	1.35	16506	62.04	9613	36.13	-	-	26607
March	125	0.94	779	5.89	10890	82.28	1440	10.88	-	-	13234
April	398	1.64	758	3.12	18164	74.79	4950	20.38	18	0.07	24288
May	325	2.07	800	5.09	10920	69.44	3660	23.28	20	0.12	15725
June	290	8.16	1934	12.24	11540	72.99	1007	6.37	40	0.25	15810
July	1477	16.59	890	10.00	5100	57.25	1420	15.94	20	0.22	8908
August	4130	54.93	1686	22.42	3	0.04	1680	22.34	20	0.27	7519
September	4380	56.71	2821	36.53	-	-	-	-	522	6.76	7723
October	1400	7.96	2860	16.27	3900	22.18	9420	53.58	-	-	17580
November	2995	26.22	1449	12.68	3540	30.99	3400	29.76	40	0.35	11424
December	1210	10.55	2570	22.42	3046	26.57	4595	40.08	43	0.38	11464
1978											
January	1845	8.24	3658	16.36	4615	34.01	9240	41.13	65	0.29	22393
February	115	3.02	260	6.83	2469	64.91	950	24.97	10	0.26	3804

(Unit/l given are rounded off to the nearest whole number).

Fig.9a

Seasonal fluctuation in the numerical density (unit/l) of total phytoplankton in Station-II (WII) of Ward Lake. (September, 1976 to February, 1978)

Fig.9b

Seasonal variation in the percentage composition of phytoplankton in Station-II (WII) of Ward Lake. (September, 1976 to February, 1978)

Fig. 9a

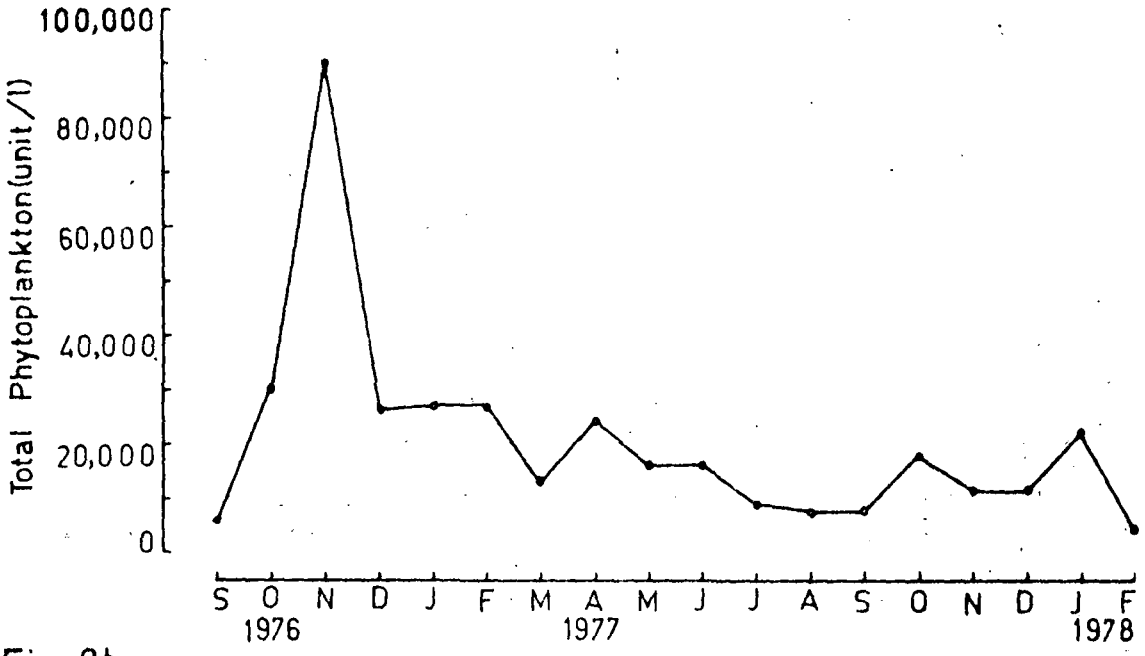

100,000
80,000
60,000
40,000
20,000
0
Total Phytoplankton(unit/l)
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fig. 9b

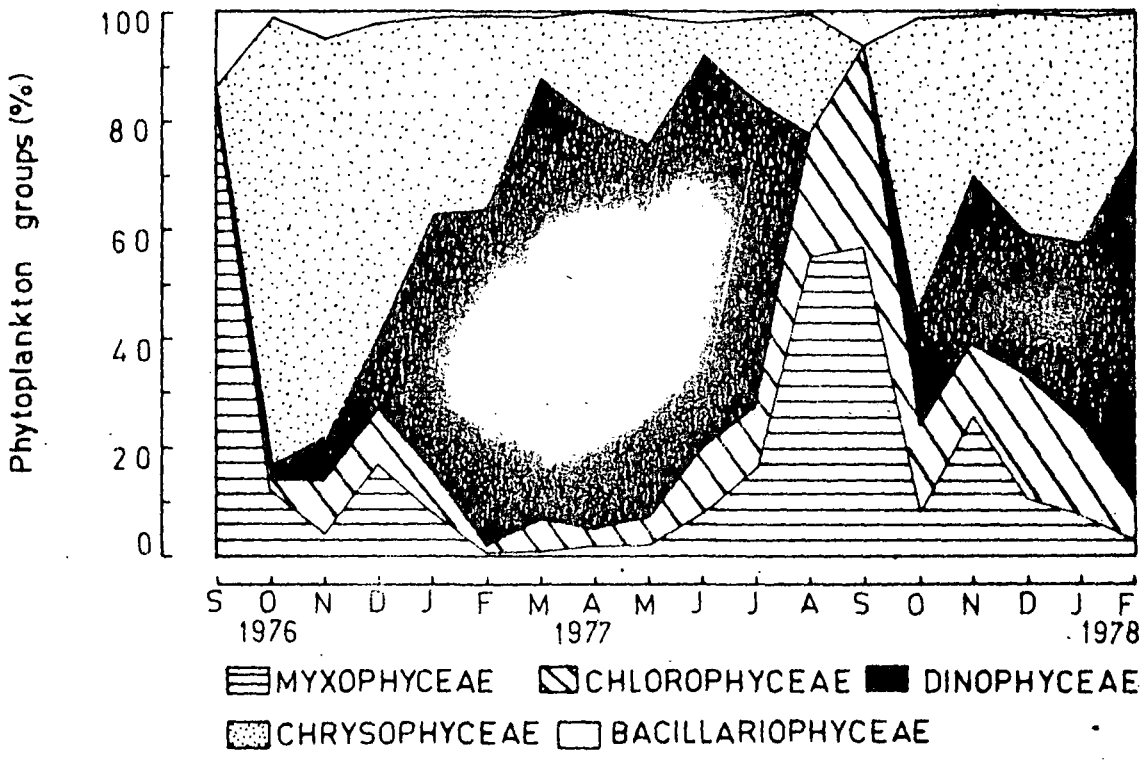

100
80
60
40
20
0
Phytoplankton groups (%)
S O N D J F M A M J J A S O N D J F
1976
1977
1978
MYXOPHYCEAE
CHLOROPHYCEAE
DINOPHYCEAE
CHRYSOPHYCEAE
BACILLARIOPHYCEAE

Table-39 : Showing the seasonal fluctuations of different phytoplanktonic groups and their percentage composition in Station-III (WIII) of Ward Lake. (September, 1976 to February, 1978)

Month	Myxophyceae		Chlorophyceae		Dinophyceae		Chrysophyceae		Bacillario-phyceae		Total phytoplankton(unit/l)
	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	
1976											
September	775	32.20	222	9.19	25	1.04	-	-	1390	57.57	2414
October	160	11.82	112	8.29	36	2.66	10	0.74	1035	76.49	1354
November	110	0.42	255	0.96	30	0.11	30	0.11	25910	98.44	26230
December	195	1.00	4911	25.23	889	4.56	3600	18.50	9871	50.71	19464
1977											
January	3732	16.41	3005	13.21	353	1.55	1451	6.38	14202	62.44	22744
February	1977	23.28	2064	24.31	360	4.24	-	-	4087	48.15	8487
March	4722	28.97	9625	59.04	955	5.86	270	1.66	730	4.48	16303
April	342	15.39	323	14.51	960	43.14	280	12.58	320	14.38	2225
May	1347	19.07	888	12.57	2053	29.08	387	5.48	2387	33.80	7061
June	3943	24.33	2783	17.18	2530	15.62	240	1.48	6706	41.39	16202
July	5620	46.95	189	1.58	1360	11.36	-	-	4802	40.11	11971
August	4416	59.97	356	4.84	619	8.41	573	7.79	1400	19.01	7364
September	1670	35.15	1260	26.52	301	6.35	180	3.79	1340	28.20	4751
October	33125	85.24	835	2.15	1740	4.48	1560	4.01	1600	4.12	38860
November	1215	19.26	1662	26.35	820	13.00	880	13.95	1730	27.43	6307
December	504	8.10	1902	30.55	1565	25.14	524	8.42	1729	27.78	6225
1978											
January	300	2.22	6852	50.64	203	1.50	270	2.00	5905	43.64	13531
February	350	10.36	378	11.19	260	7.69	-	-	2391	70.76	3379

(Unit/l values given are rounded off to the nearest whole number).

Fig.10a

Seasonal fluctuation in the numerical density (unit/l) of total phytoplankton in Station-III (WIII) of Ward Lake. (September, 1976 to February, 1978)

Fig.10b

Seasonal variation in the percentage composition of phytoplankton in Station-III(WIII) of Ward Lake. (September, 1976 to February, 1978)

Fig. 10a

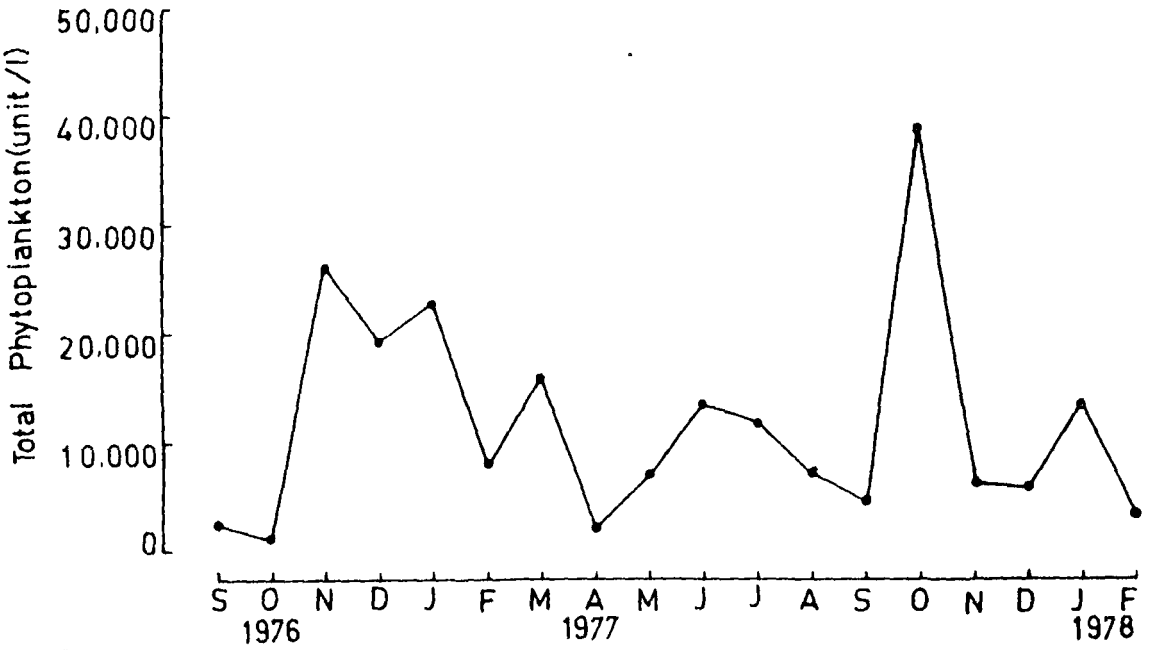


Fig. 10b

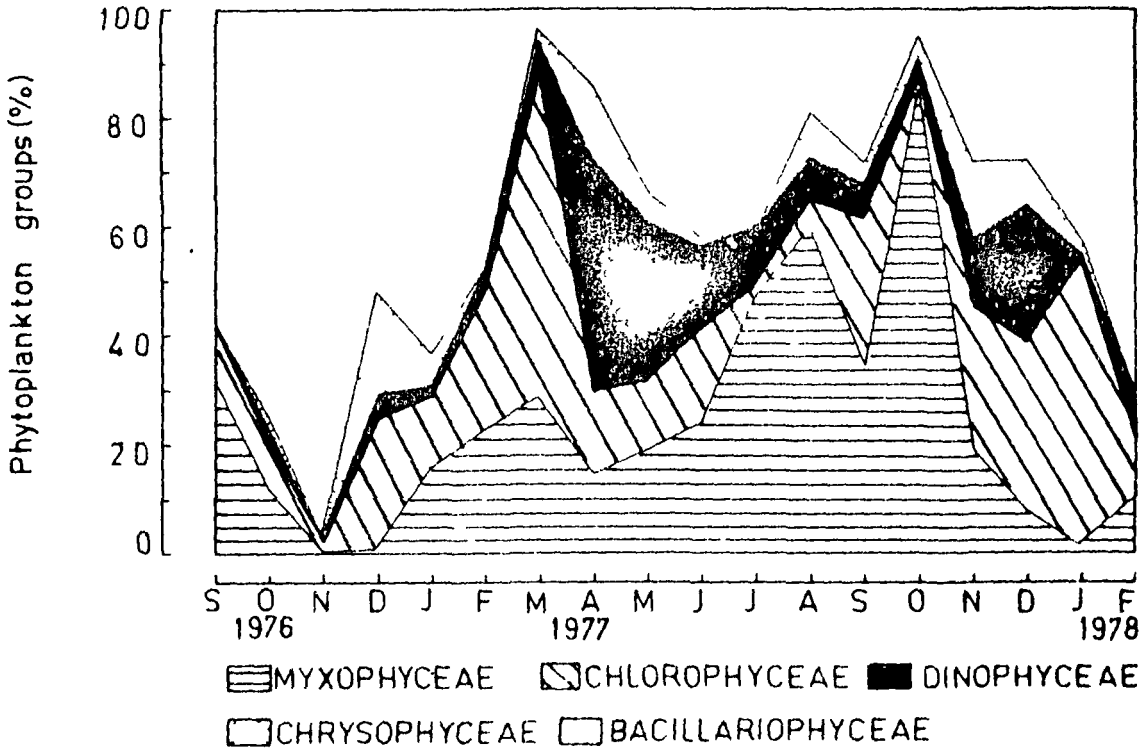


Table-40 : Showing the seasonal fluctuations of different phytoplanktonic groups and their percentage composition in Station-IV (WIV) of Ward Lake. (September, 1976 to February, 1978).

Month	Myxophyceae		Chlorophyceae		Dinophyceae		Chrysophyceae		Bacillario-phyceae		Total phytoplankton (unit/l)
	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	
1976											
September	940	23.86	1100	27.92	-	-	-	-	1900	48.22	3940
October	595	1.46	220	0.54	-	-	-	-	39885	98.00	10700
November	145	2.33	250	4.02	-	-	20	0.32	5813	93.34	6228
December	15810	28.45	5074	9.13	-	-	-	-	34685	62.42	55569
1977											
January	9288	11.16	7330	8.91	200	0.24	4	0.01	66400	79.79	83222
February	9500	14.31	18877	28.44	-	-	-	-	38000	57.25	66377
March	8983	49.33	3832	21.05	-	-	-	-	5387	29.60	18203
April	2780	38.86	2303	33.14	5	0.07	-	-	2065	28.87	7154
May	2280	14.76	2123	13.75	-	-	-	-	11044	71.49	15448
June	1407	12.13	3158	27.21	-	-	30	0.26	7007	60.40	11603
July	667	8.02	1968	23.63	10	0.12	-	-	5682	68.23	8327
August	7570	29.27	6594	25.49	-	-	-	-	11700	45.24	25864
September	1974	33.76	1202	20.57	-	-	--	-	2670	44.67	5846
October	1980	33.56	1020	17.29	-	-	120	2.03	2780	47.12	5900
November	60	4.90	985	80.41	-	-	-	-	180	14.69	1225
December	5650	42.76	3250	24.60	-	-	-	-	4312	32.64	13212
1978											
January	620	9.38	2175	32.89	-	-	10	0.15	3808	57.58	6613
February	380	19.61	121	6.24	-	-	-	-	1437	74.15	1938

(Unit/l values given are rounded off to the nearest whole number).

Fig.11a

Seasonal fluctuation in the numerical density (unit/l) of total phytoplankton in Station-IV (WIV) of Ward Lake. (September, 1976 to February, 1978)

Fig.11b

Seasonal variation in the percentage composition of phytoplankton in Station-IV (WIV) of Ward Lake. (September, 1976 to February, 1978)

Fig. 11a

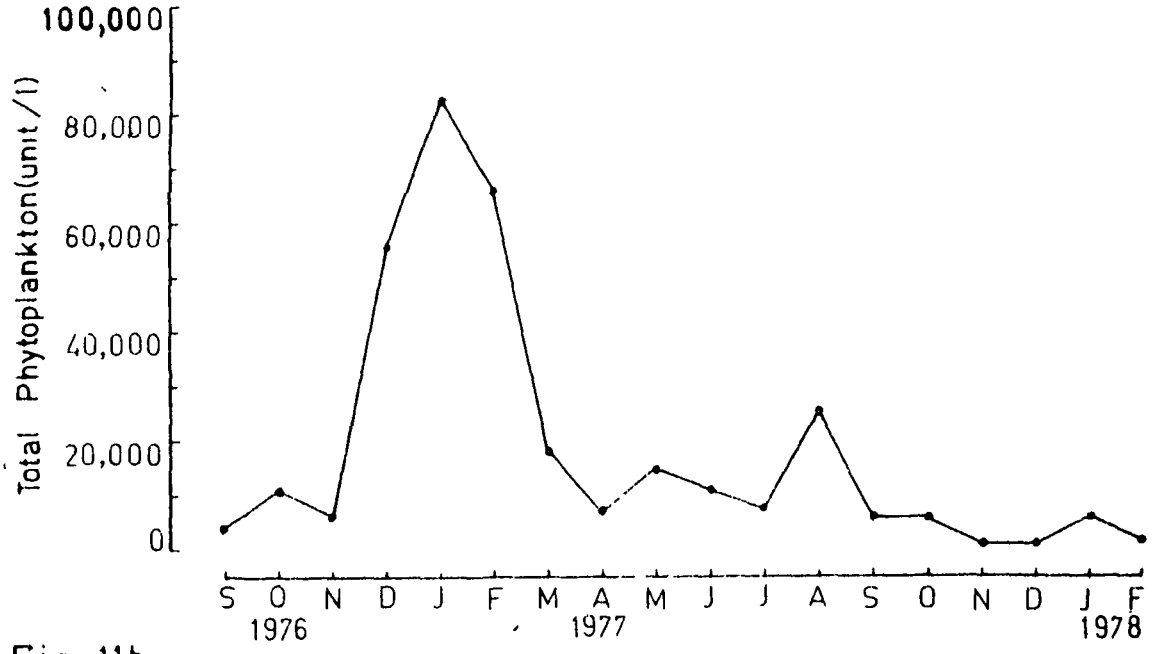
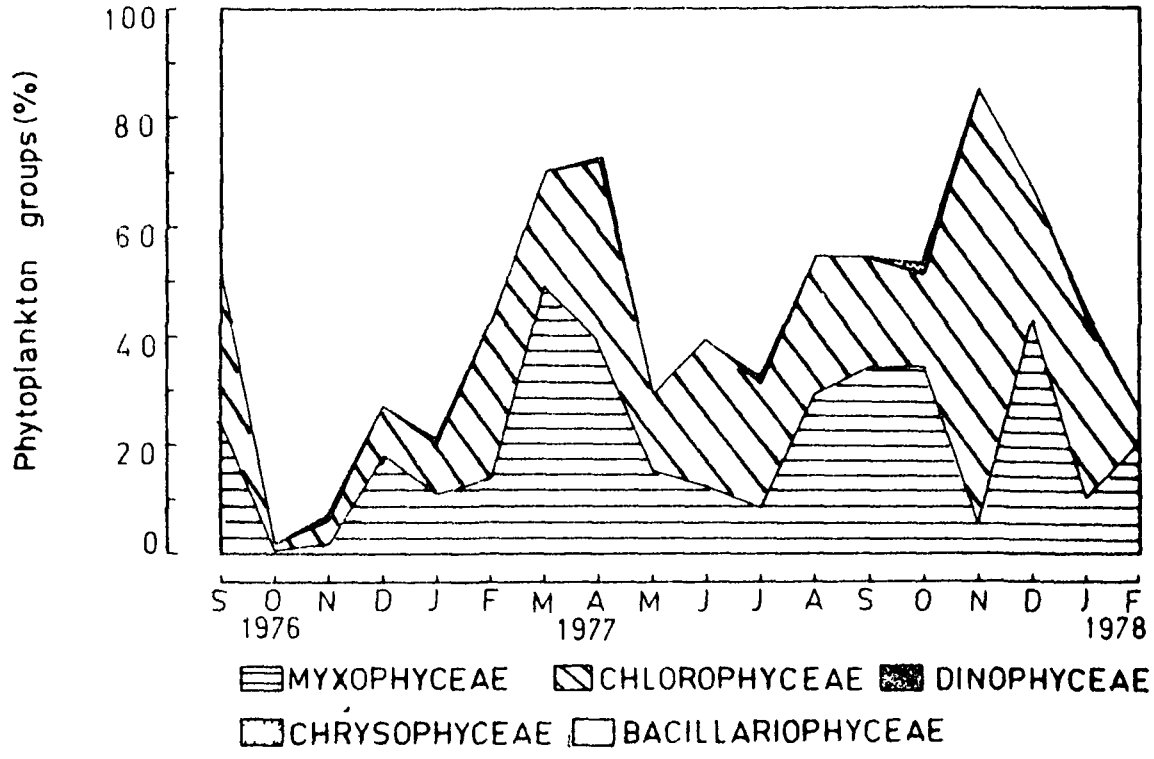


Fig. 11b



abundance was 66400.00 units/l (January, 1977) while only 180 units/l was recorded in November, 1977.

(b) Zooplankton :

Zooplankton always showed comparatively poor numerical density in WI (Table-41, Fig.12a) forming a maximum of 21.50% (September, 1976) of total plankton. They formed only 0.44% in the month of November, 1977. Highest numerical density recorded in this station was 921.34/l in September, 1976 while the lowest was 123.67/l observed during August, 1977.

In WII (Table-42, Fig.13a) highest and lowest densities of zooplankton were 1913.75/l and 169.99/l recorded during April, 1977 and February, 1977. During maximum abundance (April, 1977) they formed 46.23% of the total plankton. Their lowest contribution was in November, 1976 forming only 0.80% of the total plankton. December, 1976 also exhibited a higher density of zooplankton (1714.99/l).

Total zooplankton in Station WIV (Table-44, Fig.15a) showed the peak value which formed 25.48% of total plankton. February, 1978 on the other hand, showed their minimum abundance, the number being 58.00/l zooplankton formed 47.57% of total plankton in November, 1977 and only 0.14% in January, 1977. The different organists contributing to the total zooplankton have been dealt with groupwise.

Protozoa : A maximum of 640/l has been recorded in WI (Table-41, Fig.12b) in the month of January, 1978 while the minimum density was found in November, 1976 with 2.33/l.

Maximum and minimum percentage composition of protozoans were 85.62% and 1.14% encountered during January and February, 1978 respectively.

Protozoans were not recorded (Table-42, Fig.13b) during October, 1976, December, 1977, January, 1978 and February, 1978 in WII. Their maximum abundance was recorded in January, 1977 with 650/l and the lowest density was in July, 1977 when 8.25/l was recorded. In this station protozoans contributed to as much as 92.72% in January, 1977 and only 0.97% in September, 1976 which was the minimum.

In WIII (Table-43, Fig.14b) protozoans were recorded during the entire study period. The peak in number was seen in April, 1977 (1830.25/L) forming 95.64% of the total zooplankton. The minimum number of protozoans recorded was 4.0/l during November, 1976. Their least contribution to total zooplankton was 0.33% in the month of December, 1976.

The highest number of protozoans recorded in WIV (Table-44, Fig.15b) was in October, 1976 (157.75/l) whereas November, 1976 showed their lowest abundance (2.50/l). Protozoans formed 55.54% of the total zooplankton in May, 1977 while their lowest contribution was 0.58% in November, 1977.

Rotifera : In WI (Table-41, Fig.12b) rotifers were present throughout the 18 months study period. They occurred in highest numbers in the month of December, 1977 (257/l) and the lowest density was in August, 1977 (12.66/l). Rotifers formed 53.17%

of the total zooplankton in March, 1977 and 2.34% in January, 1978.

In WII (Table-42, Fig.13b) highest recorded number of rotifers was 222.50/l seen in the month of December, 1977 and the lowest value was 6.50/l in September, 1976. Highest percentage composition was 86.59% in February, 1978 and only 8.63% in the month of September, 1976.

In WIII of Ward Lake, rotifers were totally absent in the collections of November, 1976 (Table-43, Fig.14b). The minimum and maximum number of rotifers were observed during December, 1976 and April, 1977 contributing 1663.99 and 9.25 units/litre. The highest and lowest percentage contributions were 97.03% (December, 1976) and 0.48% (April, 1977) respectively. They formed more than 20% of the total zooplankton throughout the season except in April, 1977.

Rotifers were not recorded in WIV (Table-44, Fig.15b) during September, 1976 and December, 1977. Density of rotifera, in this station was rather low and the highest number recorded ever was 103.00/l while the lowest number was 6.75/l in October, 1976. They formed 58.55% of total zooplankton in January, 1978 and their lowest contribution was 1.03% in November, 1977.

Ostracoda : In WI (Table-41, Fig.12b) ostracods were not recorded throughout the study period and thus absent in February, 1977, 1978, July, 1977, October, 1977 and November, 1977. Their highest density was recorded in Sepetember, 1976 with

14.67 units/l and lowest in June, 1977 when only 0.25 animals/l were present. They formed 6.44% of total zooplankton in October, 1976 and only 0.04% in January, 1977.

Ostracods were never recorded throughout the seasons in WII (Table-42).

In WIII (Table-43,Fig.14b) ostracod population reached its peak in August, 1977 when 29.33 animals/l was recorded. They formed 9.14% of the total zooplankton in the same month. The lowest number observed was 0.67/l in May, 1977 forming only 0.19% of the total zooplankton. They were present throughout the study period.

In WIV, on the other hand, ostracods were absent during the months of February, May, October and November, 1977 (Table-44, Fig.15b). The highest numerical density attained by them was 83.00/l (September, 1976) and the lowest recorded was 0.50/l observed during July,1977. Their contribution to zooplankton was maximum in December, 1976 (11%) and lowest in July,1977 (0.17%).

Copepoda : Copepods were well represented in all the seasons in WI (Table-41,Fig. 12b). The maximum abundance was found during October, 1977 when the number was 125.50/l. The lowest value recorded was 16.33/l in August, 1977. Copepods formed 44.93% of the total zooplankton in November, 1977 and only 2.75% in September, 1976.

In WII (Table-42,Fig.13b) their highest count was

801.25/1 and lowest was 2.67/1 in September, 1976 and February, 1977 respectively. They formed a maximum of 65.85% in the total zooplankton in October, 1976 and only 0.39% in January, 1977.

Maximum number of copepods in WIII (Table-43, Fig.14b) was in the month of August, 1977 (29.33/l) forming 9.14% of the total zooplankton. On the other hand, only 5.0/l was recorded during January, 1978. They made the highest contribution of 21.75% during October, 1976 while only 0.72% in December, 1976.

In WIV (Table-44, Fig.15b) highest recorded number was 232.0/l in September, 1976 and the lowest value was 4.50/l in February, 1978. Highest percentage contribution of copepods was 23.49% and lowest was 0.72% recorded during the months of April, 1977 and December, 1977 respectively.

Cladocera : Cladocerans were present throughout the study period in WI (Table-41). Highest numerical density was recorded in February, 1977 (436/l) and formed 88.26% of the zooplankton population (Fig.22). Lowest number was recorded in January, 1977 with 16.8/l, while in terms of percentage they formed the least in January, 1978 (2.94%).

In WII (Table-42, Fig.22) cladocerans were absent in the month of June, 1977 and formed the highest numerical representation in September, 1977 with 226.00/l forming 61% of the total zooplankton. The lowest record in numbers per litre was 0.50 in November, 1977, the lowest of 0.32% in January, 1977.

Station-WIII also had a fair representation of

cladocerans throughout the study period. Their highest and lowest numbers were recorded in November, 1976 and July, 1977 when 131.50 and 21.0 units/l were observed. These organisms formed a maximum of 61.59% in November, 1976 and a minimum of 1.30% during December, 1976 (Table-43, Fig.22).

WIV showed a higher density of Cladocera (Table-44, Fig.22) with the maximum of 1084.50/l (November, 1977) forming 97.57% of the total zooplankton. The lowest number was observed in August, 1977 with 49.50 animals/l which was 4.24% of the total.

(c) Associated organisms :

Associated organisms included members of Nematoda, Sporoblasts of Bryozoa and members of Insecta. In WI (Table-41, Fig.12b) nematodes appeared for 10 out of the total of 18 months. Their highest numerical density was only 1.50/l (March, 1977), contributing 0.57% to total zooplankton. During the rest of the period their numbers never exceeded 1 animal per litre. In WII (Table-42, Fig.13b) nematodes were recorded only during the month of December, 1976 forming 0.18% of total zooplankton when the numerical density was 0.67/l. Except in the month of May and August, 1977, nematodes were always present in WIII (Table-43, Fig.14b). Maximum number recorded was 2.50/l (January, 1978) while they were only 0.25/l in April, 1977. Nematodes formed 0.98% of total zooplankton in February, 1977 and only 0.01% in April, 1977. In WIV (Table-44, Fig.15b)

nematodas were present throughout the major part of the study period except in the months of October, 1976, November, 1976 and September, 1977. The highest number recorded in February, 1977 was 18.00/l while the lowest was 0.50/l in November, 1977. They contributed 18.97% to the total zooplankton in February, 1978 and their lowest was 0.05% recorded in November, 1977.

In WI statoblasts of Bryozoa were recorded in the months of October, 1976, April, June and October, 1977. In none of these months they occurred in more than 1 unit/litre and highest contribution made by them was 0.25% to the total zooplankton (Table-41). Statoblasts were recorded only twice in plankton samples of WII. These were in September, 1976 (0.25/l; 0.02%) and November, 1976 (0.33/l; 0.17%) (Table-42). Although the contribution made by broyzoan sporoblast was never more thar 0.5%, they appeared on 10 occasions out of 18 months in WIII (Table-43). Their maximum number per litre was 1.60 found in January, 1977. In Station-WIV (Table-44) bryozoan sporoblasts were never recorded in the samples throughout the 18 months.

Insecta were mainly represented by members of family Chironomidae, Ephemeroptera, Odonata, Zygoptera and Coleoptera. In WI (Table-41) maximum number of insects were recorded in the month of September, 1976 (16.99/l) and the lowest number was observed in both December, 1976 (0.33/l) and May, 1977 (0.33/l). Their highest contribution to zooplankton counts was in August, 1977 forming 5.39% while the lowest being 0.04% in the month of December, 1976. Insects were recorded on three occasions in

Table-41 : Showing the seasonal fluctuations in the numerical density and percentage composition of different groups of Zooplankton and other associated organism in Station-I (WI) of Ward Lake.
(September, 1976 to February, 1978).

Month	Zooplankton										Associated organisms						Total (unit/l)
	Protozoa		Rotifera		Ostracoda		Copepoda		Cladocera		Nematoda		Bryozoan sporoblasts		Insecta		
	(U/l)	(%)	(U/l)	(%)	(U/l)	(%)	(U/l)	(%)	(U/l)	(%)	(U/l)	(%)	(U/l)	(%)	(U/l)	(%)	
1976																	
September	618	67.0	72	7.8	15	1.6	25	2.7	175	19	1	0.1	-	-	17	1.8	921
October	6	3.1	15	7.4	13	6.4	26	13	129	63.9	*	0.1	1	0.1	11	5.7	202
November	2	1.3	16	9.3	6	3.6	22	12.3	121	69.0	1	0.4	-	-	7	3.9	175
December	403	46.6	107	12.3	*	0.04	51	5.9	303	35.1	-	--	-	-	*	0.04	865
1977																	
January	256	64.0	107	26.85	*	0.2	17	4.2	17	4.2	-	-	-	-	2	0.4	400
February	8	1.7	28	5.7	-	-	18	3.6	436	88.2	-	-	-	-	3	0.7	494
March	52	19.7	140	53.2	*	0.1	25	9.6	43	16.5	1	0.5	-	-	1	0.3	264
April	49	24.5	41	20.6	*	0.2	56	28.4	51	25.5	*	0.2	*	0.1	1	0.4	199
May	312	73.9	15	3.6	1	0.2	61	14.5	32	7.7	-	-	-	-	*	0.1	421
June	83	37.8	44	20.0	*	0.1	49	22.4	42	19.0	-	-	*	0.1	1	0.56	220
July	103	44.3	24	10.2	-	-	34	14.6	69	29.6	*	0.1	-	-	3	1.2	233
August	38	31.0	13	10.2	2	1.3	16	13.2	47	38.2	1	0.5	-	-	7	5.4	124
September	32	8.6	21	5.7	4	1.1	46	12.2	266	70.5	1	0.3	-	-	7	1.8	378
October	102	18.5	66	12.1	-	-	125	22.8	253	45.9	*	0.1	1	0.1	2	0.3	550
November	30	12.6	65	27.1	-	-	108	44.9	32	13.4	*	0.2	-	-	4	1.6	241
December	316	34.7	257	28.2	3	0.3	37	4.1	297	32.6	-	-	-	-	1	0.1	911
1978																	
January	640	85.6	17	2.3	2	0.2	62	8.4	22	2.9	-	-	-	-	3	0.4	747
February	5	1.1	40	8.4	-	-	17	3.6	413	85.9	-	-	-	-	4	0.9	481

(U/l = Unit/litre; *density less than 0.5 unit/l; density figures given are rounded off to the nearest whole number)

Fig.12a

Seasonal fluctuation in the numerical density (No/l) of total zooplankton in Station-I (WI) of Ward Lake. (September, 1976 to February, 1978)

Fig.12b

Seasonal variation in the percentage composition of zooplankton in Station-I (WI) of Ward Lake. (September, 1976 to February, 1978)

Fig. 12a

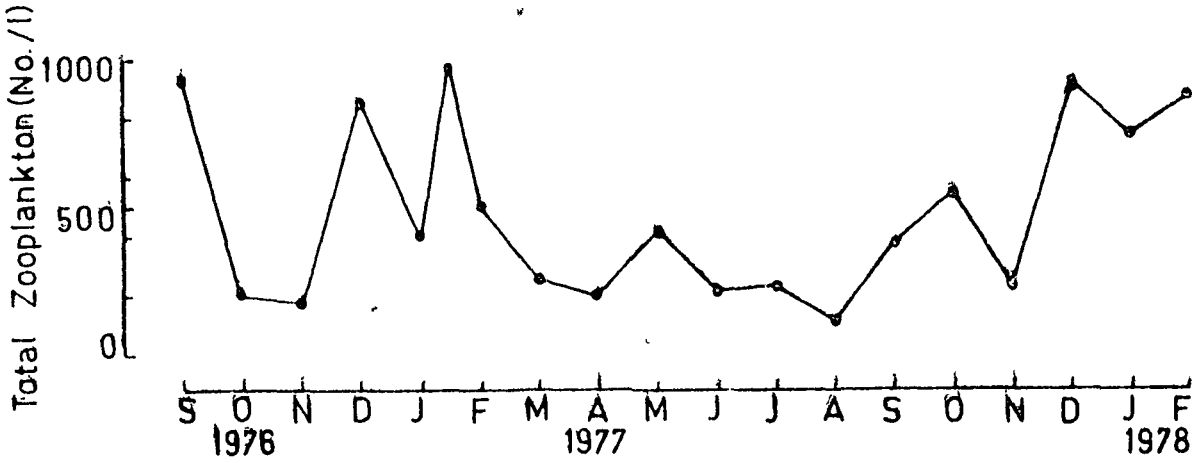


Fig. 12b

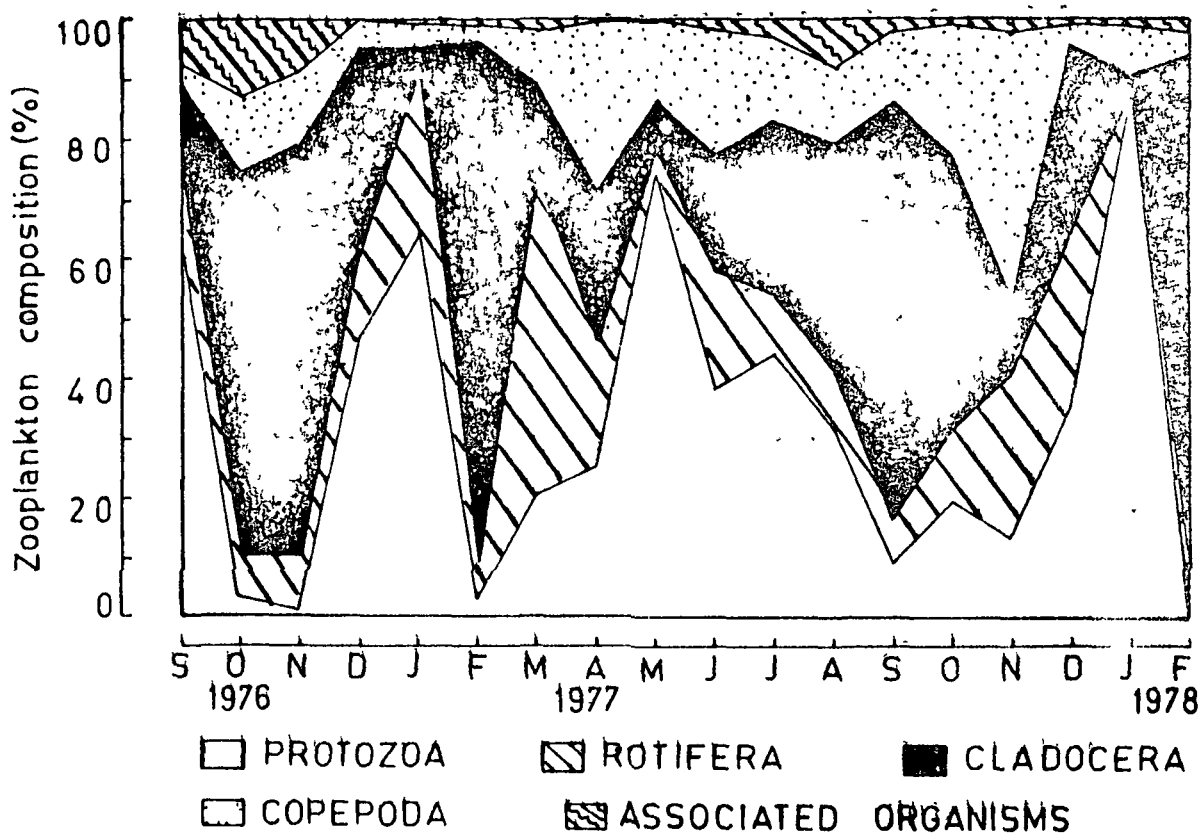


Table-42 : Showing the seasonal fluctuations in the numerical density (unit/l) and percentage composition of different groups of Zooplankton and other associated organism in Station-II (WII) of Ward Lake. (September, 1976 to February, 1978).

Month	Zooplankton										Associated organisms						Total
	Protozoa		Rotifera		Ostracoda		Copepoda		Cladocera		Nematoda		Bryozoan sporoblasts		Insecta		
	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(unit/l)
1976																	
September	10	1.0	6	0.6	-	-	801	78.0	209	20.3	-	-	*	0.02	-	-	1027
October	-	-	16	19.2	-	-	54	65.8	12	14.3	-	-	-	-	*	0.6	82
November	50	26.1	123	64.2	-	-	8	4.3	10	5.2	-	-	*	0.3	*	0.2	193
December	115	31.5	196	53.6	-	-	29	7.8	25	6.9	1	0.2	-	-	-	-	365
1977																	
January	650	92.7	46	6.6	-	-	3	0.4	2	0.3	-	-	-	-	-	-	701
February	29	42.7	32	47.1	-	-	3	3.9	4	6.3	-	-	-	-	-	-	69
March	18	30.4	25	43.0	-	-	9	15.2	6	11.0	-	-	-	-	*	0.4	99
April	204	48.7	181	43.2	-	-	31	7.3	3	0.8	-	-	-	-	-	-	418
May	11	12.2	70	74.6	-	-	11	11.6	1	1.5	-	-	-	-	-	-	94
June	59	28.4	140	67.7	-	-	8	3.9	-	-	-	-	-	-	-	-	207
July	8	26.4	14	44.0	-	-	8	27.2	1	2.4	-	-	-	-	-	-	31
August	9	3.8	182	77.8	-	-	42	17.9	1	0.4	-	-	-	-	-	-	234
September	30	8.1	77	20.9	-	-	37	10.0	226	61.0	-	-	-	-	-	-	370
October	25	21.2	49	41.5	-	-	40	33.9	4	3.4	-	-	-	-	-	-	118
November	33	50.8	25	38.6	-	-	6	9.8	*	0.7	-	-	-	-	-	-	66
December	-	-	222	69.7	-	-	61	19.3	35	11.0	-	-	-	-	-	-	319
1978																	
January	-	-	68	80.6	-	-	13	15.9	3	3.5	-	-	-	-	-	-	85
February	-	-	35	86.6	-	-	3	7.3	2	6.1	-	-	-	-	-	-	41

(u/l = Unit/litre; * density less than 0.5 unit/l; density figures given are rounded off to the nearest whole number).

Fig.13a

Seasonal fluctuation in the numerical density (No/l) of total zooplankton in Station-II (WII) of Ward Lake. (September, 1976 to February, 1978)

Fig.13b

Seasonal variation in the percentage composition of zooplankton in Station-II (WII) of Ward Lake. (September, 1976 to February, 1978)

Fig.13a

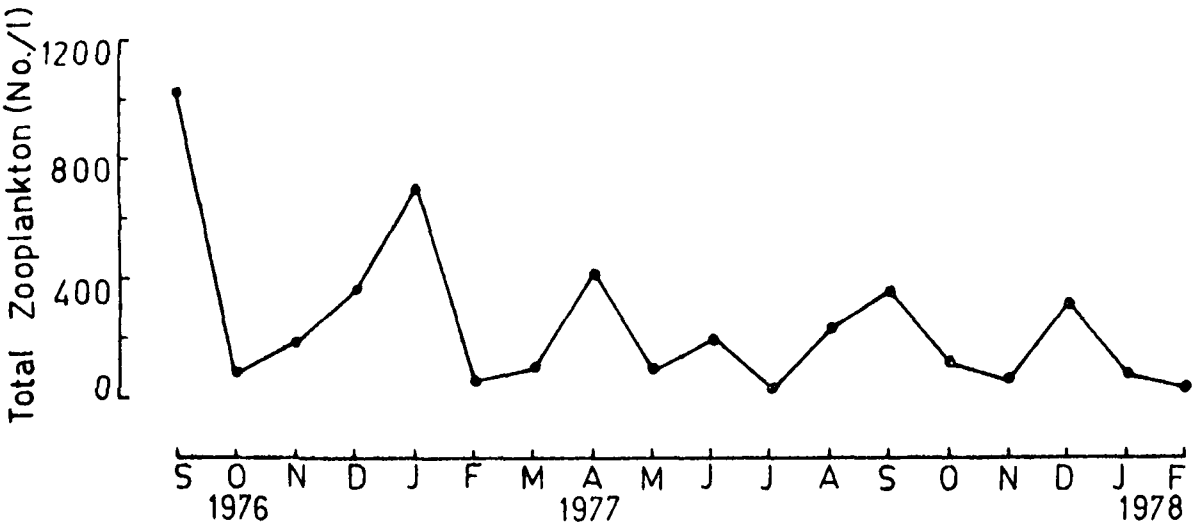


Fig.13b

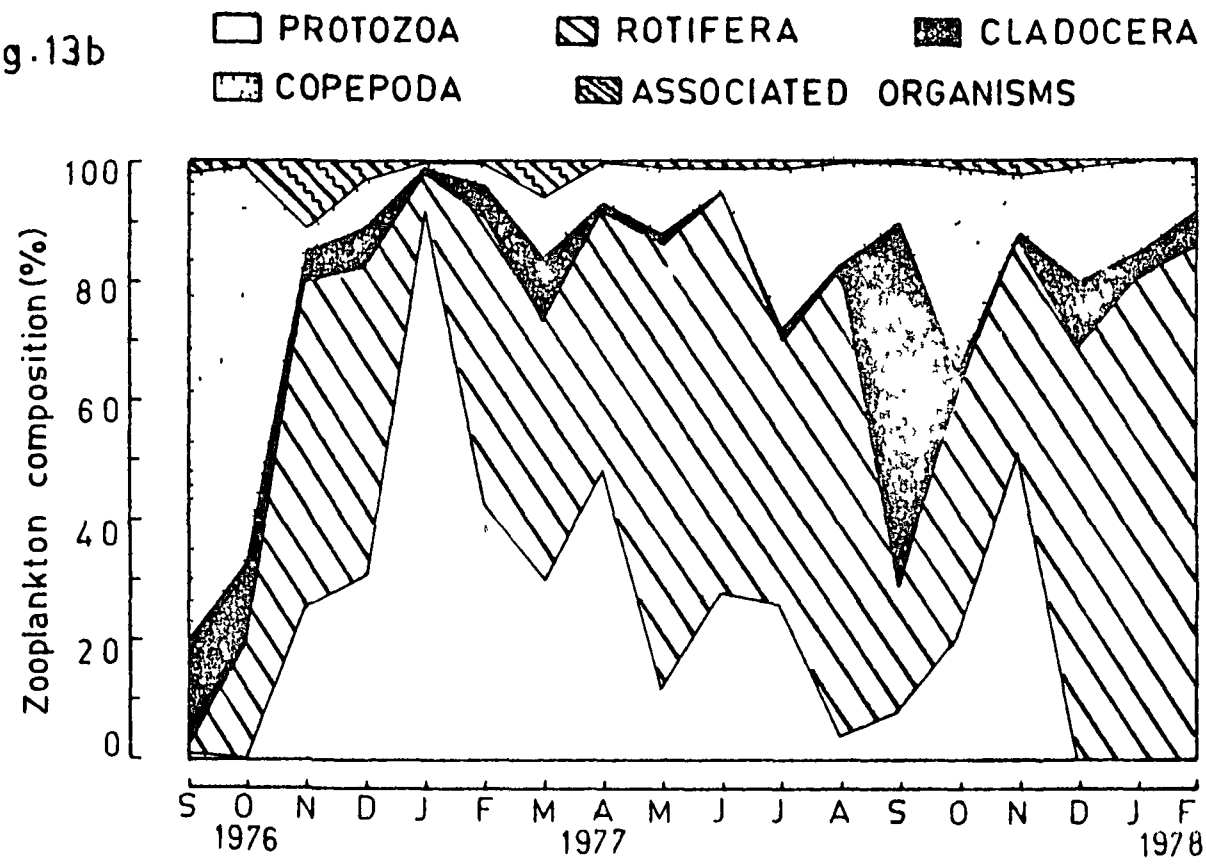


Table-43 : Showing the seasonal fluctuations in the numerical density (unit/l) and percentage composition of different groups of zooplankton and other associated organism in Station-III (WIII) of Ward Lake. (September, 1976 to February, 1978)

Month	Zooplankton										Associated organisms						Total
	Protozoa		Rotifera		Ostracoda		Copepoda		Cladocera		Nematoda		Bryozoan sporoblasts		Insecta		
	(i/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(unit/l)
1976																	
September	18	6.6	129	47.7	11	4.0	57	21.2	44	16.2	*	*	0.2	*	0.2	11	3.9	270
October	5	2.8	63	32.4	13	6.8	42	21.7	53	27.5	*	*	0.1	1	0.4	16	8.1	194
November	4	1.9	-	-	16	7.5	32	15.0	131	61.6	*	*	0.2	1	0.7	28	13.1	203
December	6	0.3	1664	97.0	4	0.2	12	0.7	22	1.3		1	0.1	-	-	6	0.4	1714
1977																	
January	172	39.7	218	50.5	1	0.3	6	1.4	28	6.5		1	0.3	2	0.4	4	0.9	432
February	37	21.8	75	44.1	1	0.8	6	3.5	47	27.6		2	1.0	*	0.2	2	1.0	170
March	94	12.4	563	74.1	5	0.7	30	3.9	63	8.3	*	*	0.7	-	-	3	0.5	759
April	1830	95.6	9	0.5	4	0.2	26	1.3	43	2.2		*	0.01	-	-	1	0.05	1914
May	149	41.7	85	23.9	1	0.2	75	21.1	43	12.1		*	0.2	-	-	3	0.8	357
June	167	42.5	112	28.6	2	0.5	72	18.4	32	8.2		2	0.6	1	0.4	3	0.8	393
July	173	46.8	82	22.2	5	1.3	86	23.2	21	5.7		2	0.5	-	-	1	0.3	370
August	52	16.1	96	30.0	29	9.1	89	27.6	45	14.1		-	-	1	0.2	9	2.9	321
September	34	9.2	175	46.7	11	2.9	67	17.9	75	19.9		*	0.1	1	0.5	10	2.8	376
October	37	8.5	287	66.2	2	0.5	74	17.0	24	5.6		*	0.1	-	-	8	1.9	434
November	32	15.3	54	25.8	7	3.6	28	13.6	75	36.1		*	0.2	-	-	11	5.2	209
December	15	2.9	464	87.0	6	1.1	13	2.5	29	5.5		1	0.2	-	-	4	0.7	534
1978																	
January	127	43.3	127	43.3	2	0.7	5	1.7	24	8.2		2	0.8	*	0.2	5	1.7	293
February	32	20.4	88	55.5	2	1.2	6	3.8	25	15.9		*	0.3	1	0.6	3	2.2	159

(u/l= Unit/litre; * density less than 0.5 unit/l; density figures given are rounded off to the nearest whole number)

Fig.14a

Seasonal fluctuation in the numerical density (No/l) of total zooplankton in Station-III (WIII) of Ward Lake. (September, 1976 to February, 1978)

Fig.14b

Seasonal variation in the percentage composition of zooplankton in Station-III (WIII) of Ward Lake. (September, 1976 to February, 1978)

Fig.14a

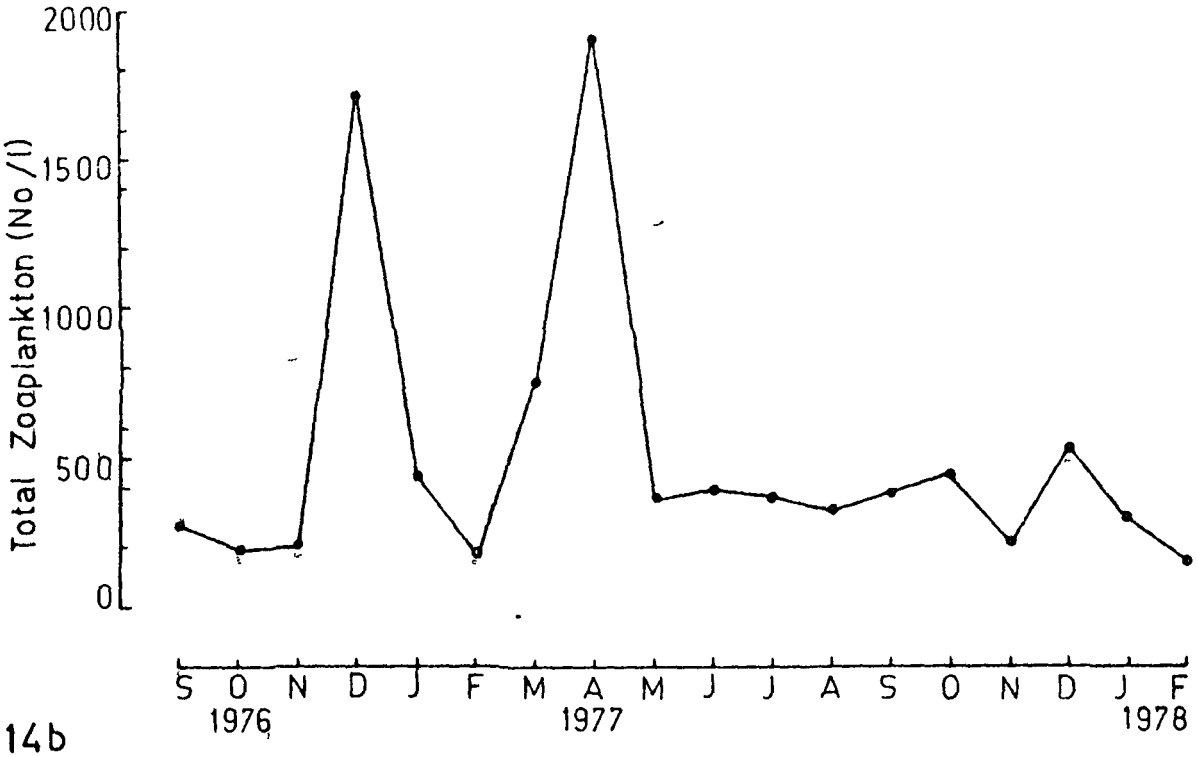


Fig.14b

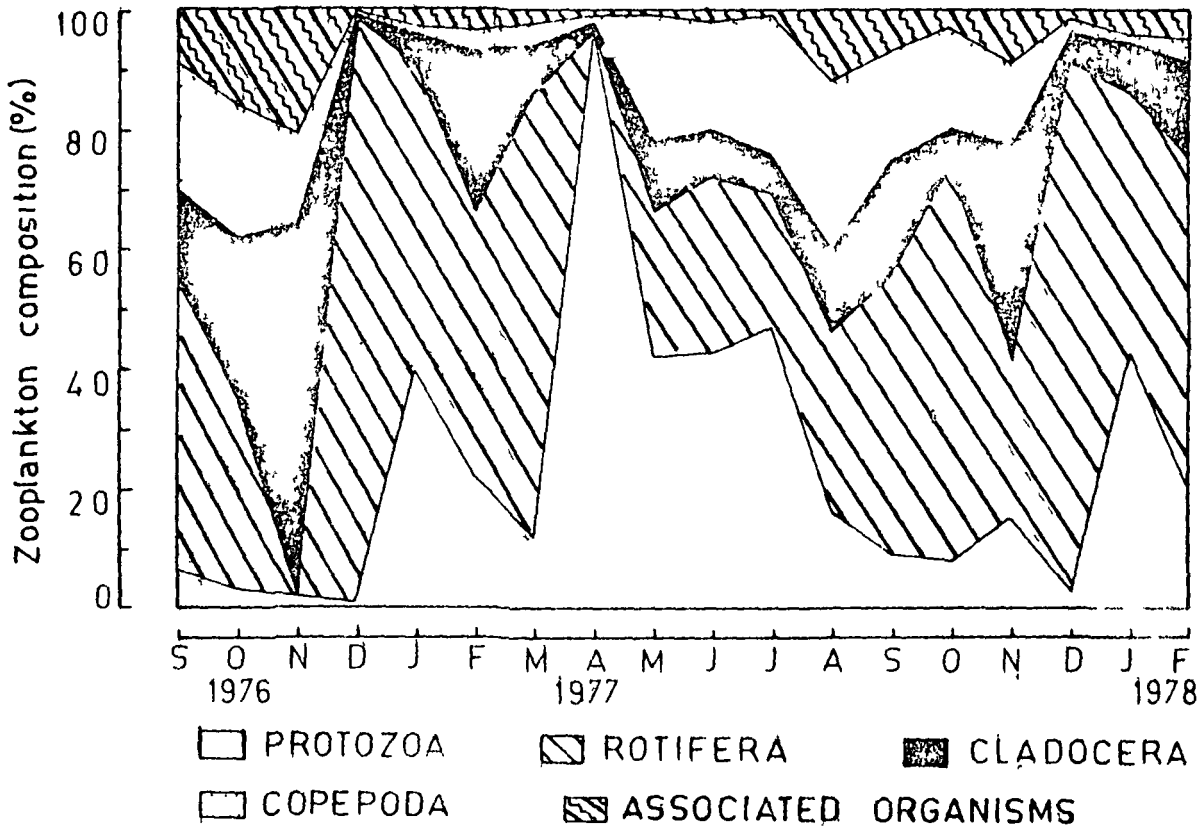


Table-44 : Showing the seasonal fluctuations in the numerical density (unit/l) and percentage composition of different groups of zooplankton and other associated organism in Station-IV (WIV) of Ward Lake.
(September, 1976 to February, 1978)

Month	Zooplankton										Associated organisms						Total
	Protozoa		Rotifera		Ostracoda		Copepoda		Cladocera		Nematoda		Bryozoan sporoblasts		Insecta		
	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(unit/l)
1976																	
September	140	10.4	-	-	83	6.2	232	17.2	878	65.2	1	0.1	-	-	12	0.9	1347
October	158	31.2	7	1.3	24	4.7	63	12.5	244	48.3	-	-	-	-	10	2.0	506
November	2	1.7	54	36.0	12	8.0	12	8.0	56	37.3	-	-	-	-	13	8.7	150
December	26	13.0	33	16.4	22	11.0	14	6.8	92	45.7	2	1.1	-	-	12	5.9	202
1977																	
January	24	20.3	44	37.5	1	0.8	9	7.3	28	23.7	6	5.1	-	-	6	5.3	117
February	30	21.0	24	16.8	-	-	8	5.6	61	42.7	18	13.0	-	-	2	1.4	143
March	21	7.8	87	32.8	4	1.5	16	6.1	117	44.3	6	2.2	-	-	14	5.4	265
April	32	19.6	18	11.1	3	2.2	38	23.5	60	36.9	5	3.1	-	-	6	3.5	162
May	132	55.5	26	11.1	-	-	11	4.5	53	22.4	6	2.5	-	-	9	3.9	238
June	111	48.8	56	24.5	3	1.3	15	4.6	32	14.2	4	1.6	-	-	6	2.6	228
July	110	38.5	31	11.0	*	0.2	41	14.2	89	31.0	7	2.3	-	-	6	2.0	287
August	41	41.1	24	23.7	1	1.5	19	19.2	4	4.2	6	6.5	-	-	2	2.2	100
September	132	39.0	103	30.5	2	0.6	34	10.1	62	18.5	-	-	-	-	4	1.3	338
October	101	37.6	28	10.4	-	-	29	10.9	102	37.8	4	1.7	-	-	4	1.7	270
November	6	0.6	11	1.0	-	-	8	0.7	1084	97.6	*	0.05	-	-	*	0.05	1111
December	34	4.6	-	-	18	0.4	19	2.6	668	88.4	3	0.5	-	-	12	1.6	756
1978																	
January	12	10.7	68	58.5	2	2.1	4	3.8	9	7.7	16	13.7	-	-	4	3.4	117
February	21	37.1	8	13.8	1	1.7	4	7.8	10	17.2	11	19.0	-	-	2	3.4	58

(u/l = Unit/litre; * density less than 0.5 unit/l; density figures given are rounded off to the nearest whole number).

Fig.15a

Seasonal fluctuation in the numerical density (No/l) of total zooplankton in Station-IV (WIV) of Ward Lake. (September, 1976 to February, 1978)

Fig.15b

Seasonal variation in the percentage composition of zooplankton in Station-IV (WIV) of Ward Lake. (September, 1976 to February, 1978)

Fig.15a

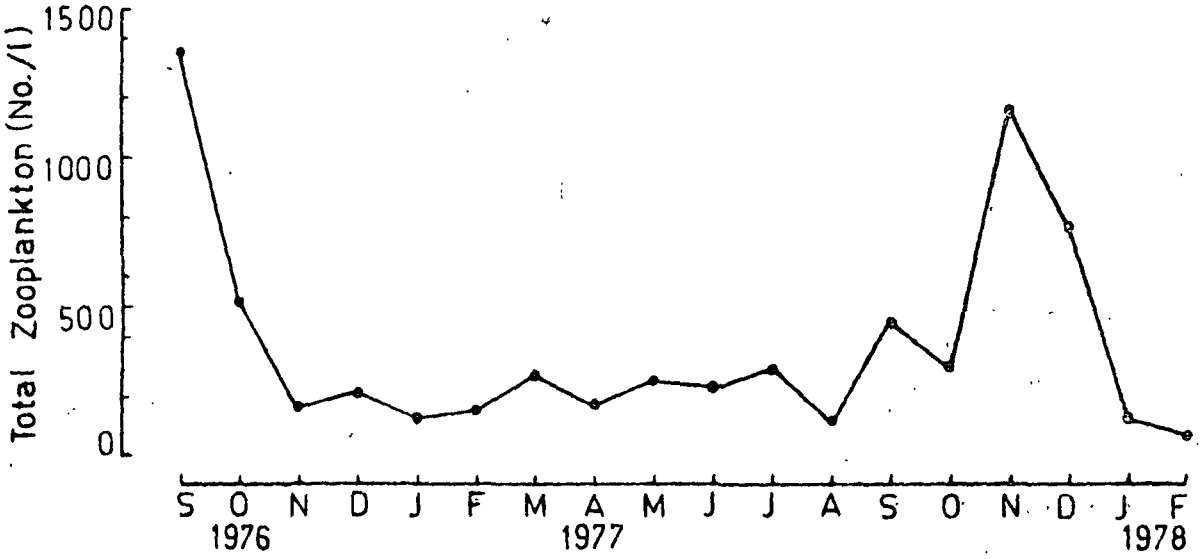
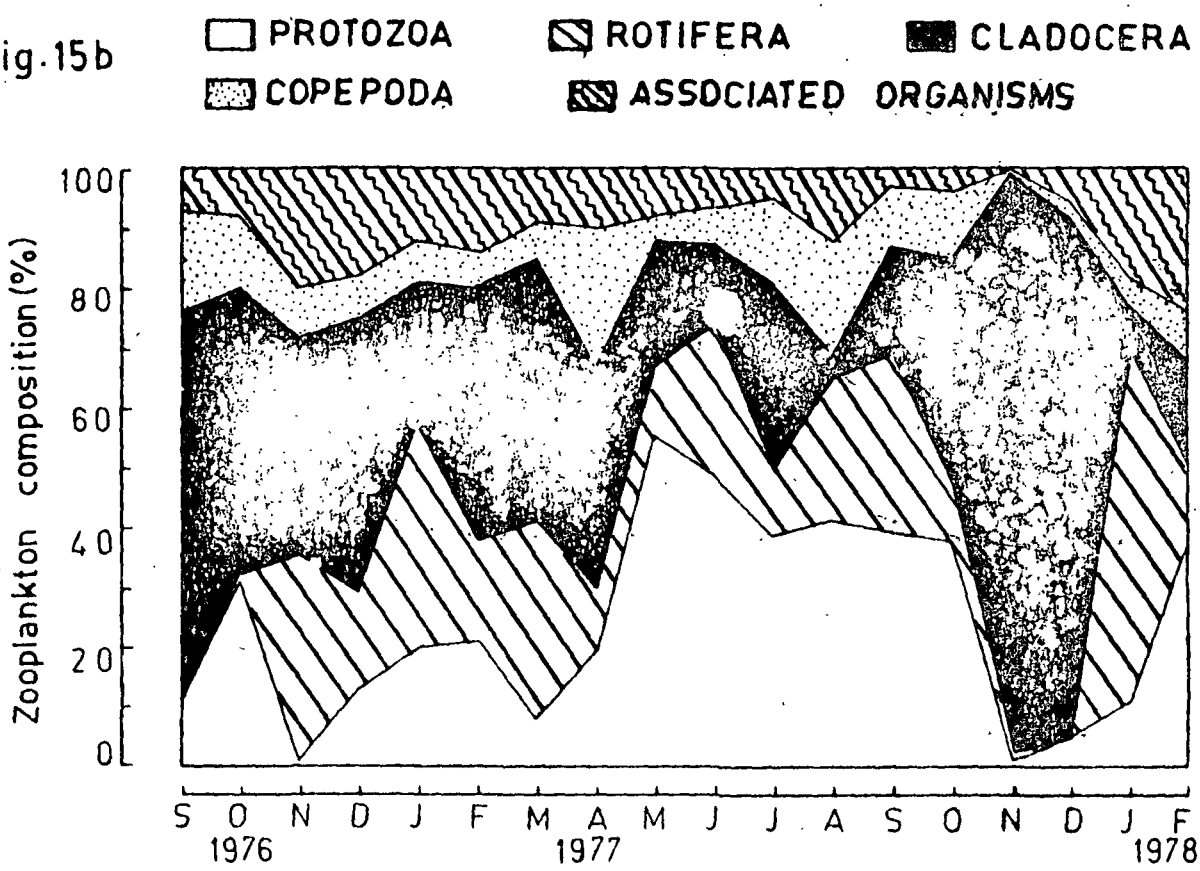


Fig.15b



WII (Table-42) forming 0.61% (October, 1976), 0.17% (November, 1976) and 0.42% (March, 1977) of the total counts. This group was always represented in WIII (Table-43). The highest and lowest recorded numbers were 28/l (November, 1976) and 1.0/l (April, 1977) forming 13.11% and 0.05% respectively. In WIV, on the other hand, highest number of insects were recorded in March, 1977 (14.25/l), while the lowest was in November, 1977 (0.50/l). They formed a maximum of 8.67% of total zooplankton counts in the month of November, 1976 (Table-44).

II. FISH DALE POND :

A. PHYSICOCHEMICAL PARAMETERS :

Temperature :

Air : Highest recorded atmospheric temperature was in July, 1977 with 25.17°C. The lowest value, on the other hand, was during January, 1978 when the atmospheric temperature was 11°C. Except in the months of December, January and February, air temperature ranged between 18° - 25°C (Table-45).

Water : Water temperature in this system never exceeded that of the atmosphere. The highest record of surface water temperature was 24°C in August, 1977 while the lowest value was 9°C observed during January, 1978 (Fig.16).

Hydrogen ion concentration (pH) :

Seasonal variations in pH has been shown in Table-45 and Fig.16. pH value was always in the acidic range excepting

in July, 1977 when it became slightly alkaline with 7.18 units. January, 1978 showed the lowest value of 5.90 which was unlike that of January, 1977 (6.64). During the 18 months study period, September, 1976 onwards, there was a gradual rise in pH value till January, 1977 (6.64), followed by a decrease during February and March, 1977 only to increase again in April, 1977 reaching the value of 6.87. May and June, 1977 showed comperably lower values which suddenly rose to 7.18 in July, 1977. The other maxima of pH value in this system was in December, 1977 with a value of 6.75.

Conductivity :

Conductivity values (Table-45, Fig.16) of Fish Dale pond showed two maxima in addition to the peak value in March, 1977 with 110.87 /umhos/cm. Lowest conductivity value was in October, 1977 when 31.63 /umhos/cm was recorded. October, 1976 showed a comparatively lower value (32.12 /umhos/cm) which gradually rose in the following months to reach the highest value of 110.87 /umhos/cm in March, 1977. Subsequent months again showed a steady fall in conductivity values reaching 39.06 /umhos/cm in June, 1977. The two other maxima recorded were in July and December, 1977 with 63.53 /umhos/cm and 61.95 /umhos/cm respectively.

Dissolved oxygen :

Results on the analysis of dissolved oxygen content has been presented in Table-45, Fig.16. Highest oxygen was

recorded in August, 1977 with a concentration of 10.11 mg/l, while the lowest value was 5.24 mg/l in January, 1978. In September, 1976 oxygen concentration was only 5.72 mg/l, which increased gradually to reach the value of 8.35 mg/l in January, 1977. The maximum concentration was attained in the month of August, 1977, followed by a sharp decline in September, 1977 (10.11 mg/l to 6.71 mg/l) only to gradually increase till December, 1977. January and February, 1978 recorded only 5.24 mg/l and 5.84 mg/l respectively.

Free carbon dioxide :

Free carbon dioxide exhibited a fluctuating nature during the study period showing five distinct maxima (Table-45, Fig.16). These were in September, 1976 with 8.35 mg/l, December, 1976 with 7.45 mg/l, March, 1977 showing 9.05 mg/l, May 1977 containing 8.40 mg/l and August, 1977 with 7.13 mg/l. Carbon dioxide values declined steadily reaching the lowest of 2.89 mg/l in December, 1977.

Alkalinity :

This system had a comparatively low alkalinity range as shown in Table-45 and Fig. 16. However, there were three maxima of methyl orange alkalinity (bicarbonate) observed during the study and the peak value was in the month of July, 1977 with 38.6 mg/l. A value of 8.20 mg/l alkalinity (hydride and carbonate) was also recorded during July, 1977 making, thus, a total alkalinity value of 40.85 mg/l. During the rest of the

study period the alkalinity was due to the presende of bicarbonates only. The other two maxima were in Mafch, 1977 and January, 1978 with 37.00 mg/l and 37.60 mg/l respectively. The lowest alkalinity value recorded was 10.13 mg/l in November, 1976.

Phosphate :

Phosphate content due to inorganic PO_4-P in Fish Dale pond was found to be the highest in April, 1977 when the concentration was 1.43 mg/l (Table-45,Fig.16). From December, 1976 to February, 1977, on the other hand a concentration of less than 0.37 mg/l was seen while the lowest reading was that of August, 1977 when a considerable increase in phosphate content reaching 0.89 mg/l. During the remaining months no marked variation was observed.

Nitrate :

Nitrate content as NO_3-N showed considerable variations during the different seasons and the data has been presented in Table-45,Fig.16. There were three distinct modes in nitrate content with the peak value in May, 1977 when a concentration of 1.5 mg/l was found. The lowest concentration was in September, 1976 with only 0.11 mg/l. The two other higher values of nitrate were 1.07 mg/l and 1.20 mg/l seen in the months of January,1977 and 1978 respectively. Monthly fluctuations in nitrate contents were not so high during the rest of the study period.

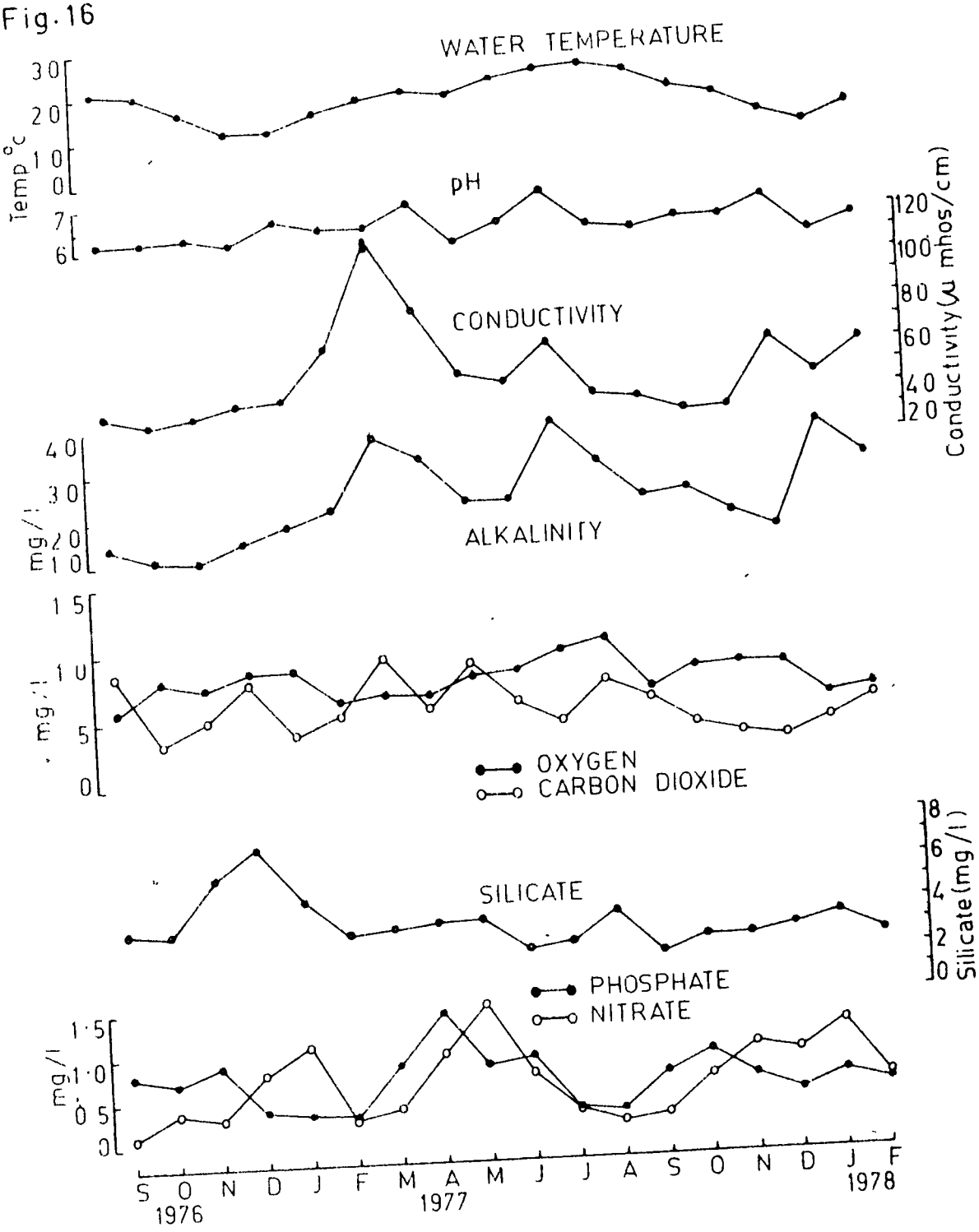
Table-45 : Showing seasonal changes in the physicochemical factors of Fish Dale pond. (September, 1976 to February, 1978)

Month	Temperature °C		pH	Conductivity (umhos/cm)	Dissolved oxygen (mg/l)	Carbon dioxide (mg/l)	Alkalinity (mg/l)	Phosphate (mg/l)	Nitrate (mg/L)	Silicate (mg/l)
	Air	Water								
1976										
September	22.00	20.88	6.16	36.75	5.72	8.35	13.55	0.79	0.11	3.62
October	22.13	20.13	6.18	32.35	7.89	3.35	11.10	0.73	0.38	3.43
November	19.00	16.00	6.24	36.12	7.45	4.93	10.13	0.87	0.31	5.74
December	14.50	11.25	6.16	39.95	8.37	7.45	14.20	0.36	0.79	7.24
1977										
January	16.25	11.25	6.64	40.48	8.35	3.85	17.50	0.36	1.07	4.78
February	18.67	15.33	6.40	64.23	5.83	5.00	21.20	0.31	0.25	3.22
March	22.38	17.63	6.43	110.87	6.42	9.05	37.20	0.83	0.35	3.34
April	21.20	18.40	6.87	80.34	6.09	5.40	32.64	1.43	0.94	3.62
May	19.50	18.25	6.05	51.53	7.38	8.40	23.20	0.79	1.50	2.64
June	22.38	21.38	6.41	39.06	8.23	5.40	23.35	0.89	0.70	2.33
July	25.17	22.83	7.18	63.53	9.49	4.05	38.65+8.2	0.32	0.30	2.55
August	24.25	24.00	6.30	40.04	10.11	7.13	29.87	0.29	0.15	3.95
September	22.00	21.50	6.21	38.95	6.71	5.53	22.20	0.68	0.22	2.11
October	20.50	17.75	6.38	31.63	7.82	3.70	23.10	0.89	0.61	2.64
November	18.50	15.75	6.41	32.71	8.02	3.20	18.20	0.69	0.98	2.63
December	15.00	12.00	6.75	61.95	8.00	2.80	14.40	0.42	0.85	3.10
1978										
January	11.00	9.00	5.90	47.15	5.24	3.80	37.60	0.59	1.20	3.51
February	14.05	13.25	6.30	59.06	5.84	5.20	29.70	0.47	0.56	2.64

Fig.16

Seasonal variation in the physicochemical factors of Fish Dale pond during September, 1976 to February, 1978.

Fig.16


WATER TEMPERATURE
Temp °C
30
20
10
0
pH
7
6
CONDUCTIVITY
120
100
80
60
40
20
Conductivity (μ mhos/cm)
ALKALINITY
mg/l
40
30
20
10
15
10
5
0
OXYGEN
CARBON DIOXIDE
SILICATE
8
6
4
2
0
Silicate (mg/l)
PHOSPHATE
NITRATE
1·5
1·0
0·5
0
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Silicate :

In Fish Dale Pond, the amount of silicate, did not exhibit much seasonal fluctuation, the highest amount being 7.24 mg/l in December, 1976. The lowest concentration was 2.11 mg/l in September, 1977. During the remaining period of the investigation silicate values ranged between 2 to 4 mg/l (Table-54, Fig.16).

B. BIOLOGICAL CHARACTERISTICS :

Biological characteristic was studied under the categories of phytoplankton, zooplankton and associated organisms.

(a) Phytoplankton :

The highest numerical density of phytoplankton was recorded in May, 1977 when a total of 43275 units/l was found which formed 99.77% of the total plankton. The lowest phytoplankton density was in November, 1976 with only 823 units/l while the lowest percentage contribution was in December, 1976 with 67.08%. During November, 1976, December, 1977 and January, 1978 also had a density of less than 1000 units/l was observed (Table-46, Fig.17a).

Seasonal fluctuation in different groups of phytoplankton in Fish Dale pond have been shown in Table-46.

Myxophyceae : In this pond myxophyceae density was considerably low as shown in Fig.17b. Both in February, 1977 and 1978

myxophytes were altogether absent while their highest density was in July, 1977 with 473 units/l. Lowest abundance of these algae were in January, 1977 with only 2.40 units/l. Maximum contribution made by these algae to total phytoplankton was 24.03% in October, 1976, while the lowest was 0.01% in May, 1977.

Chlorophyceae : Chlorophyceae was the most dominant group of phytoplankton appearing throughout the study period (Fig.17b). Their highest numerical density was 39770 units/l in May, 1977 while the lowest was 158 units/l during September, 1976. Maximum and minimum percentage contributions of 98.34% and 5.85% were recorded in September, 1977 and September, 1976 respectively (Fig.17b).

Dinophyceae : Out of the total of 18 months study period, dinophyceae was recorded during only 9 months, these being September and December, 1976, January, March, June, July, August, September and November, 1977. Highest numerical density was 254 units/l in June, 1977 while the lowest was 4 units/l recorded during September, 1977. They contributed a maximum of 5.45% in March, 1977 and only 0.05% in July, 1977 to the total phytoplankton (Fig. 17b).

Chrysophyceae : Chrysophyceae appeared from November, 1976 to February, 1977. During the rest of the period they were not recorded in the plankton samples. Among these months chrysophyceae was highest in density during November, 1977 with 320 units/l. The lowest density was recorded in December, 1977 with 9 units/l. Highest and lowest percentage contributions made by these algae

Table-46 : Showing the seasonal fluctuations of different phytoplanktonic groups and their percentage composition in Fish Dale pond.
(September, 1976 to February, 1978)

Month	Myxophyceae		Chlorophyceae		Dinophyceae		Chrysophyceae		Bacillario-phyceae		Total phytoplankton
	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)
1976											
September	83	5.04	158	5.85	10	0.61	-	-	1462	88.50	1652
October	428	24.03	329	18.49	-	-	-	-	1023	57.46	1781
November	11	1.37	216	26.33	-	-	15	2.59	580	40.47	823
December	23	1.08	1039	48.29	34	1.61	136	6.32	919	42.70	2152
1977											
January	2	0.22	531	47.69	30	2.73	21	1.87	534	47.66	1115
February	-	-	1616	75.63	-	-	120	5.62	401	18.75	2137
March	35	2.38	931	63.41	80	5.45	-	-	422	28.75	1468
April	66	0.73	8529	94.10	-	-	-	-	469	5.17	9066
May	5	0.01	39770	91.90	-	-	-	-	3500	8.09	43275
June	28	0.10	25999	98.28	254	0.96	-	-	176	0.66	26455
July	472	2.20	20368	95.00	10.	0.05	-	-	590	2.75	21441
August	87	0.70	12080	97.90	13	0.11	-	-	160	1.30	12340
September	45	0.68	6472	98.34	4	0.06	-	-	60	0.91	6581
October	20	0.97	1867	90.32	-	-	40	1.94	140	6.77	2067
November	120	5.44	1726	78.22	20	0.91	320	14.50	20	0.93	2206
December	58	7.07	149	18.07	-	-	8	1.03	611	73.84	827
1978											
January	18	1.87	178	18.09	-	-	15	1.52	775	78.52	978
February	-	-	2129	89.04	-	-	130	5.46	131	5.50	2391

(Unit/l values given are rounded off to the nearest whole number).

Fig.17a

Seasonal fluctuation in the numerical density (unit/l) of total phytoplankton in the Fish Dale pond. (September, 1976 to February, 1978)

Fig.17b

Seasonal variation in the percentage composition of phytoplankton in the Fish Dale pond. (September, 1976 to February, 1978)

Fig.17a

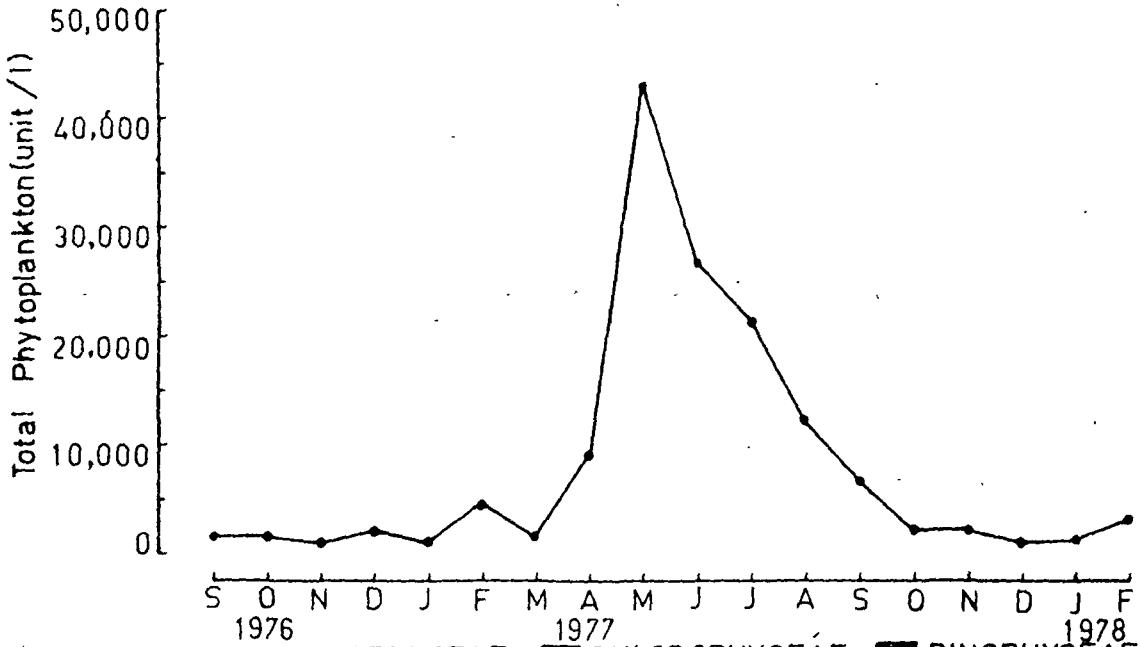
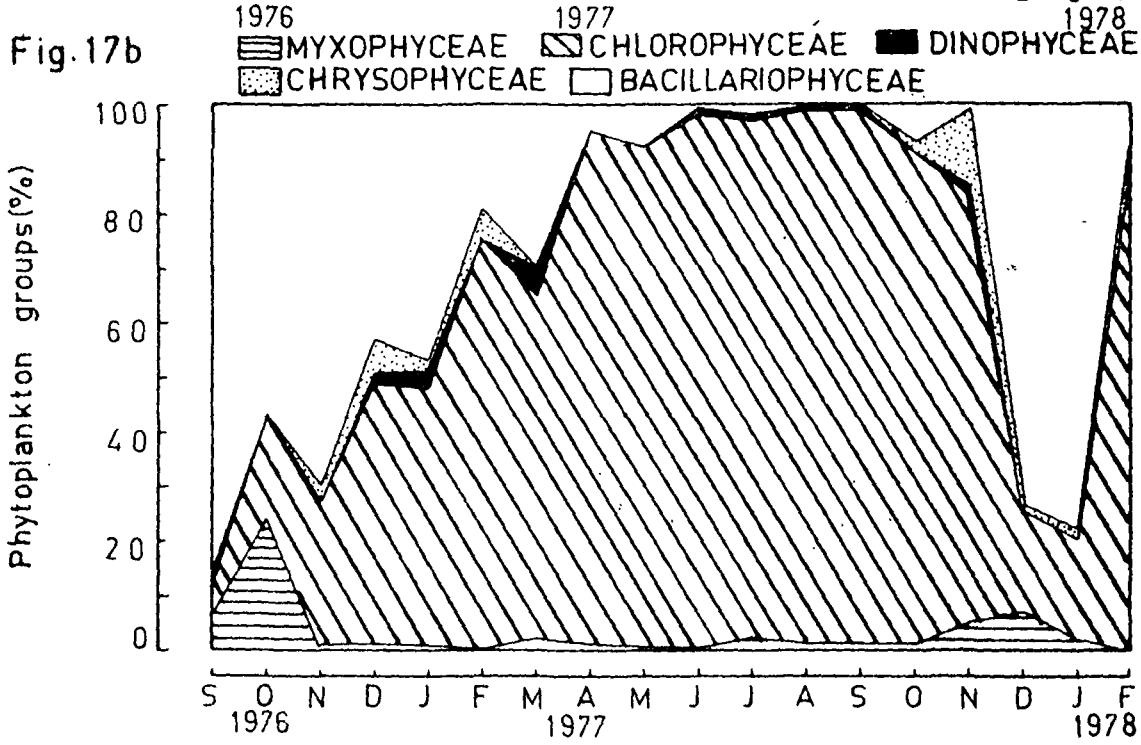


Fig.17b



were 14.50% (November, 1977) and 1.03% (December, 1977).

Bacillariophyceae : Highest density of bacillariophyceae was in May, 1977 with 3500 units/l while the lowest count/litre was 21 units in the month of November, 1977 (Fig.17b). On the other hand, highest contribution in percentage was 88.50% in September, 1976 and the lowest was that of September, 1976 when they contributed only 0.91% to the total phytoplankton.

(b) Zooplankton :

Total zooplankton numbers varied between 29 to 270 units/l throughout the study period except in December, 1976 when a peak of 1056 units/l was recorded (Table 47). The lowest numerical density was 29 units/l in November, 1977 . In the month of highest density, zooplankton formed 32.92% of the total plankton while the lowest contribution was 0.25% in May, 1977. Seasonal fluctuations in zooplankton have been shown in Fig.18a.

Protozoa : Protozoans were recorded throughout the study period in System-II as shown in Fig. 18b . The highest density of population was during the month of December, 1976 with 1007 units/l . Their lowest numerical abundance was in April,1977 (17 units/l). Highest and lowest contributions of protozoa to the total zooplankton were 95.33% and 11.04% recorded in December, 1976 and April, 1977 respectively.

Rotifera : In System-II numerical density of rotifers was highest in April, 1977 (129 units/l) which formed 34.76% of

the total zooplankton (Fig.18b). The lowest density was only 0.75 units/l observed during September, 1976. Rotifers contributed to 2.11% of the total zooplankton in December, 1976 and were totally absent in January, 1978.

Ostracoda : Seasonal fluctuations in ostracod density in System-II have been presented in Fig.18b. They were found during 8 months out of the total of 18 months study. Highest recorded number/litre was 4 during May, 1977 which formed 3.54% of the total zooplankton. During the rest of the months they were present as less as 1 unit/litre and contributed about 1.50% to total zooplankton. They were recorded during the periods of October to December, 1976, February to April, 1977, October and December, 1977.

Copepoda : In System-II highest copepod number was observed in September, 1977 (164 units/l) forming 63.13% of total zooplankton (Fig.18b). The lowest density was 1 unit/l found in the months of December, 1976, February and April, 1977. Their lowest contribution to zooplankton was 0.66% and were not recorded in November, 1977 and January, 1978.

Cladocera : Cladocerans were always present in System-II as shown in Fig.22. 130 animals/l was the maximum recorded density of cladocera, observed during July, 1977. Their lowest numerical density was in November, 1977 when only 2 units/l was present. A rise in density of these organisms was seen in February, 1978 with 74 units/l after a period of low density during November, 1977

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to January, 1978. Cladocerans formed 48.19% of total zooplankton in July, 1977 and only 1.74% in December, 1976.

C. ASSOCIATED ORGANISMS :

Due to their frequent occurrence in plankton samples, they were included in the study inspite of this groups being not strictly planktonic. In Fish Dale pond nematodes appeared during 9 out of 18 months of the study period. However, their monthly mean density was always less than 1 unit/l except in May, 1977 when they were as many as 20 units/l, forming 20% of the total zooplankton. During the rest of the period of their occurrence, they formed less than 1% of the total zooplankton (Table-47).

Bryozoan statocysts were encountered in plankton samples during November and December, 1976 and also in June, 1977. Their numerically mean density was below 1 unit/l which was less than 0.17% of the total zooplankton (Table-47).

In the present study insect belonging to Chironomidae Ephemeropta, Odnata, Zygoptera and coleoptera were included despite the fact that they are not truly planktonic. The highest recorded number was 6 units/1 (December, 1976) and the lowest was 0.20 units/l in April, 1977. The highest percentage contribution was 14.29% (September, 1976) while the lowest was 0.13% in April, 1977. They were absent in the months of June and July, 1977 and January and February, 1978 (Table-47).

Table-47 : Showing the seasonal fluctuations in the numerical density (unit/l) and percentage composition of different groups of zooplankton and other associated organism in Fish Dale pond.
(September, 1976 to February, 1978)

Month	Zooplankton										Associated organisms						Total
	Protozoa		Rotifera		Ostracoda		Copepoda		Cladocera		Nematoda		Bryozoan sporoblasts		Insecta		
	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(unit/l)
1976																	
September	21	63.9	1	2.2	-	-	3	8.3	3	8.3	*	0.7	-	-	5	14.3	33
October	55	71.3	4	4.8	1	0.8	1	1.6	13	17.4	*	0.6	-	-	2	3.2	77
November	67	68.4	5	5.4	1	0.8	4	4.6	16	16.8	-	-	*	0.3	4	4.1	98
December	1007	95.3	22	2.1	1	0.1	1	0.1	18	1.7	*	0.03	1	0.1	6	0.6	1056
1977																	
January	137	70.0	49	25.1	-	-	2	1.0	7	3.5	-	-	-	-	1	0.4	196
February	33	29.9	40	35.9	*	0.3	1	0.9	36	32.6	-	-	-	-	*	0.3	111
March	40	40.4	25	25.0	3	3.5	2	2.5	27	27.0	*	0.5	-	-	1	1.0	99
April	17	11.0	129	84.8	*	0.3	1	0.7	5	3.0	*	0.1	-	-	*	0.1	152
May	17	17.5	49	49.5	-	-	4	4.5	8	8.0	20	20.0	-	-	*	0.5	100
June	83	43.7	50	26.4	-	-	4	2.3	52	27.3	*	0.2	*	0.2	-	-	191
July	49	18.2	63	26.6	-	-	27	10.0	129	48.2	-	-	-	-	-	--	269
August	29	16.1	11	5.9	-	-	101	56.1	37	21.5	*	0.2	-	-	*	0.2	180
September	29	11.4	17	6.8	-	-	163	63.1	48	18.5	-	-	-	-	*	0.2	259
October	29	38.4	8	11.2	1	1.3	10	13.8	25	32.9	-	-	-	-	1	1.9	76
November	19	67.2	7	24.1	-	-	-	-	2	6.9	-	-	-	-	*	1.7	29
December	145	76.4	33	17.6	2	1.1	3	1.8	4	2.1	*	0.3	*	0.1	4	0.8	190
1978																	
January	36	83.7	-	-	-	-	-	-	7	16.3	-	-	-	-	-	-	43
February	24	20.0	19	16.2	-	-	2	2.1	74	61.7	-	-	-	-	-	-	120

(u/l= Unit/litre; * density less than 0.5 unit/l; density figures given are rounded off to the nearest whole number).

Fig.18a

Seasonal fluctuation in the numerical density (No/l) of total zooplankton in the Fish Dale pond.
(September, 1976 to February, 1978)

Fig.18b

Seasonal variation in the percentage composition of zooplankton in the Fish Dale pond.
(September, 1976 to February, 1978)

Fig.18a

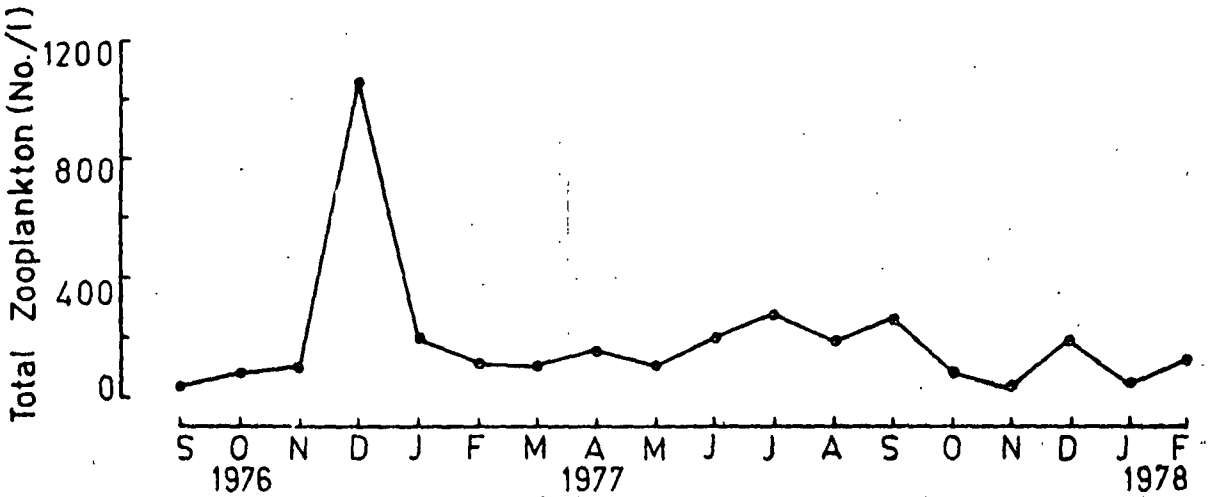
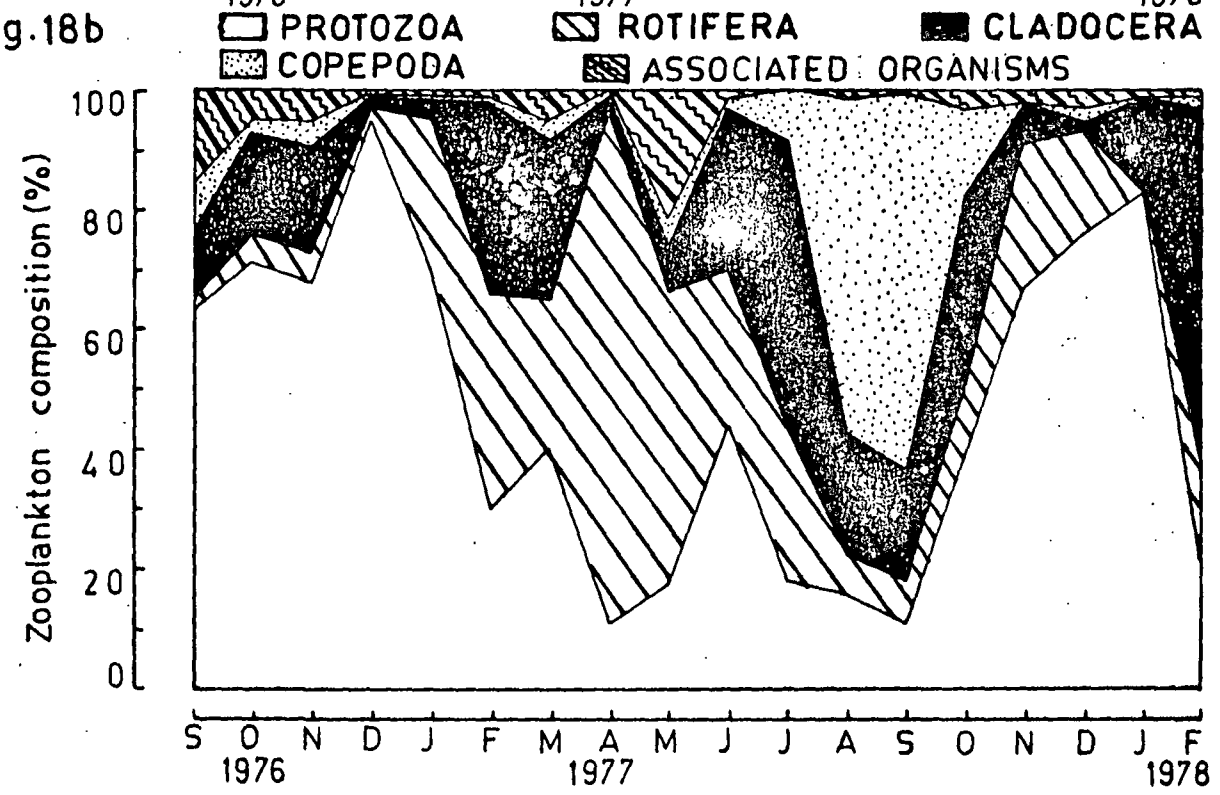


Fig.18b



III. LADY HYDERI PARK POND :

A. PHYSICOCHEMICAL PARAMETERS :

The physicochemical data for the period September, 1976 to February, 1978 has been presented in Table-48.

Temperature :

Air : The highest atmospheric temperature was recorded in July, 1966 when air temperature reached 24.66°C at the time of sampling. The lowest temperature value was that of January, 1978 with 12°C. The air temperature carve of this system was closely similar to those of Ward Lake and Fish Dale pond (Table-48).

Water : Surface water temperature (Fig.19) in this pond never exceeded air temperature with the highest value of 23.17°C in August, 1977 and lowest with 11°C in January, 1978. The water temperature curve followed more or less the same trend as that of the air temperature (Fig. 19).

Hydrogen ion concentration (pH) :

pH value ranged between 5.56 to 6.51 (Fig.19). The highest was (6.51) in July, 1977 and the lowest of 5.58 in January, 1978. During the whole period of study, three distinct maxima in pH values were recorded in the months of April, 1977 (6.40), July, 1977 (6.51) and December, 1977 (6.50).

Conductivity :

Seasonal fluctuations in conductivity in System-III

have been shown graphically in Fig. 19. Both March and December, 1977 showed higher conductivity values with the peak in March, 1977 having recorded 99.15 µmhos/cm. The lowest limit of conductivity was found in August, 1977 with 55.82 µmhos/cm. During the rest of the months, fluctuations in conductivity values were not very well marked.

Dissolved oxygen :

Fluctuations in dissolved oxygen content has been shown in Fig.19. The seasonal cycle was distinguished by 3 distinct maxima with the peak value in August, 1977 (9.04 mg/l). The lowest concentration was found to be 2.68 mg/l in March, 1977. Dissolved oxygen increased from September, 1976 onwards reaching 7.81 mg/l in January, 1977, forming the first peak. The second peak was in August, 1977 followed by a third higher value in January, 1978 with 8 mg/l which declined subsequently in February, 1978.

Free carbon dioxide :

The carbon dioxide values showed a more flunctuating nature ranging from 5.60 mg/l to 21.80 mg/l (Fig. 19). These lower and higher limits were in January, 1978 and May, 1977 respectively. During December, 1977 and January, 1978 carbon dioxide content was distinctly lower than that of other months.

Alkalinity :

In System-III, phenolphthalein alkalinity was never

recorded and therefore the alky was always due to methyl orange. The range of alkalinity values was 14.25 mg/l in October, 1976 to 49.15 mg/l in March, 1977. The months, September, October and November, 1976 showed a lower value of alkalinity, while during the remaining 15 months study period no such marked differences were noted. During August and September, 1977 there was a depression in alkalinity curve (Fig.19).

Phosphate:

The range of phosphate value was from 0.39 mg/l in November, 1976 to 1.21 mg/l in March, 1977 (Fig.19). The two other higher values of phosphates were 1.09 mg/l and 0.93 mg/l seen in April and June, 1977 respectively. During the rest of the months no marked seasonal trend could be seen in the phosphate values.

Nitrate :

The nitrate content showed a greater range of fluctuation varying between 0.10 mg/l in February, 1977 to 1.70 mg/l in May, 1977. October to December, 1977 showed a relatively higher value ranging between 0.68 and 0.79 mg/l. On the other hand, February, March and August, 1977 showed comparatively lower values (Fig.19).

Silicate :

In Lady Hyderi Park pond the highest concentration of silicate was 12.73 mg/l in January, 1977 while the lowest was

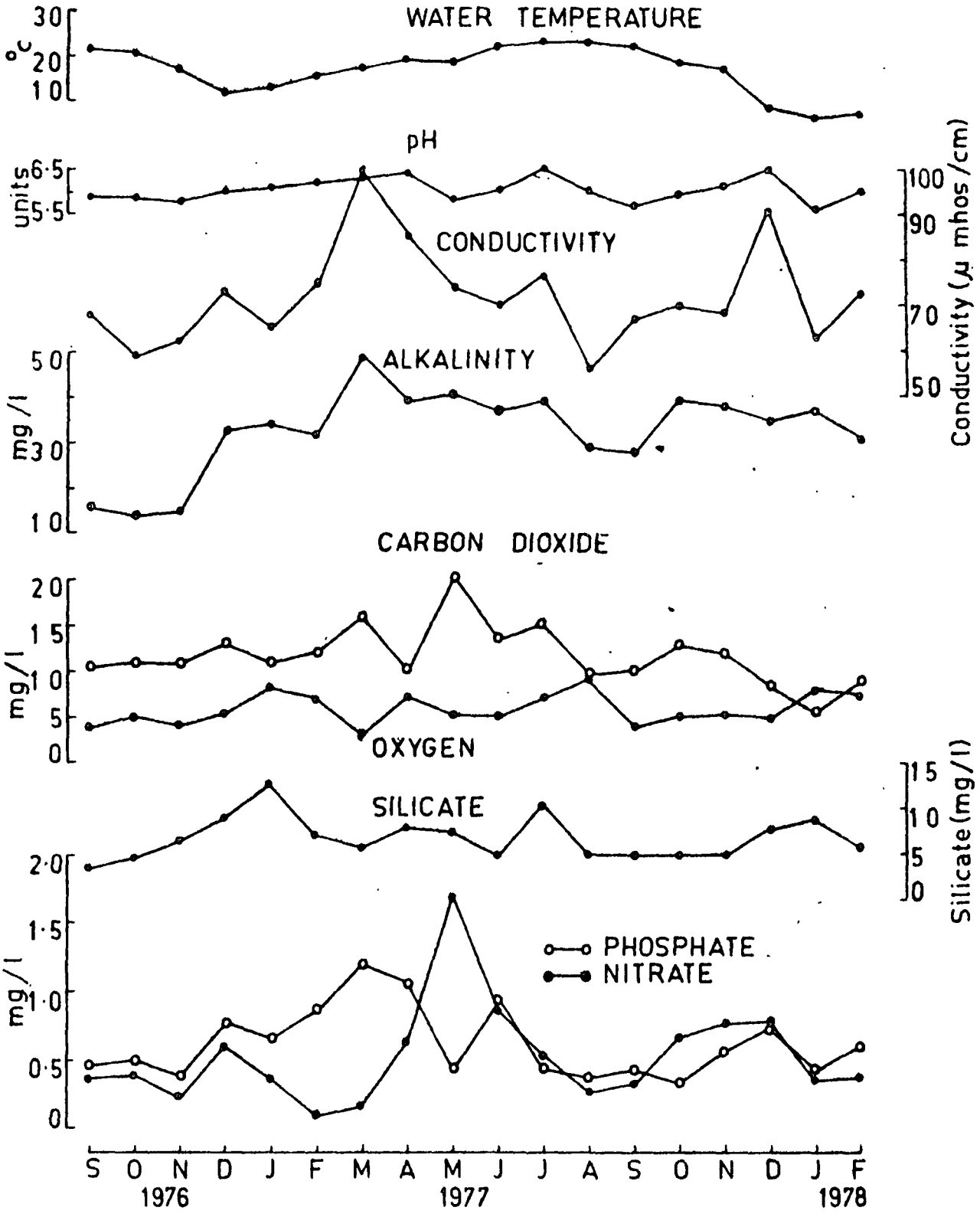
Table-48 : Showing seasonal changes in the physicochemical factors of Lady Hyderi Park pond.
(September, 1976 to February, 1978)

Month	Temperature °C		pH	Conductivity (umhos/cm)	Dissolved oxygen (mg/l)	Carbon dioxide (mg/l)	Alkalinity (mg/l)	Phosphate (mg/l)	Nitrate (mg/l)	Silicate (mg/l)
	Air	Water								
1976										
September	23.25	21.63	5.95	68.06	4.04	10.65	16.25	0.48	0.37	3.51
October	22.38	20.75	5.88	59.23	4.66	10.90	14.25	0.52	0.41	4.87
November	20.33	17.00	5.80	62.93	3.85	10.87	15.40	0.38	0.24	6.49
December	15.13	12.00	6.03	73.23	5.36	12.95	32.90	0.78	0.62	9.17
1977										
January	17.00	12.50	6.08	64.92	7.81	10.65	34.25	0.65	0.36	12.73
February	18.67	15.00	6.17	74.97	7.00	11.80	32.33	0.86	0.10	7.31
March	22.50	17.25	6.26	99.15	2.68	15.80	49.15	1.20	0.17	5.84
April	20.70	19.00	6.40	84.87	6.83	9.76	39.00	1.09	0.64	8.18
May	20.50	18.50	5.80	73.61	5.26	21.80	41.20	0.44	1.70	7.90
June	23.13	21.88	6.03	70.29	4.89	13.55	36.75	0.93	0.87	4.83
July	24.66	23.00	6.51	76.64	6.81	15.10	38.70	0.43	0.54	10.53
August	23.67	23.17	6.00	55.82	9.04	9.57	29.27	0.39	0.28	5.18
September	24.25	22.00	5.69	67.08	4.08	9.92	27.92	0.44	0.34	5.00
October	21.50	18.25	5.94	70.04	4.79	13.20	38.80	0.33	0.69	5.27
November	19.00	17.50	6.13	68.51	4.68	12.40	37.50	0.56	0.78	5.27
December	15.00	13.50	6.50	91.35	5.28	8.60	35.20	0.73	0.79	7.90
1978										
January	12.00	11.00	5.58	63.07	8.00	5.60	37.20	0.44	0.35	8.78
February	13.50	12.00	6.01	72.67	7.51	9.11	30.95	0.61	0.36	5.84

Fig.19

Seasonal variation in the physicochemical factors in the Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig. 19


WATER TEMPERATURE
°C
30
20
10
pH
units
6·5
5·5
CONDUCTIVITY
Conductivity (μ mhos/cm)
100
90
70
50
ALKALINITY
mg/l
50
30
10
CARBON DIOXIDE
mg/l
20
15
10
5
0
OXYGEN
SILICATE
Silicate (mg/l)
15
10
5
0
2·0
1·5
1·0
0·5
0
mg/l
PHOSPHATE
NITRATE
S O N D J F M A M J J A S O N D J F
1976
1977
1978

observed in October, 1976 when 4.87 mg/l was recorded. During the months of August to November, 1977, silicate content was uniformly low ranging between 5.00 - 5.27 mg/l (Fig.19).

B. BIOLOGICAL CHARACTERISTICS :

As in other systems biological characteristics were broadly studied under the heads of phytoplankton, zooplankton and associated organisms.

(a) Phytoplankton :

Seasonal fluctuations in the density of phytoplankton have been shown in Table-49 and Fig.20a. The highest numerical density of phytoplanktons, being much lower than those in other systems, was 6940 units/l recorded in November, 1977. The lowest abundance, on the other hand, was 600 units/l in September, 1977. Their minimum and maximum contributions to total plankton were 65.67% and 99.04% recorded during March and November, 1977 respectively.

Fluctuations in the seasonal density of different groups of phytoplankton have been shown in Table-49.

Myxophyceae : In this pond myxophytes were recorded throughout the study period (Fig.20b). The highest density was noted in November, 1977 with 3700 units/l while the lowest was 20 units per litre in December, 1977. They formed 62.50% of the total phytoplankton in August, 1977 while in December, 1977 their contribution was only 1.51%.

Chlorophyceae : Density of chlorophyceae was less than that of myxophyceae in System-III (Fig.20b). The maximum numerical abundance was recorded in July, 1977 with 1655 units/litre while the lowest density was 14 units/l in September, 1977. During the months of October, 1976, December, 1976, January, 1978 and July, 1977, the numerical density of chlorophyceae was more than 1000 units/l. Their maximum and minimum contributions were 74.71% and 1.56% respectively.

Dinophyceae : Seasonal distribution of these algae in System-III were sporodic as shown in Fig.20b as they were recorded only during 5 out of the 18 months study period with a maximum density of 52 units/l (April, 1977). The lowest number was 0.50 units/l forming 0.06% of the total phytoplankton, while the maximum contribution was 4.93% .

Chrysophyceae : In course of the 18 months sampling chrysophyceae was recorded during 9 months in System-III (Fig.20b). Lowest and highest numerical density of these algae were 2 units/l and 460 units/l observed during December, 1977 and February, 1978, respectively. They contributed to 27.19% to total phytoplankton in February, 1977 and only 0.14% in January, 1977.

Bacillariophyceae : In System-III, bacillariophyceae was recorded throughout the study period. Their seasonal fluctuations have been shown in Fig.20b. The maximum numerical abundance was in November, 1977 when 2580 units/l was noted

Table-49 : Showing the seasonal fluctuations of different phytoplanktonic groups and their percentage composition in Lady Hyderi Park pond. (September, 1976 to February, 1978)

Month	Myxophyceae		Chlorophyceae		Dinophyceae		Chrysophyceae		Bacillariophyceae		Total phytoplankton(unit/l)
	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	(unit/l)	(%)	
1976											
September	90	10.15	160	18.00	1	0.06	-	-	640	71.79	891
October	170	4.76	1112	31.13	-	-	20	0.56	2270	63.55	3572
November	280	22.28	417	33.17	20	1.59	20	1.59	520	41.37	1257
December	49	2.46	1157	58.49	-	-	9	0.44	764	38.61	1979
1977											
January	150	5.19	1245	42.89	28	0.96	4	0.14	1476	50.82	2904
February	40	3.02	608	45.62	-	-	360	27.19	320	24.17	1324
March	1062	35.12	483	15.97	-	-	10	0.33	1470	48.58	3026
April	66	6.26	785	74.71	52	4.93	32	3.03	120	13.36	1054
May	20	2.94	440	64.71	-	-	-	-	220	32.35	680
June	164	22.57	237	32.69	10	1.38	-	-	315	43.36	726
July	420	16.30	1654	64.22	-	-	-	-	502	19.48	2576
August	3228	62.50	59	1.56	-	-	-	-	1877	36.34	5164
September	120	20.08	14	2.34	-	-	-	-	465	77.58	600
October	1260	49.89	225	8.93	-	-	-	-	1040	41.18	2525
November	3700	53.31	660	9.51	-	-	--	-	2580	37.18	6940
December	19	1.51	211	16.39	-	-	2	0.15	1057	81.95	1290
1978											
January	325	10.43	1405	45.08	-	-	-	-	1386	44.49	3116
February	40	1.93	402	19.38	-	-	460	22.15	1174	56.54	2076

(Unit/l values given are rounded off to the nearest whole number).

Fig.20a

Seasonal fluctuation in the numerical density (unit/l) of total phytoplankton in the Lady Hyderi Park pond. (September, 1976 to February, 1978)

Fig.20b

Seasonal variation in the percentage composition of phytoplankton in the Lady Hyderi Part pond. (September, 1976 to February, 1978)

Fig. 20a

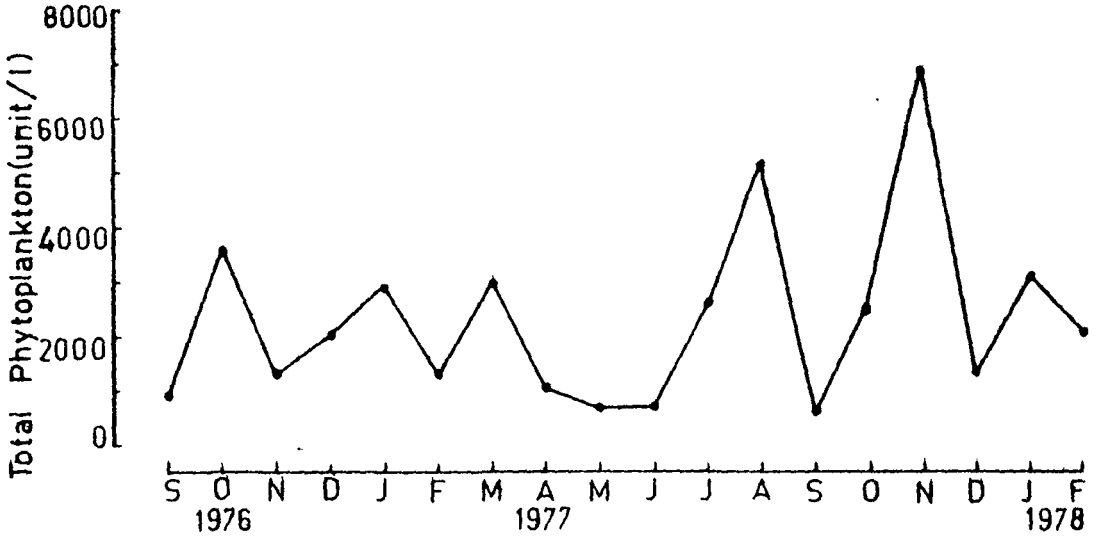
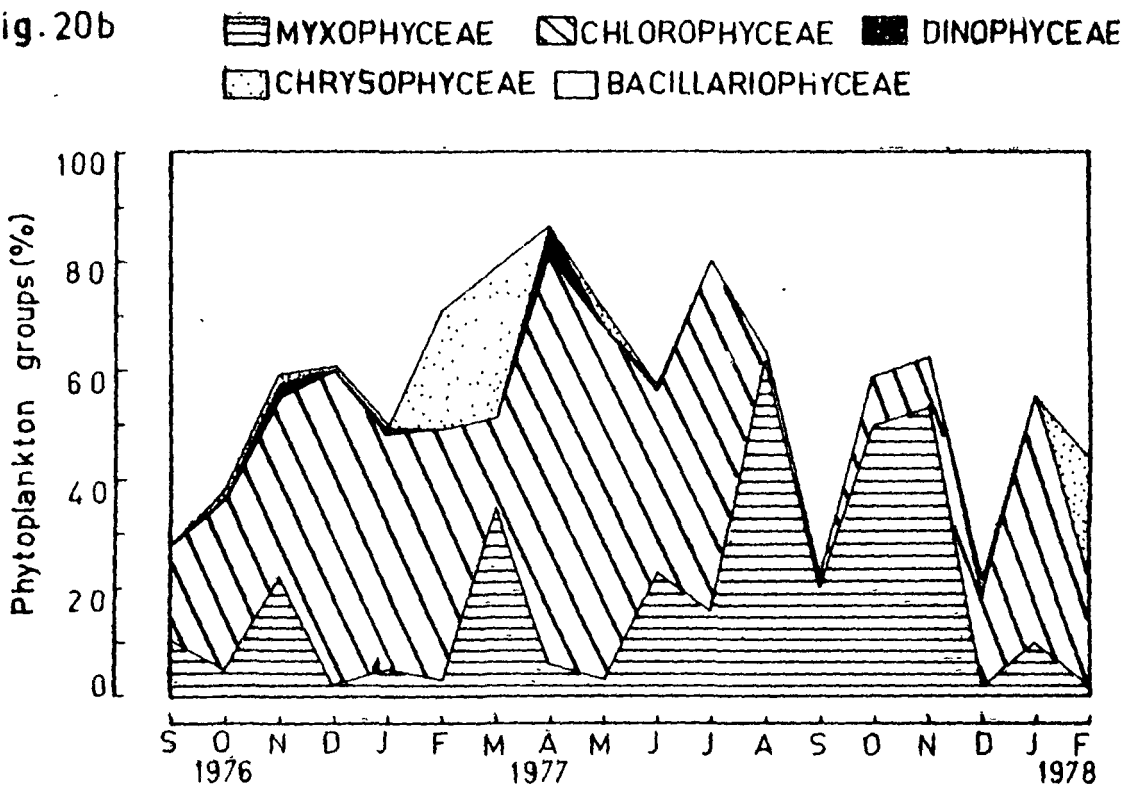


Fig. 20b



while the lowest value was 120 units/l in April, 1977. A maximum of 81.95% of the total phytoplankton was formed by diatoms in December, 1977 while their minimum contribution was 13.36% in April, 1977.

(b) Zooplankton :

Variations in the total number of zooplankton ranged from 68 - 1682 units/l in System-III as shown in Table-50, Fig.21a. Highest and lowest values were found in March and November, 1977 respectively. The zooplanktonic organisms formed a maximum of 34.33% of the total plankton in March, 1977 while their minimum contribution was 0.96% in the month of November, 1977.

Protozoa : Protozoans were recorded throughout the study period in this system (Fig.21b) with their peak in March, 1977 with 326 units/l and the lowest number recorded was 5 units/l in October, 1976. They formed 51.33% of the total zooplankton in October, 1977 while they contributed 2.46% in October, 1976.

Rotifera : Minimum and maximum density of rotifer populations were 6 units and 858 units/l, recorded in November, 1976 and January, 1978 respectively. They were present throughout the seasons contribution 76.41% to the total zooplankton in October, 1976 and 3.28% in December, 1976 (Fig.21b).

Ostracoda : During the total of 18 months study period, ostracods were not recorded during February, May, July and

November, 1977 and also in February, 1977. Ostracods were numerically dominant in December, 1977 (26 units/l) contributing 6.60% to the total count of zooplankton. Their lowest number was found in April, 1977 with a value of 0.40 units/l. The lowest percentage composition, however, was 0.05% recorded in March, 1977 (Fig.21b).

Copepoda : Copepods were well represented throughout the study period in System-III (Fig.21b). Their peak density of 99 units/l was observed in June, 1977 contributing 39.40% to the total zooplankton. The lowest number has been recorded in the month of January, 1977 forming 18% of the total zooplankton.

Cladocera : Cladocera population was most dominant in March, 1977 reaching a density of 1138 units/l (Fig.22). The lowest count/litre was observed in August, 1977 when only 8 units were present. Their maximum contribution in terms of percentage was 83.46% (December, 1976) and minimum was 9.46% in October, 1976.

(c) Associated organisms :

Except in the month of February, 1978, nematodes were present throughout the sampling period in this system (Table-50). However, they were found in low numbers of which 7 units/l was the maximum density in which mere trace recorded in November, 1976 and August, 1977. The lowest mean abundance was 0.25 units/l in January, 1977. They contributed 12.27% to zooplankton counts in the month of May, 1977 and only 0.02% in January, 1977.

Table-50 : Showing the seasonal fluctuations in the numerical density (unit/l) and percentage composition of different groups of zooplankton and other associated organism in Lady Hyderi Park pond.
(September, 1976 to February, 1978)

Month	Zooplankton										Associated organisms						Total
	Protozoa		Rotifera		Ostracoda		Copepoda		Cladocera		Namatoda		Bryozoan sporoblasts		Insecta		
	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(u/l)	(%)	(unit/l)
1976																	
September	7	6.0	17	14.7	2	1.7	39	33.6	45	39.0	1	0.8	-	-	6	5.0	116
October	5	2.5	155	76.4	1	0.4	14	7.1	19	9.5	1	0.5	*	0.1	7	3.6	203
November	8	4.0	6	3.3	5	2.8	22	12.2	135	70.4	7	3.6	-	-	9	4.7	193
December	35	6.4	18	3.3	18	3.3	11	2.0	449	83.4	*	0.4	-	-	8	1.5	538
1977																	
January	126	8.9	535	39.0	5	0.4	2	0.2	730	51.4	*	0.02	-	-	2	0.1	1420
February	51	19.7	161	61.6	-	-	4	1.5	43	16.4	1	0.5	-	-	*	0.2	262
March	325	20.6	100	6.3	1	0.05	15	70.9	1137	71.9	1	0.1	[illegible]	[illegible]	2	0.1	1581
April	43	13.1	172	51.8	*	0.1	76	22.8	34	10.4	1	0.2	-	-	5	1.4	331
May	37	23.8	14	9.2	-	-	25	15.8	69	43.8	2	1.2	1	0.6	8	5.4	156
June	60	24.0	14	5.8	2	0.7	99	39.4	69	27.4	*	0.2	1	0.3	6	2.3	251
July	113	47.5	18	7.5	-	-	50	21.2	51	21.4	2	0.8	-	-	4	1.7	237
August	33	48.0	7	9.8	1	1.9	7	9.8	8	11.3	7	10.3	-	-	6	8.8	68
September	16	10.2	59	37.9	2	1.5	17	11.1	57	36.6	2	1.3	-	-	2	1.3	157
October	38	51.3	17	22.7	*	0.7	7	10.0	9	12.0	1	1.3	-	-	1	2.0	75
November	20	30.4	8	11.8	-	-	6	8.9	26	38.5	6	9.6	-	-	*	0.7	67
December	25	6.4	42	10.1	26	6.6	22	5.6	270	68.1	1	0.2	-	-	6	1.6	393
1978																	
January	106	7.8	858	63.4	10	0.8	5	0.4	368	27.2	*	0.04	-	-	5	0.4	1354
February	25	10.0	183	73.4	-	-	5	2.2	34	13.6	-	-	-	-	2	0.8	250

(u/l = Unit/l; * density less than 0.5 unit/l; density figures given are rounded off to the nearest whole number).

Fig.21a

Seasonal fluctuation in the numerical density (No/l) of total zooplankton in the Lady Hyderi Park pond.
(September, 1976 to February, 1978)

Fig.21b

Seasonal variation in the percentage composition of zooplankton in the Lady Hyderi Park pond.
(September, 1976 to February, 1978)

Fig. 21a

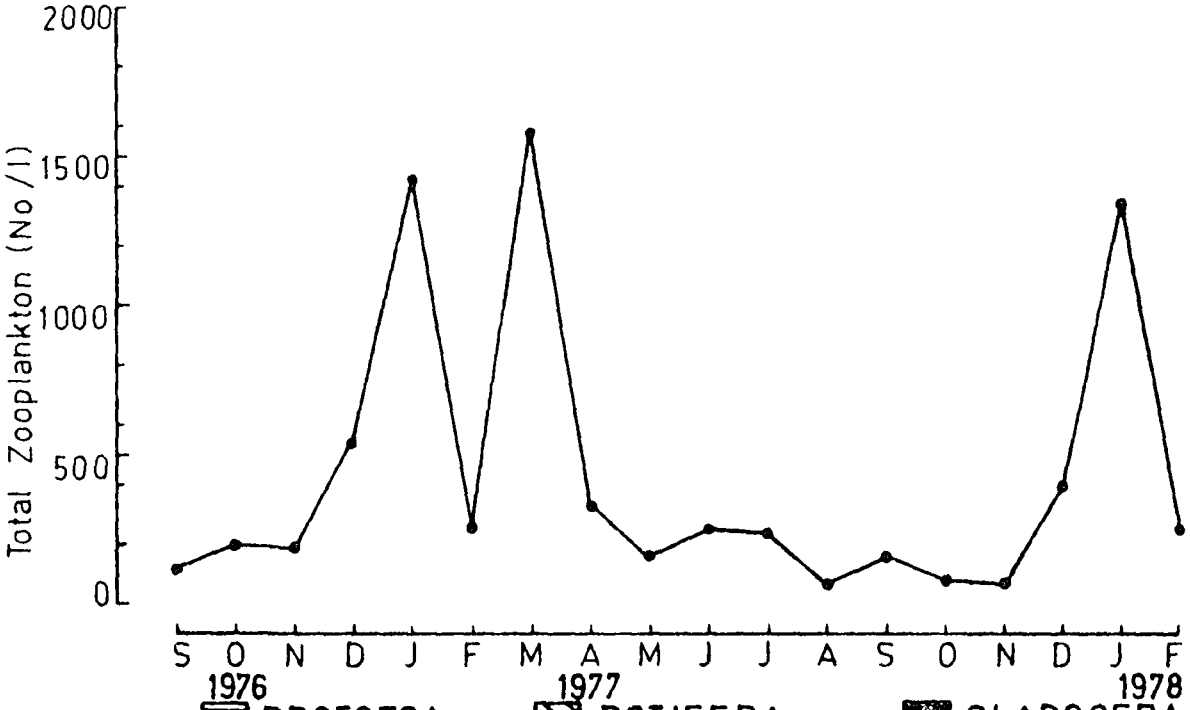


Fig. 21b

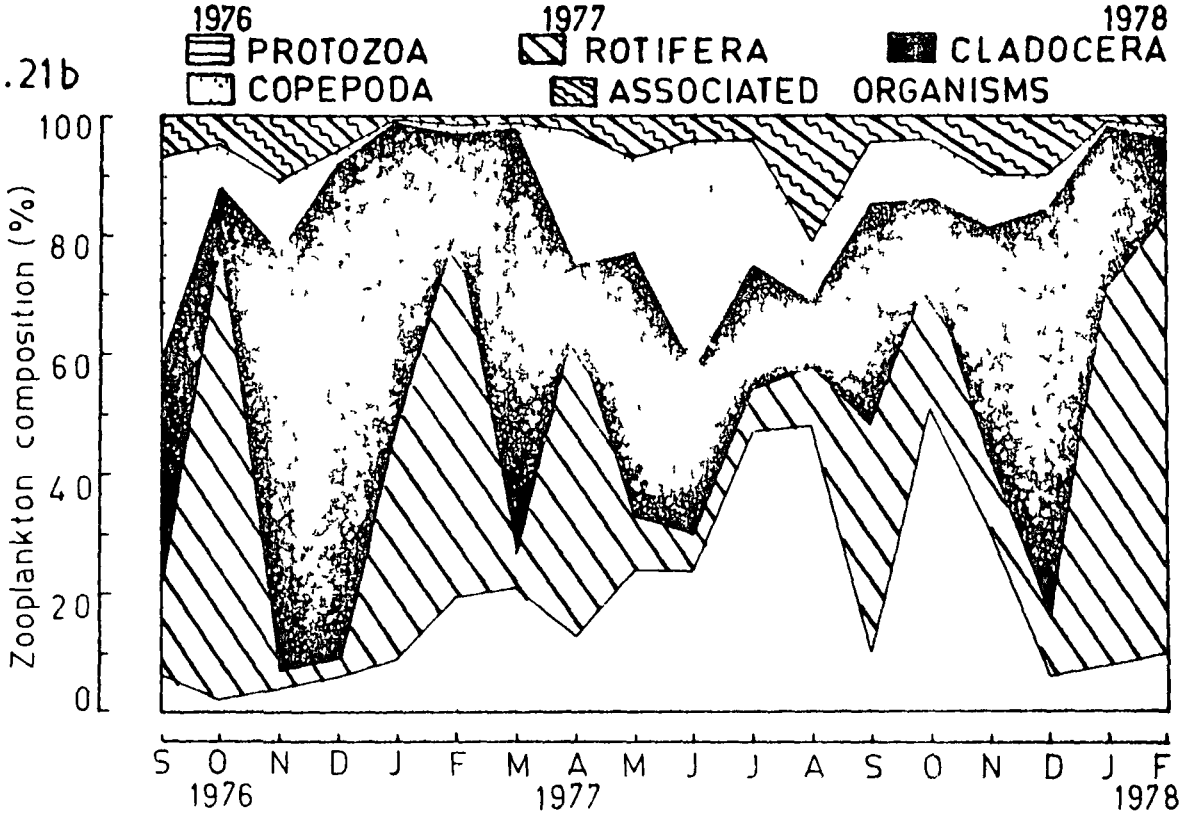
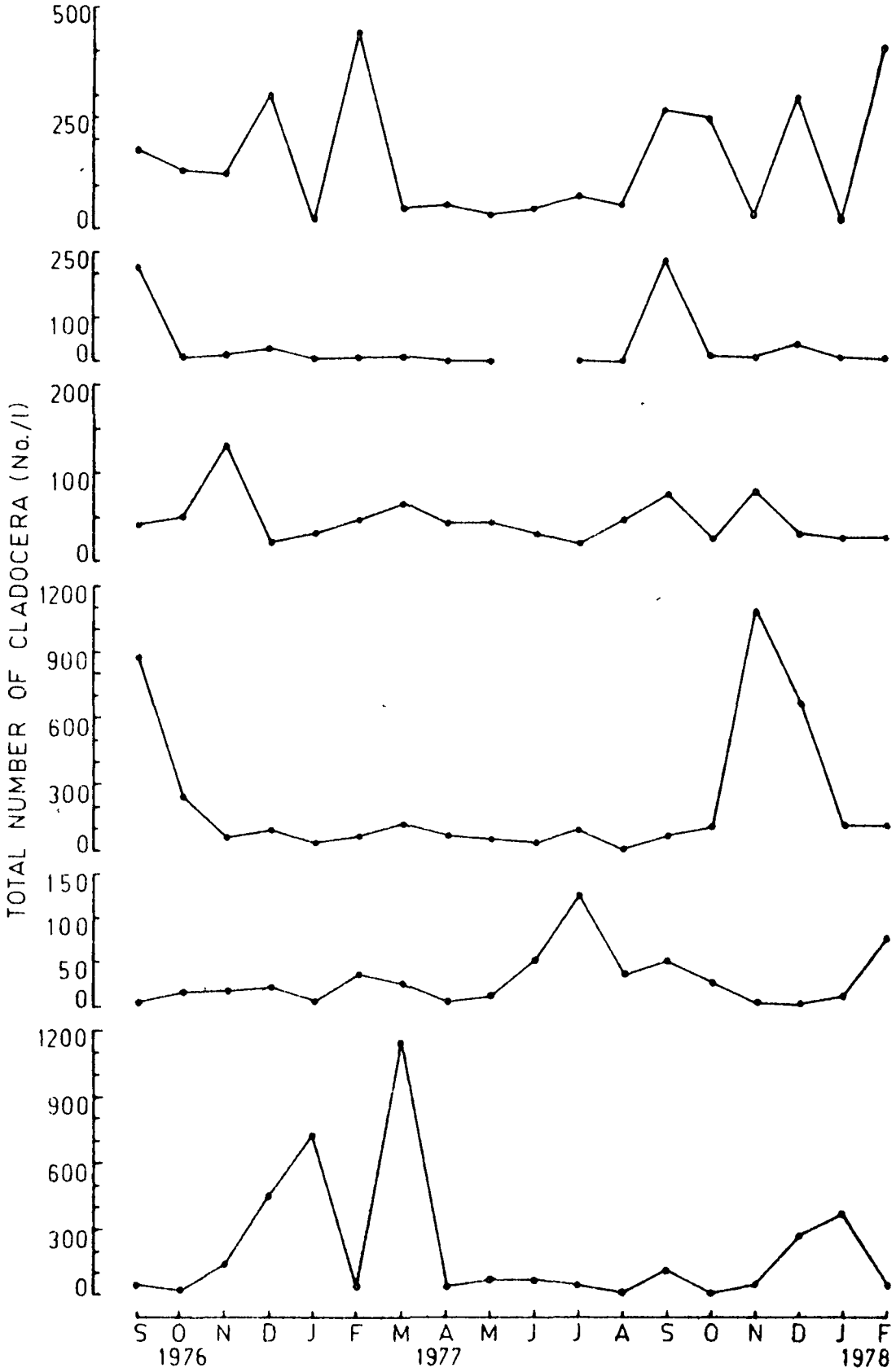


Fig.22

Seasonal variations in the numerical density (No/l) of total Cladocera in the four stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond.
(September, 1976 to February, 1978)

Fig.22


TOTAL NUMBER OF CLADOCERA (No./l)
500
250
0
250
100
0
200
100
0
1200
900
600
300
0
150
100
50
0
1200
900
600
300
0
S O N D J F M A M J J A S O N D J F
1976
1977
1978

In System-III, statocysts appeared only 3 times in the plankton samples forming less than 0.65% of total zooplankton and their maximum number recorded was 1 unit/l (Table-50).

Highest insect population has been recorded in the month of November, 1976 with 9 units/l while the lowest value was 0.50 units/l (February and November, 1977). They formed 8.82% of the total zooplankton counts in August, 1977 and only 0.12% during January, 1977. These insects were recorded throughout the study period (Table-50).

II. BIOLOGY

OCCURRENCE OF CLADOCERAN SPECIES

Ward Lake

Fish Dale Pond

Lady Hyderi Park Pond

SEASONAL DISTRIBUTION OF DIFFERENT CLADOCERAN SPECIES

POPULATION DENSITIES OF DIFFERENT CLADOCERAN SPECIES

STRUCTURE (SIZE GROUP, FEMALES WITH AND WITHOUT EGGS, EGGS/BROOD, GAMOGENESIS AND SEX RATIO) OF THE FIELD POPULATIONS OF DIFFERENT CLADOCERAN SPECIES

OCCURRENCE OF CLADOCERAN SPECIES

The different cladoceran species recorded in course of the 18 months study period have been listed below separately for each of the 4 stations of Ward Lake and Fish Dale and Lady Hyderi Park ponds.

WARD LAKE :

Station-I (WI) : A total of 11 species of Cladocera have been recorded in WI of which Chydoridae was most dominant. The other families recorded here included Sididae, Daphnidae and Bosminidae with 1, 2 and 1 species respectively as shown below:

Family Sididae :
- *Diaphanosoma excisum*

Family Daphnidae :
- *Ceriodaphnia cornuta*
- *Scapholeberis kingi*
- *Simocephalus exspinosus*

Family Bosminidae :
- *Bosmina longirostris*

Family Chydoridae :
- *Chydorus sphaericus*
- *Biapertura affinis*
- *Camptocercus australis*
- *Acroperus harpae*
- *Pleuroxus similis*
- *Alonella excisa*

Station-II (WII) : Only 7 species representing 4 families were recorded in this station as shown below :

Family Sididae :
Diaphnosoma excisum

Family Daphnidae:
Daphnia lumholtzi
Scapholeberis kingi

Family Bosminidae :
Bosmina longirostris

Family Chydoridae :
Chydorus sphaericus
Biapertura affinis
Alonella excisa

Station-III (WIII) : In WIII, a total of 10 species have been recorded belonging to Daphnidae, Macrothricidae, Bosminidae and Chydoridae. The different species recorded in this station are shown below:

Family Daphnidae :
Scapholeberis kingi
Simocephalus exspinosus

Family Macrothricidae :
Ilyocruptus spinifer

Family Bosminidae :
Bosmina longirostris

Family Chydoridae :
Chydorus sphaericus
Biapertura affinis
Camptocercus australis
Acroperus harpae
Pleuroxus similis
Alonella excisa

Station-IV (WIV) : Altogether 14 species of Cladocera have been recorded from this station and Chydoridae were found to be dominant. Family Moinidae was present in this station.

Family Sididae :
Sida crystallina

Family Daphnidae :
Scapholeberis kingi
Simocephalus exspinosus
Simocephalus serrulstus

Family Moinidae :
Moina micrura

Family Bosminidae :
Bosmina longirostris

Family Chydoridae :
Chydorus sphaericus
Biapertura affinis
Camptocercus australis
Acroperus harpae
Alonella excisa
Pleuroxus similis
Alona sp.
Alonella nana

Thus the record of all cladoceran species occurring in different parts of Ward Lake, when summed up represented the total cladoceran species composition of the lake as listed below:

Family Sididae :
Sida crystallina
Diaphanosoma excisum

Family Daphnidae :
Daphnia lumholtzi
Ceriodaphnia cornuta
Scapholeberis kingi
Simocephalus exspinosus
Simocephalus serrulatus

Family Moinidae :
Moina micrura

Family Macrothricidae :
Ilyocryptus spinifer

Family Bosminidae:
Bosmina longirostris

Family Chydoridae :
Chydorus sphaericus
Biapertura affinis
Camptocercus australis
Acroperus harpae
Alonella excisa
Alonella nana
Pleuroxus similis
Abona sp.

FISH DALE POND :

The nursery pond at Fish Dale exhibited the following species composition of Cladocera during the 18 months study period :

Family Daphnidae :
Scapholeberis kingi
Simocephalus exspinosus

Family Bosminidae :
Bosmina longirostris

Family Chydoridae :
Chydorus sphaericus
Acroperus harpae
Pleuroxus similis
Alonella excisa

LADY HYDERI PARK POND :

A total number of 9 species of Cladocera belinging to families Daphnidae, Bosminidae and Chydoridae were recorded in this system. The species list is furnished below:

Family Daphnidae :
Daphnia sp.
Scapholeberis kingi
Simocephalus exspinosus

Family Bosminidae :
Bosmina longirostris

Family Chydoridae :
Chydorus sphaericus
Biapertura affinis
Acroperus harpae
Pleuroxus similis
Alonella excisa

In Table-51 the representation of different Cladocera species in the 3 systems taken for comparative study has been given. A total of 19 species have been recorded in these three systems. Ward Lake appeared to contain the maximum number of species, although Lady Hyderi Park pond being very small in comparison to Ward Lake, hosted as many as 9 species during the different seasons. Fish Dale pond, on the other hand,

represented only 7 species and was still smaller in size, cemented and devoid of any vegetation.

Table-51 : Showing the occurrence of different cladoceran species in Ward Lake, its four stations, Fish Dale and Hyderi Park ponds during September, 1976 to February, 1978.

Species	WI	WII	WIII	WIV	*WL	*FD	*LH
Family Sididae:							
Sida crystallina	-	-	-	+	+	-	-
Diaphanosoma excisum	+	+	-	-	+	-	-
Family Daphnidae :							
Daphnia lumholtzi	-	+	-	-	+	-	-
Daphnia sp.	-	-	-	-	-	-	+
Ceriodaphnia cornuta	+	-	-	-	+	-	-
Scapholeberis kingi	+	+	+	+	+	-	-
Simocephalus exspinosus	+	-	+	+	+	+	+
Simocephalus serrulatus	-	-	-	+	+	+	+
Family Moinidae :							
Moina micrura	-	-	-	+	+	-	-
Family Macrothricidae :							
Ilyocryptus spinifer	-	-	+	-	+	-	-
Family Bosminidae :							
Bosmina longirostris	+	+	+	+	+	+	+
Family Chydoridae :							
Chydorus sphaericus	+	+	+	+	+	+	+
Biapertura affinis	+	+	+	+	+	-	+
Camptocercus australis	+	-	+	+	+	-	-
Acroperus harpae	+	-	+	+	+	+	+
Pleuroxus similis	+	-	+	+	+	+	+
Alonella excisa	+	+	+	+	+	+	+
Alonella nana	-	-	-	+	+	-	-
Alona sp.	-	-	-	+	+	-	-
Total-19	11	7	10	14	18	7	9

* WL represents Ward Lake, *FD, Fish Dale Pond & *LH, Lady Hyderi Park Pond.

SEASONAL DISTRIBUTION OF DIFFERENT CLADOCERAN SPECIES

Seasonal distribution of different cladoceran species in WI, WII, WIII, WIV, Fish Dale pond and Lady Hyderi Park pond have been shown in Figs. 23, 24, 25, 26, 27 and 28 respectively.

Family Sididae :

Sida crystallina : This species is a weed inhabiting form, generally found in ponds and lakes.

This species was present only at WIV of Ward Lake (Table-51). They occurred in this station for the first time at the end of February, 1978 and hence no detailed study was attempted on this species as their density wasaalso very low.

Distribution : Cosmopolitan.

Diaphanosoma excisum : This species was first recorded from India by Sewell (1935) from Calcutta area. Later Biswas (1971) and Nayer (1971) recorded it from the state of Rajasthan, India.

Distribution : Common in tropics and subtropics.

In the present study D. excisum was recorded in WI and WII of Ward Lake.

WI : D. excisum occurred in this station in the month of April, 1977 (Fig.23).

WII : In this station D. excisum occurred in the month of September and October, 1976 and June and July, 1977, while absent during the rest of the study period (Fig.24).

Family Daphnidae :

Daphnia lumholtzi : Sewell (1935) recorded this species from Calcutta, Biswas (1971) and Nayer (1971) from Rajasthan and Michael (1973) recorded it from Tamil Nadu, India.
Distribution : Australia, Africa, Egypt and also wide spread in Asia.

D. lumholtzi was recorded only from WII of Ward Lake (Table- 51, Fig.24) and that too present only in the month of February, 1978. This species, like Sida crystallina, made its appearence towards the last part of February, 1978, as a result no detailed study on its seasonal occurrence and population dynamics could be worked out.

Daphnia sp. : This Daphina species was recorded from Lady Hyderi Park pond. They suddenly made their appearence during April and May, 1977. They were not recorded any more in the system. An attempt was made to collect this species in the subsequent year although without success (Table-51, Fig.28).

Ceriodaphnia cornuta : C. cornuta was first recorded by Gurney (1906, 1907) from West Bengal, India. Sewell (1935) again recorded it from West Bengal. Biswas (1971) and Nayer (1971) recorded C. cornuta from Rajasthan while Patil (1976) recorded from the Meghalaya state of India.
Distribution : Cosmotropical, also recorded from China and Japan.

This daphnid species was recorded only at WI of Ward

Lake and was absent in all other sampling stations and systems. In WI Ceriodaphnia cornuta has been recorded during the whole of June and July, 1977. This species was absent during the rest of the study period (Fig.23).

Scapholeberis kingi : This epineustic species was first reported from India by Gurney (1906, 1907) from West Bengal. Brehm (1936) recorded it from Kashmir and Nilgiri Hills in South India. Subsequently Biswas (1971) and Patil (1976) reported it from Rajasthan and Meghalaya respectively. Distribution : Africa, Australia, North America, Ceylon, India, Germany, China, Thailand and Indonesia.

In the present study Scapholeberis kingi has been recorded from all the 3 systems.

WI : This species occurred from the very beginning of the study (September, 1976) and continued upto January, 1977 (Fig.23, Table-51). S. Kingi was not recorded during February, 1977, April, 1977, January, 1978 and February, 1978.

WII : In WII, in course of the 18 months study commencing from September, 1976 to February, 1978, Scapholeberis kingi was recorded only in the months of October and November, 1977 (Fig.24, Table-51).

WIII : Seasonal distribution of S.kingi in WIII has been somewhat different (Fig.25). They were present during the months of September to November, 1976. They were not

recorded from December, 1976 to February, 1977 while were again present in March and April, 1977. They were not found in May and June, 1977 only to reappear in November, 1977 and, as in the previous year, were absent during December, 1977 till February, 1978.

WIV : WIV exhibited a different pattern of occurrence of S. kingi. They were recorded only during September, 1976, October, 1976 and March, 1977. During the rest of the period they were absent (Fig.26).

Fish Dale pond : In this system S.kingi was recorded from September, 1976 till January, 1977. They appeared again in March, 1977 and were absent from plankton during the rest of the study period except in August and September, 1977 (Fib. 27).

Lady Hyderi Park pond : Occurrence of Scapholeberis kingi was very patcy in this system and were only recorded during the months of April, July and November, 1977. They were absent during the remaining 15 months (Fig.28).

Simocephalus exspinosus : This is a littoral species recorded from the weed beds. First record in India was that of Patil (1976) from Meghalaya. Sharma (1978) reported it from around Calcutta, India.

Distribution : Cosmopolitan.

Simocephalus exspinosus was present in WI, WIII and WIV of Ward Lake, Fish Dale as well as in Lady Hyderi Park pond.

WI : S.exspinosus occurred in this station in quite high frequency during the 18 months study period, though in less density. Their distribution has been shown in Fig.23. They were present during September and October, 1976, absent from November, 1976 till January, 1977; present during February and March, 1977 and again absent during March and April, 1977. They appeared once again in the samples of the months of June, July, August and September, 1977. S. exspinosus was absent in October, 1977 only to appear again in November, 1977 and later occurred during January and February, 1978 with total absence in December, 1977.

WII : This species was altogether absent throughout the study period at this station (Table-51).

WIII : S. exspinosus occurred at this station throughout the study period except during the months of Ju.y and August, 1977 and also in January, 1978 (Fig.25).

WIV : This station showed the maximum abundance of Simpecphalus exspinosus and occurred throughout the 18 months study period excepting November, 1977 (Fig.26).

Fish Dale pond : Distribution of S.exspinosus was restricted only 2 months namely, March and July, 1977 with poor numerical density (Fig.27).

Lady Hyderi Park pond : Simocephalus exspinosus was recorded during the months of November and December, 1976, March, April, June, July and December, 1977, while being absent during the rest of the period (Fig.28).

Simocephalus serrulatus : This is a weed inhabiting form, common everywhere. This daphnid species was present only in Station-WIV of Ward Lake and was recorded during the months of January, February and June, 1977 (Fig.26, Table-51).

Family Moinidae :

Moina mixrura : Brehm (1936) reported Moina micrura from the Nilgiri Hills in South India. Biswas (1971) recorded this species from Rajasthan in the North-Western India.

In the present study M. micrura was recorded from WIV of Ward Lake. This species occurred throughout the month of October, 1977 and was absent during the rest of the period of study.

Family Macrothricidae :

Ilyocryptus spinifer : Indian records of I. spinifer were those of Gurney (1907) from Calcutta, Biswas (1971) from Rajasthan and Patil (1976) from Meghalaya.
Distribution : Pantropical; also recorded from USA, China and Cuba.

Though I. spinifer is a bottom inhabiting form, it might have made accidental appearence in the plankton collections of during November, 1976 at WIII of Ward Lake (Table-51, Fig.25). It was totally absent in all other stations and systems.

Family Bosminidae :

Bosmina longirostris : The two earlier distributional records of this species in India were those of Brehm (1936) from Kashmir and Patil (1976) from Meghalaya.

Distribution : Cosmopolitan

Bosmina longirostris was the sole species representing this family and was found to be present in all the 3 systems namely, Ward Lake, Fish Dale and Lady Hyderi parak ponds.

WI : This species was recorded in all the 18 month's collections and thus was continuously present (Fig.23).

WII : In WII B.longirostris was present throughout the study period except in June, 1977 when no animal could be recorded (Fig.24).

WIII : The seasonal distribution of B. longirostris has been somewhat irregular in this station as they were absent during November and December, 1976, February, April, July and December, 1977 and also during February, 1978 (Fig.25).

WIV : Bosmina longirostris was present during 8 out of the 18 months study and was thus present in April, May, June, September, October and December, 1977 and also in January, 1978 (Fig.26).

Fish Dale pond : This bosminid species appeared during 14 out of the 18 months study period. They were absent from the samples collected during the months of November and December, 1976 and again in March and December, 1977 (Fig.27)

Lady Hyderi Park pond : Except in the months of May and July, 1977, B. longirostris has been represented in the collected samples of all other months during the study period (Fig.28).

Family Chydoridae :

Chydorus sphaericus was recorded from India by Gurney (1906, 1907) from Calcutta and Chakradharpur, Bihar. Brehm (1936) reported from Kashmir and Nilgiri Hills while Patil (1976) recorded this species from Meghalaya.

Distribution : Cosmopolitan.

Chydorus sphaericus was the most common among all the chydorids occurring in Ward Lake, Fish Dale and Lady Hyderi Park ponds.

WI : Throughout the season starting from September, 1976 to February, 1978 C. sphaericus was present continuously in this station (Fig.23).

WII : At this open water station Chydorus sphaericus has been recorded only during the months of September and October, 1976, while absent during the rest of the period (Fig.24).

WIII: C.sphaericus was present throughout the study period (Fig.25).

WIV : Once again this chydorid species was recorded throughout the 18 months study period in this station (Fig.26).

Fish Dale pond : In this system C.sphaericus was recorded throughout the study period except during July to September, 1977 (Fig.27).

Lady Hyderi Park pond : Chydorus sphaericus had a continuous distribution in this system during the 18 months study (Fig.28).

Biapertura affinis : This species was reported by Sharma (1978) from in and around Calcutta, India.

Distribution : Cosmopolitan.

In the present study this species has been recorded from all the stations of Ward Lake and Lady Hyderi Park pond while was absent in Fish Dale pond.

WI : This species was distributed almost throughout the season except in the collections of November, 1976 and April and May, 1977 (Fig.23).

WII : Biapertura affinis has been recorded only on three occasions namely, November, 1976, February and April, 1977 and that too in very low numbers (Fig.24).

WIII: In WIII, B. affinis was continuously distributed from September, 1976 to April, 1977. It was absent in May, 1977 and again present in June and July, 1977, only to be absent in August, 1977 followed by its presence in September, 1977 to finally disappear in October, 1977. They appeard again in the months of November and December, 1977, disappeared in January, 1978 and again reappeared in February, 1978 (Fig.25).

WIV : Distribution of Biapertura affinis was confined to the period of September, 1976 till the month of June, 1977.

During this period again they were absent in November, 1976, February and May, 1977 (Fig. 26).

Fish Dale pond : B. affinis never appeared in this station (Table-51).

Hyderi Park pond : Out of the 18 months, B. affinis was present only during 8 months, namely, September and October, 1976, February, March, June and July, 1977 and January and February, 1978 (Fig.28).

Camptocercus australis : In India this species was recorded by Brehm (1936) from Kashmir, Petkovski (1966) from Gujrat, Patil (1976) from Meghalaya and Sharma (1978) from West Bengal. Distribution : Also reported from Australia, USSR.

Camptocercus australis was present in WI, WIII and WIV of Ward Lake while absent in Fish Dale and Lady Hyderi Park ponds.

WI : The seasonal occurrence of this species has been shown in Fig.23. Out of the 18 months, this species was present during 9 months viz., September and October, 1976, absent in November and again appeared in December, 1976. It was absent once again during January and February, 1977. Among the remaining months its presence has been recorded in the months of March, April, June, July and August, 1977 and also in January, 1978.

WII : This species was absent in this station throughout the study period (Table-51).

WIII : Camptocercus australis has been recorded in this station throughout the study period (Fig.25).

WIV : At this station C. australis has been recorded only during the months of September and October, 1976 and again in March and April, 1977 (Fig.26).

Acroperus harpae : Acroperus harpae has been recorded by Brehm (1936) from Kashmir, Patil (1976) from Meghalaya and Sharma (1978) from West Bengal.

In the present study Acroperus harpae was recorded from all stations except WII of Ward Lake and was also present in Fish Dale and Lady Hyderi Park ponds.

WI : During the whole study period this species was not recorded during 4 different months. These were December, 1976, September, 1977, December, 1977 and January, 1978. During the remaining months they were continuously present (Fig.23).

WII : A. harpae was never recorded in WII (Table-51).

WIII : Except in January, 1977, 1978 and July, 1977 this species was recorded throughout the season (Fig.25).

WIV : A. harpae was present only during October and November, 1976. During the other months they were absent in this Station (Fig.26).

Fish Dale pond : This species was recorded only in the month of October, 1976 (Fig.27).

Lady Hyderi Park pond : A. harpae was present during the greater part of the season and only absent during the months of

January, February, August and December, 1977 and February, 1978 (Fig.28).

Pleuroxus similis : Pleuroxus similis was recorded by Sharma (1978) from West Bengal, India.

Distribution: Australia, Ceylon, Chile and Russia.

Pleuroxus similis has been recorded in WI, WIII and WIV of Ward Lake as well as in Fish Dale and Lady Hyderi Park ponds.

WI : P. similis has been distributed only in the months of March and April, 1977 in this station (Fig.23).

WII : This species was never recorded in this station (Table-51).

WIII: In WIII P. similis was seen only in the months of October and December, 1976 till March, 1977(Fig.25).

WIV : At this station, P. similis was recorded only on 3 occasions namely, March, May and July, 1977 (Fig.26).

Fish Dale pond : Pleuroxus similis has been found to occur only during the months of November and December, 1976 while absent during the rest of the period (Fig.27)

Lady Hyderi Park pond : This chydorid species was recorded at this station on a single instance in the month of December, 1976 (Fig.28).

Alonella excisa : Alonella excisa occurred in all the stations of Ward Lake and the ponds at Fish Dale and Lady Hyderi Park.

Distribution : Throughout America and Asia.

WI : In WI A.excisa was present throughout the greater part of the season except during the months of April, May, July, September and October, 1977 (Fig.23).

WII : In this deep open water station A. excisa was recorded only once in November, 1977 (Fig.24).

WIII: Alonella excisa was well represented throughout the season except in the months of March, October and November, 1977 (Fig.25).

WIV : At this station A. excisa showed a slightly different picture in its seasonal distribution. Thus from September, 1976 to January, 1977 they were present, absent during February, 1977, reappeared in March, 1977 followed by a long period of absence upto the month of November, 1977. Again from December, 1977 to February, 1978, they were present (Fig.26).

Fish Dale pond : A. excisa was present on only one occasion in the month of May, 1977 (Fig.27).

Lady Hyderi Park pond : This system exhibited a slightly different picture with regards to the occurrence of A. excisa. This species was present in alternate months from September, 1976 till May, 1977. From May, 1977 to September, 1977, they were continuously present. In the month of October, 1977 they again disappeared to reapper in November, 1977. From December, 1977 till the end of the present investigations (February, 1978) they were absent (Fig.28).

Fig.23

Occurrence and seasonal distribution of different cladoceran species in Station-I (WI) of Ward Lake during September, 1976 to February, 1978.

Fig. 23

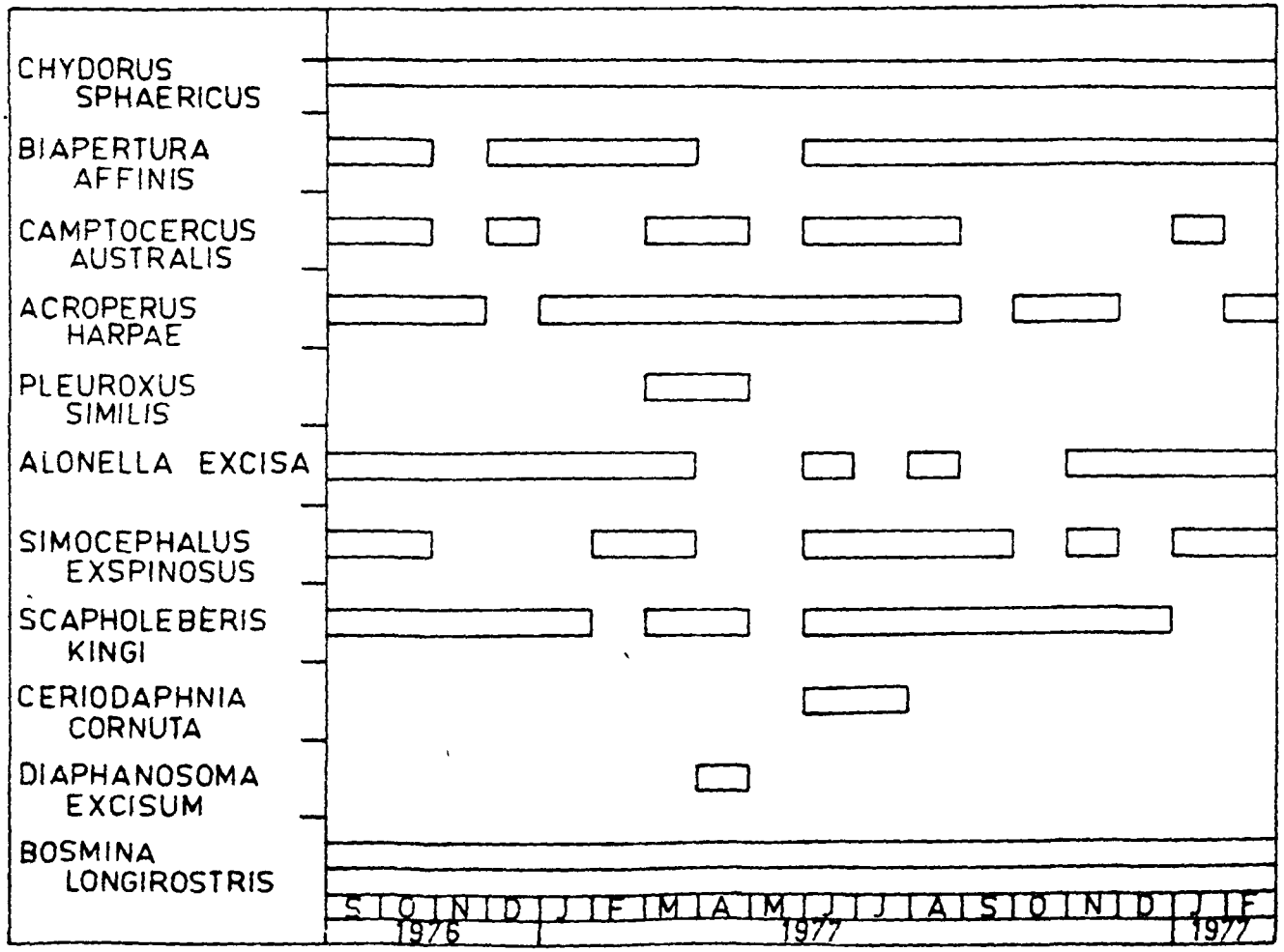

CHYDORUS SPHAERICUS
BIAPERTURA AFFINIS
CAMPTOCERCUS AUSTRALIS
ACROPERUS HARPAE
PLEUROXUS SIMILIS
ALONELLA EXCISA
SIMOCEPHALUS EXSPINOSUS
SCAPHOLEBERIS KINGI
CERIODAPHNIA CORNUTA
DIAPHANOSOMA EXCISUM
BOSMINA LONGIROSTRIS
S O N D J F M A M J J A S O N D J F
1976
1977
1977

Fig.24

Occurrence and seasonal distribution of different cladoceran species in Station-II (WII) of Ward Lake during September, 1976 to February, 1978.

Fig.24

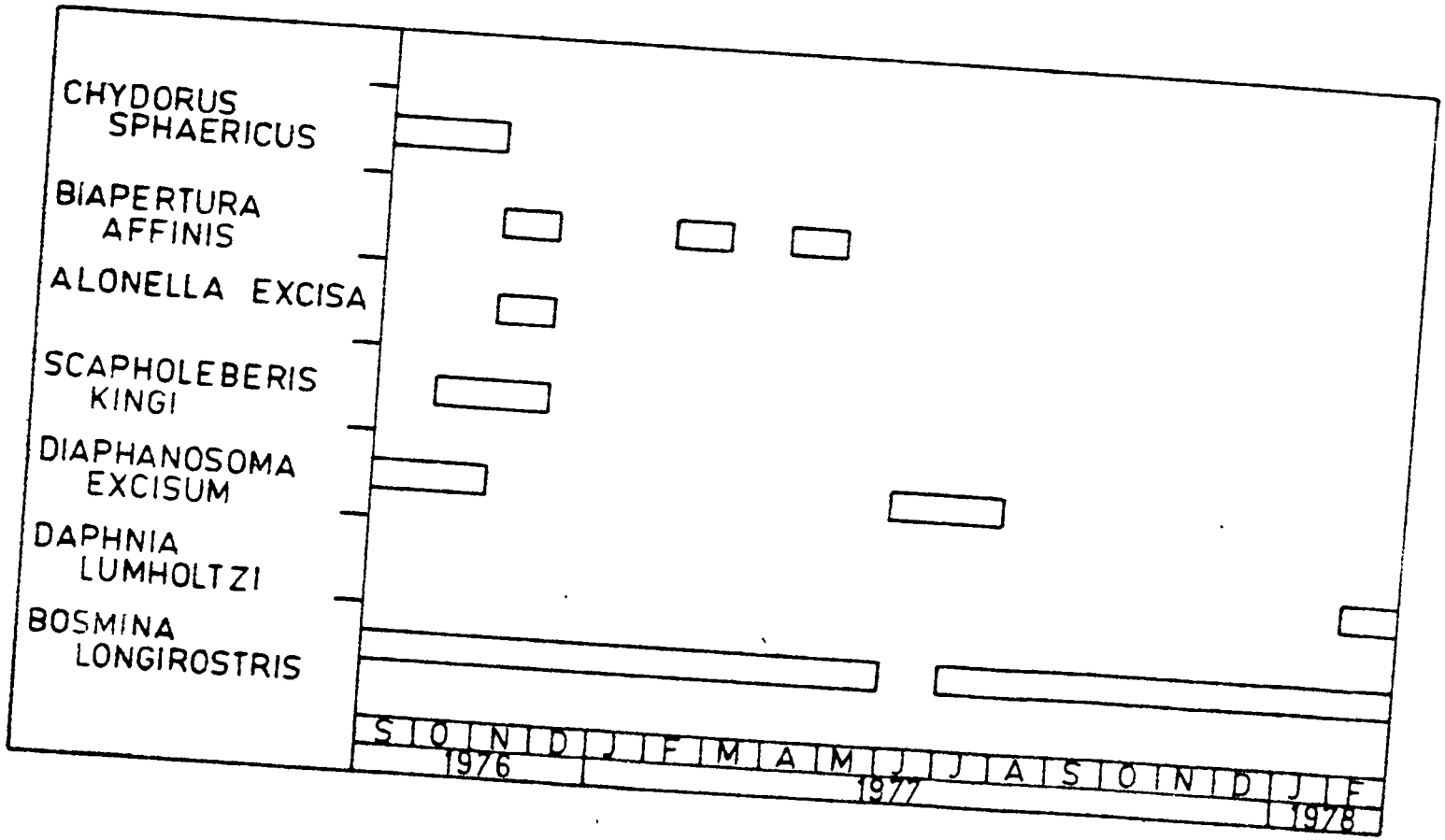

CHYDORUS SPHAERICUS
BIAPERTURA AFFINIS
ALONELLA EXCISA
SCAPHOLEBERIS KINGI
DIAPHANOSOMA EXCISUM
DAPHNIA LUMHOLTZI
BOSMINA LONGIROSTRIS
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fig.25

Occurrence and seasonal distribution of different cladoceran species in Station-III (WIII) of Ward Lake during September, 1976 to February, 1978.

Fig.25

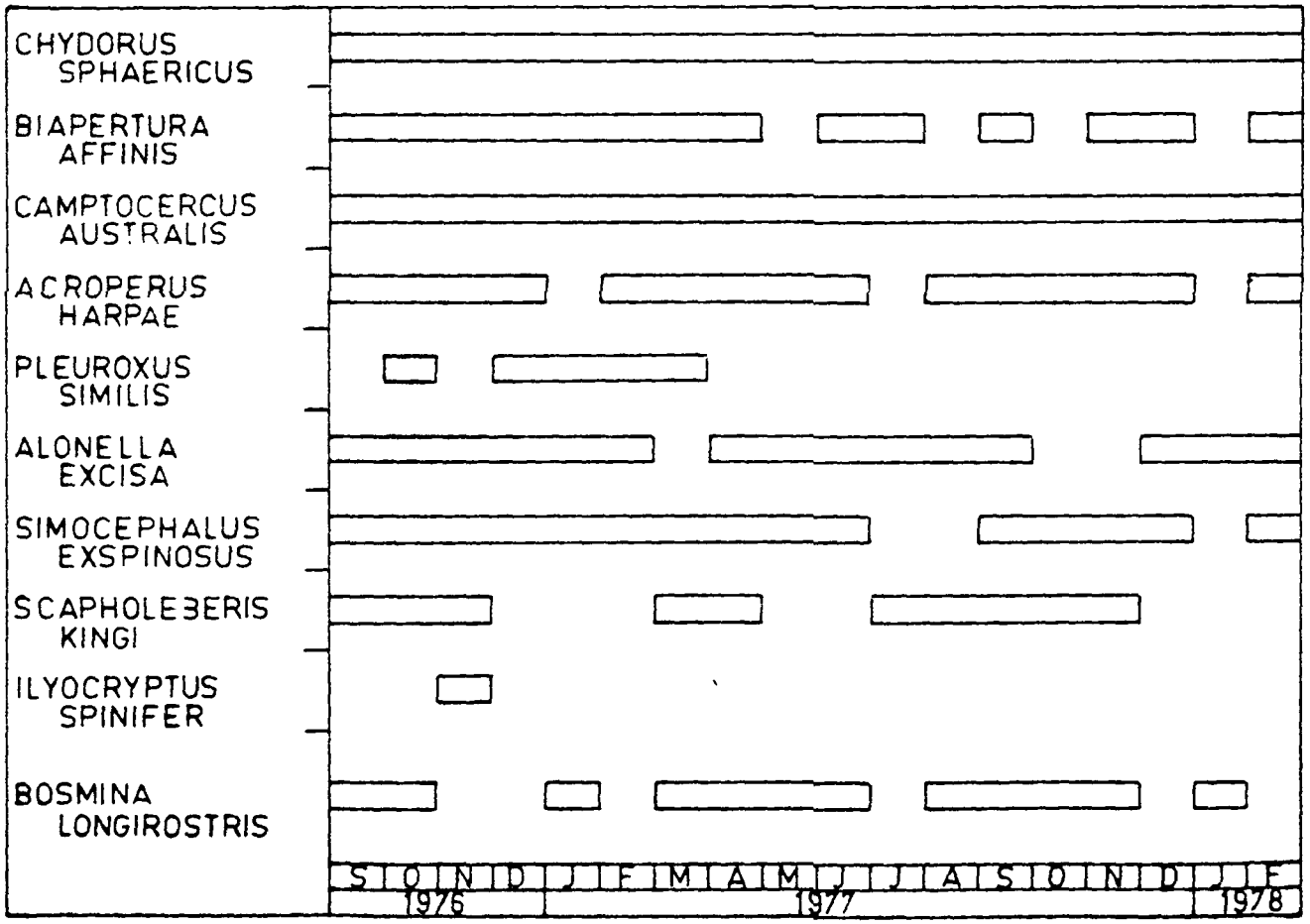

CHYDORUS SPHAERICUS
BIAPERTURA AFFINIS
CAMPTOCERCUS AUSTRALIS
ACROPERUS HARPAE
PLEUROXUS SIMILIS
ALONELLA EXCISA
SIMOCEPHALUS EXSPINOSUS
SCAPHOLEBERIS KINGI
ILYOCRYPTUS SPINIFER
BOSMINA LONGIROSTRIS
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fig.26

Occurrence and seasonal distribution of different cladoceran species in Station-IV (WIV) of Ward Lake during September, 1976 to February, 1978.

Fig 26

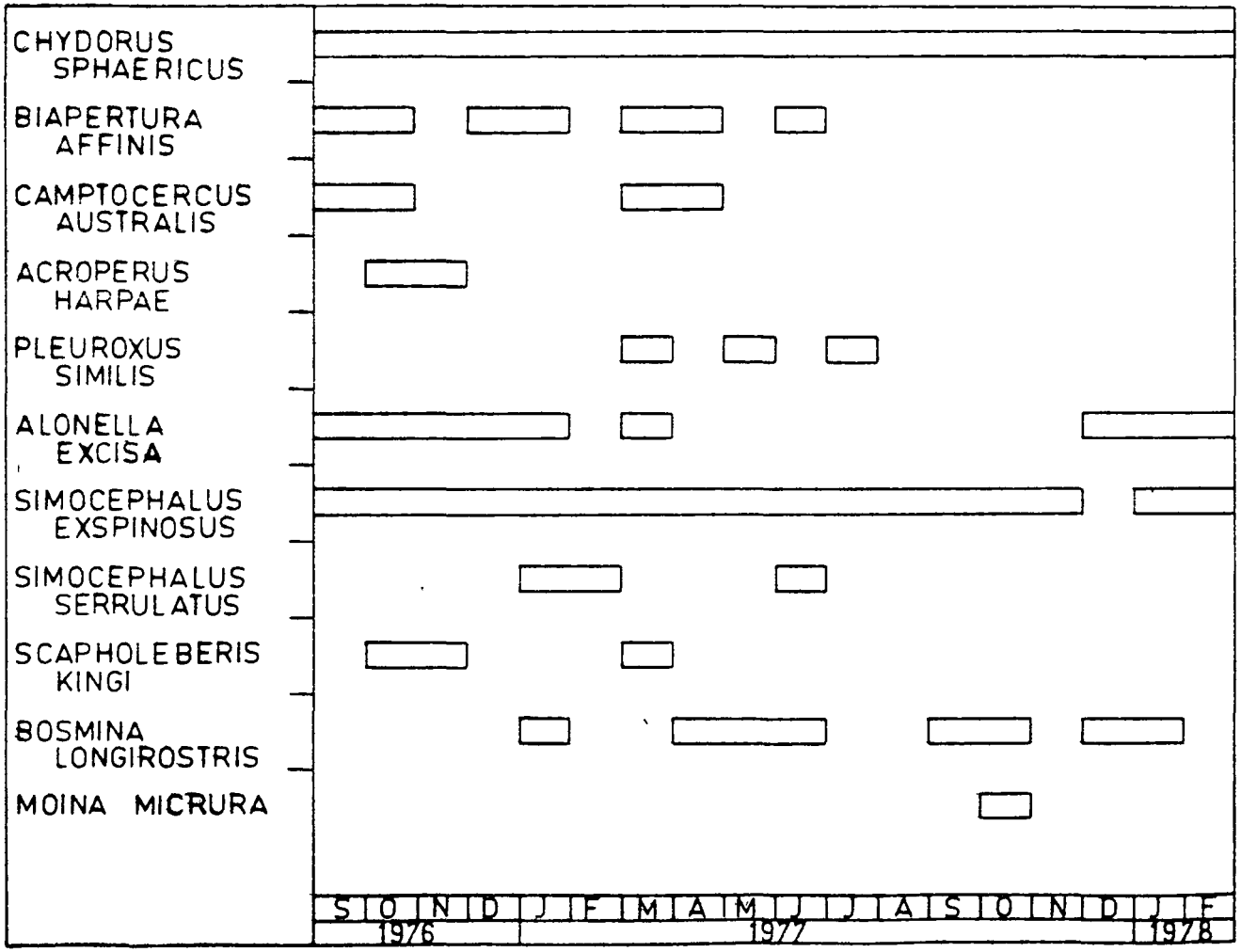

CHYDORUS SPHAERICUS
BIAPERTURA AFFINIS
CAMPTOCERCUS AUSTRALIS
ACROPERUS HARPAE
PLEUROXUS SIMILIS
ALONELLA EXCISA
SIMOCEPHALUS EXSPINOSUS
SIMOCEPHALUS SERRULATUS
SCAPHOLEBERIS KINGI
BOSMINA LONGIROSTRIS
MOINA MICRURA
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fig.27

Occurrence and seasonal distribution of different cladoceran species in the Fish Dale pond during September, 1976 to February, 1978.

Fig.27

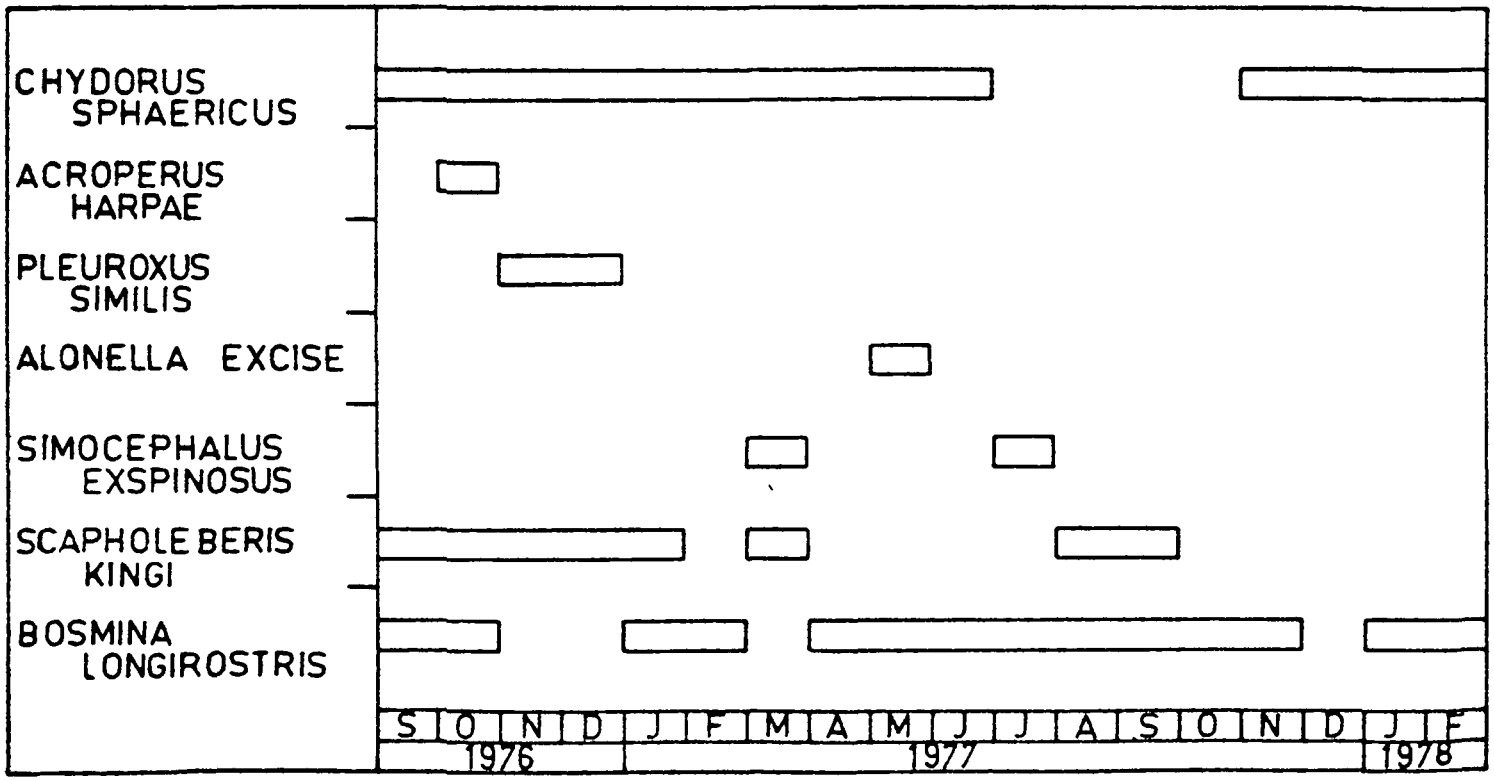
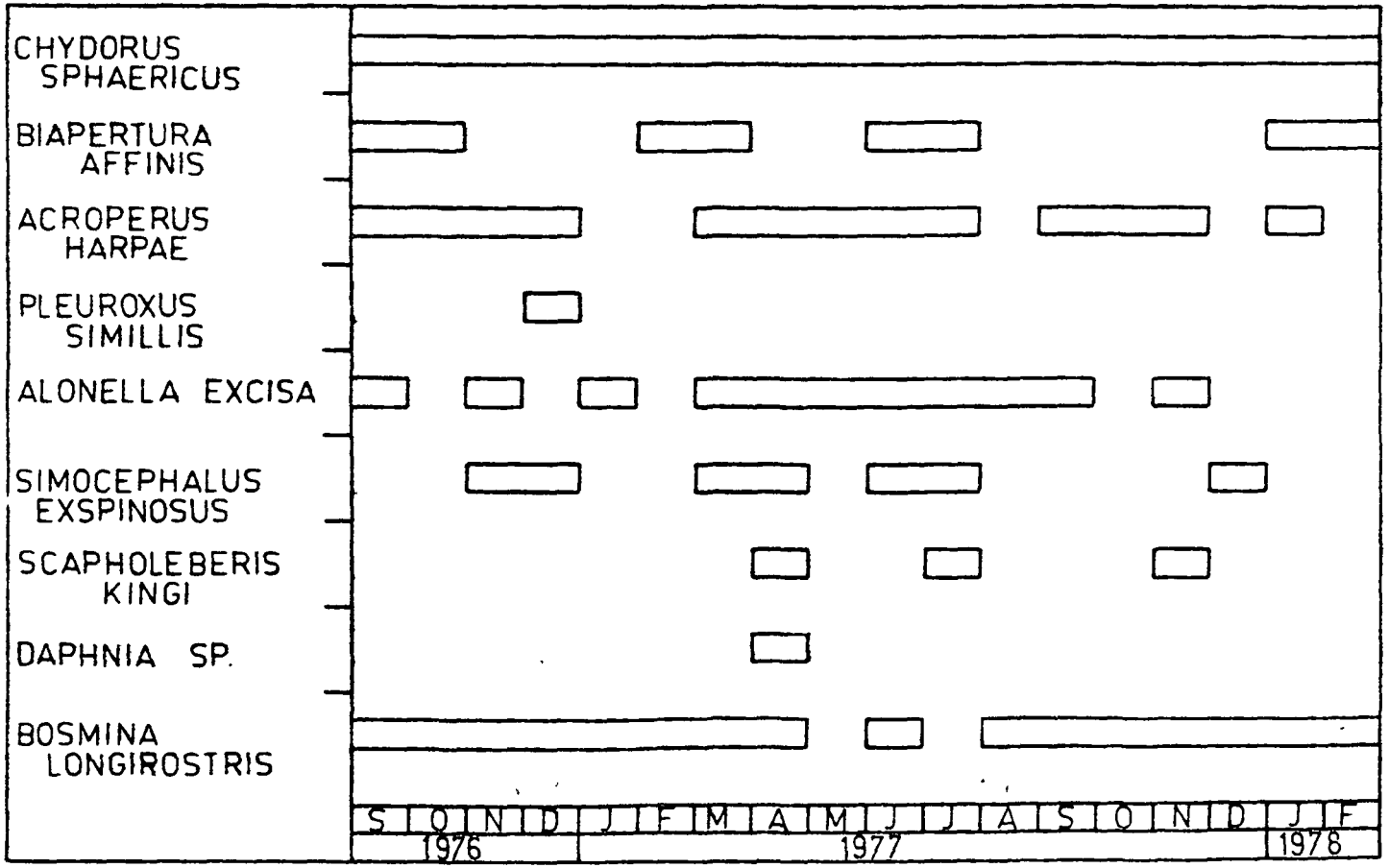

CHYDORUS SPHAERICUS
ACROPERUS HARPAE
PLEUROXUS SIMILIS
ALONELLA EXCISE
SIMOCEPHALUS EXSPINOSUS
SCAPHOLEBERIS KINGI
BOSMINA LONGIROSTRIS
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fig.28

Occurrence and seasonal distribution of different cladoceran species in the Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig. 28


CHYDORUS SPHAERICUS
BIAPERTURA AFFINIS
ACROPERUS HARPAE
PLEUROXUS SIMILLIS
ALONELLA EXCISA
SIMOCEPHALUS EXSPINOSUS
SCAPHOLEBERIS KINGI
DAPHNIA SP.
BOSMINA LONGIROSTRIS
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Alonella nana : A. nana , a very small species of chydorid appeared only once in plankton samples collected in November, 1977 in the WIV of Ward Lake. It was not recorded in any other stations of Ward Lake as well as Fish Dale and Hyderi Park Ponds (Fig.26).

Distribution : Holarctic regions. European USSR to Baikal area.

Alona sp. : This species was recorded in the month of December, 1976 in WIV of Ward Lake, while it was absent in all other stations and systems (Fig.26).

POPULATION DENSITIES OF DIFFERENT CLADOCERAN SPECIES

The numerical density of different species of Cladocera recorded in different stations and the three systems are being dealt with in this Part in a comparative way, following the species sequence given in Table-51.

Family Sididae :

Sida crystallina : This species was recorded only in WIV of Ward Lake towards the end of the 18 months study period. Hence no detailed pupulation parameters could be studied (Table-52). They were not recorded in Fish Dale and Lady Hyderi Park ponds.

Diaphanosoma excisum : D. excisum was recorded in WI and WII while they were absent in WIII, WIV, Fish Dale and Lady Hyderi Park ponds.

WI : In WI, D. excisum was recorded only during April, 1977 with a density of 1 animal/l which formed 0.39% of the total Cladocera count in that month (Table-52).

WII : At this station, D. excisum appeared in the collections of September, 1976 with 10 animals/l. This contributed 4.79% to the total cladoceran abundance of 209 units/l during that month. This species also appeared during October, 1976 and June and July, 1977, with insignificant densities (Table-52).

Table-52 : Showing numerical density (No./l) of different cladoceran species appearing only for brief periods during September, 1976 to February, 1978 in the 4 Stations of Ward Lake, Fish Dale pond and Hyderi Park pond. (Period of occurrence is shown in parenthesis)

Species	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
Diaphanosoma excisum	41.00 (April'77)	10.00 (Sept.'76)	-	-	-	-
Daphnia lumholtzi	-	0.25 (Feb.'78)	-	-	-	-
Daphnia sp.	-	-	-	-	-	6.40 (April'77)
Ceriodephnia cornuta	8.75, 32.67 (June, July'77)	-	-	-	-	-
Simocephalus serrulatus	-	-	-	0.25 (Dec.'77)	-	-
Moina micrura	-	-	-	1.00 (Oct.'77)	-	-
Ilyocryptus spinifer	-	-	4.00, 3.00 (Oct., Nov.'76)	-	-	-
Alona sp.	-	-	-	0.50 (Dec.,'76)	-	-
Alonella nana	-	-	-	0.25 (Nov.'77)	-	-

Family Daphnidae :

Daphnia lumholtzi : Out of the total of six sampling stations D.lumholtzi occurred only in WII. In this station highest numerical density recorded was less than 1 unit/l in February, 1978. They formed 33.33% of the total cladoceran count (Table-52).

Daphnia sp. : This species was only recorded in the Lady Hyderi Park pond and was absent in Ward Lake and Fish Dale.pond. In Lady Hederi Park pond this Daphnia sp. appeared only during the last week of April, 1977 with a density of 6.4 units/l and formed 18.54% of the total Cladocera (Table-52).

Ceriodaphnia cornuta : This species was only present in the WI of Ward Lake. Ceriodaphnia cornuta has been recorded during the later half of June, 1977 and extended till the end of July, 1977. The density of this species for June, 1977 was 8.75/l which formed 20.96% of the total cladoceran population of 41.75 units/l. The density during July, 1977 was 32.67 animals/l. (Table-52).

Scapholeberis kingi : S. Kingi was recorded in all the four stations of Ward Lake as well as the Fish Dale and Lady Hyderi Park ponds. Seasonal fluctuations in the numerical density of S.kingi has been shown in Table-53 and Fig.29.

WI : The highest number of animals per litre was 17.5 units in October, 1977 while the lowest number recorded was 0.40 units/l both in January and April, 1977.

The population density curve showed a moderately high value of 12.67/l in September, 1976 which declined gradually becoming absent totally in February, 1977. March, 1977 had a value of 6.25/l which declined in April, 1977 (0.40 units/l) followed by gradual rise in density reaching the peak value in October, 1977 with 17.50 units/l. The months of November and December, 1977 showed lower values followed by complete absence during the remaining two months of the study period.

WII : At this station this epineustic form was recorded only during October and November, 1976 (Table-53, Fig.29). S. scapholeberis counts were 0.25 and 0.33 units/l.

WIII : In WIII, the highest density of S.kingi has been 7 animal/l, recorded in April, 1977 while the lowest abundance was 0.50 units/l in November, 1977 (Table-53, Fig.29). During the 18 months study period in September, 1976 a value of 3.25 units/l was noted which became low in October, 1976 (0.75 units/l) and increased again in November, 1976 to 3.50 units/l followed by complete absence from December, 1976 to February, 1977. In March, 1977 the value was 5.75 units/l with the highest value of 7 units/l in April, 1977. May, 1977 showed a lower value which rose again reaching 5 units/l in August, 1977. The population density decreased further reaching lowest value in November, 1977 followed by complete absence in January and February, 1978.

WIV : Seasonal abundance of S. kingi in WIV has been shown in Table-53 and Fig.29. This species appeared only on 3 occasions out of the 18 months study period. The minimum and maximum densities were 0.25 units/l and 0.50 units/l observed in October, 1976 and both in November, 1976 and March, 1977 respectively.

Fish Dale pond : S. kingi populations showed different pattern in this pond (Table-53,Fig.29). They were highest in density in September, 1977 with 40.50 units/l while the lowest number was 1 unit/l, recorded in September, 1976 and January, 1977. The population curve showed a gradual rise from 1 unit/l to 14.67 units/l during September, 1976 to December, 1976 which declined to 1 unit/l in January only to totally disappear in February, 1977. In March, 1977, 9 units/l was found followed by theie total absence till August, 1977 when a new generation appeared to have developed reaching the maximum density in September, 1977 with 40.50 units/l. However, the population died away at the start of October, 1977 and were not recorded during the rest of the period.

Lady Hyderi Park pond : Fluctuations in the population density of Scapholeberis kingi in this system have been presented in Table-53 and shown graphically in Fig.29. This species though present, seemed never to have formed dense populations. S. kingi was first recorded in March, 1977 with

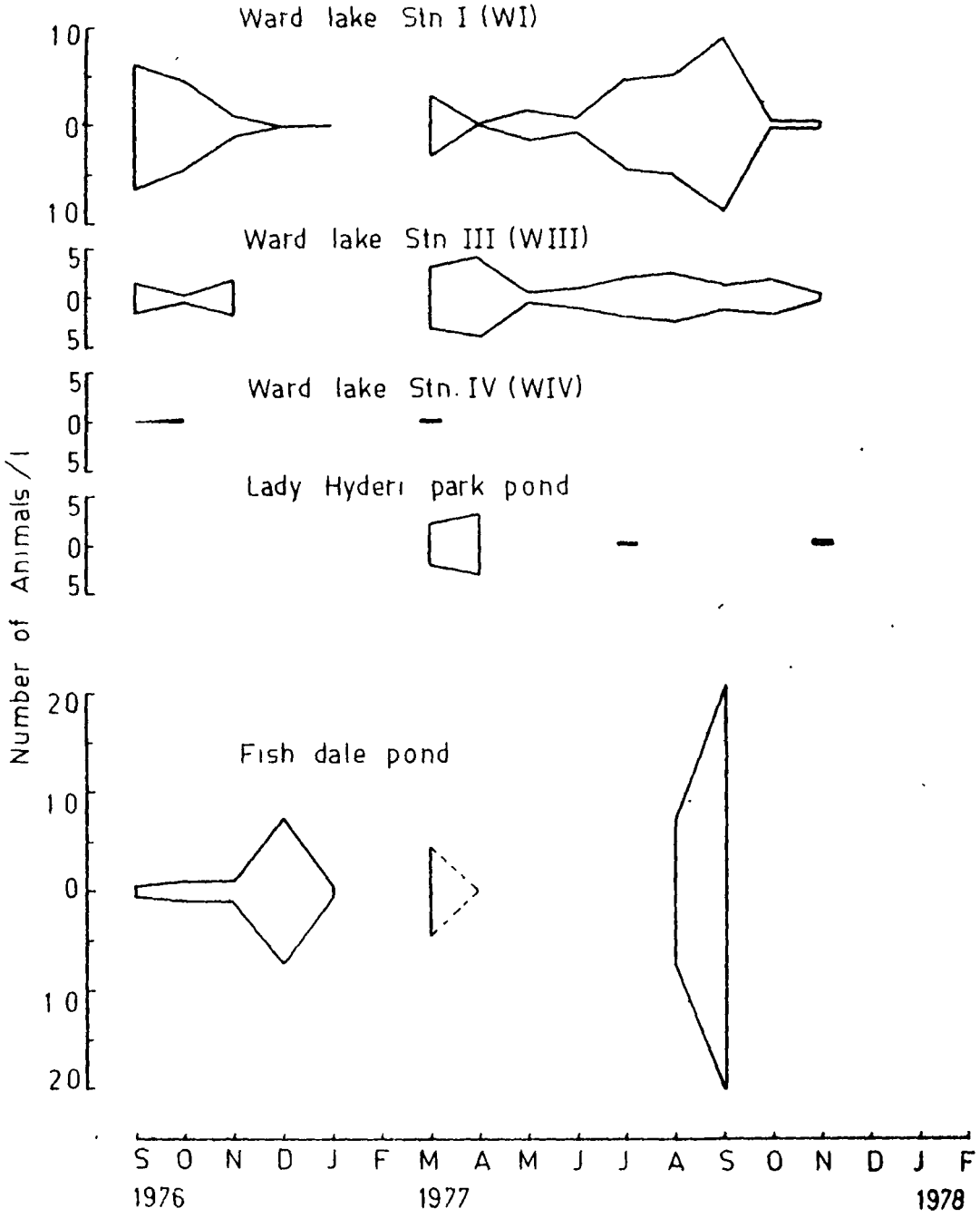
Table-53 : Showing seasonal variation in the numerical density (No./l) of Scapholeberis kingi in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976 to February, 1978).

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	12.67	-	3.25	-	1.00	-
October	9.25	0.25	0.75	0.25	1.75	-
November	2.33	0.33	3.50	0.50	2.00	-
December	0.33	-	-	-	14.67	-
1977						
January	0.40	-	-	-	1.00	-
February	-	-	-	-	-	-
March	6.25	-	5.75	0.50	9.00	3.50
April	0.40	-	7.00	-	-	5.60
May	2.67	-	1.33	-	-	-
June	1.50	-	2.00	-	-	-
July	8.67	-	4.00	-	-	0.25
August	9.00	-	5.00	-	14.33	-
September	9.50	-	2.50	-	40.50	-
October	17.50	-	3.50	-	-	-
November	0.50	-	0.50	-	-	0.50
December	0.50	-	-	-	-	-
1978						
January	-	-	-	-	-	-
February	-	-	-	-	-	-

Fig.29

Seasonal variations in the population density (No/L) of Scapholeberis kingi in the foursstations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig. 29


Ward lake Stn I (WI)
10
0
10
Ward lake Stn III (WIII)
5
0
5
Ward lake Stn. IV (WIV)
5
0
5
Lady Hyderi park pond
5
0
5
Number of Animals / l
Fish dale pond
20
10
0
10
20
S O N D J F M A M J J A S O N D J F
1976
1977
1978

3.5 units/l and continued through April, 1977 forming the highest density of 5.6 units/l. They were not recorded during May and June, 1977. Two minor densities of 0.25 units and 0.50 units/l were noted during July and November, 1977 respectively.

Simocephalus exspinosus : Except for WII of Ward Lake this species appeared in all other sampling stations.

WI : The highest numerical abundance of this species in WI was 381 units/l in February, 1977 while the lowest was in May, 1977 with only 0.33 units/l. Population dynamics of S. exspinosus in WI has been shown in Table-54 and Fig.30. February, 1977 and 1978 showed the two numerical maxima of Simocephalus populations while during the rest of the study period population density showed little fluctuation as it ranged from 0.33 units to 4 units/l only.

WII : Simicephalus exspinosus was never recorded in this station.

WIII: Table-54, Fig.30 show the seasonal fluctuations in the population density of S. exspinosus in WIII. Except during the months of July, 1977 and January, 1978, this species appeared throughout the season. Their highest abundance was marked by 38 units/l observed during November, 1976 while the lowest was in January, 1977 when only 0.2 units/l was seen. Numerical density of S. exspinosus was restricted to the range of 0.20 - 5 units/l except for the month of

peak density observed in November, 1976.

WIV : In WIV Simocephalus exspinosus showed highest abundance as compared to all other sampling stations (Table-54, Fig.30). Their maximum density was 676.50 units/l in September, 1976 forming 77.05% of the total cladocera. Their lower limit, on the other hand, was 0.50 units/l (February, 1978) forming 5.0% of the total Cladocera. From September, 1976 onwards Simocephalus populations were continuously recorded till October, 1977, although during the last three months (August, 1977 - October, 1977) their number dwindled to a negligible limit followed by complete absence during November and December, 1977. In January and February, 1978, they were recorded once again though in poor densities.

Fish Dale Pond : In this station Simocephalus was recorded only twice forming less than 1% of the total cladocera (Table-54, Fig.30). In March, 1977 unit/l was recorded which formed 0.93% of total cladocerans while in June, 1977 only 0.25 units/l was recorded forming 0.19% of the total. During the 18 months study period, this species was recorded altogether in 7 months (Table-54, Fib.30). The maximum numerical abundance was 5 units/l in March, 1977 while the lowest number recorded was 0.25 units/l in the month of June, 1977. They had a somewhat sporadic distribution in this pond and were recorded during November and December, 1976, March and April, 1977 June and July, 1977 and also

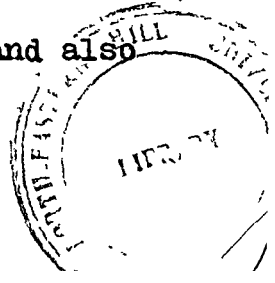


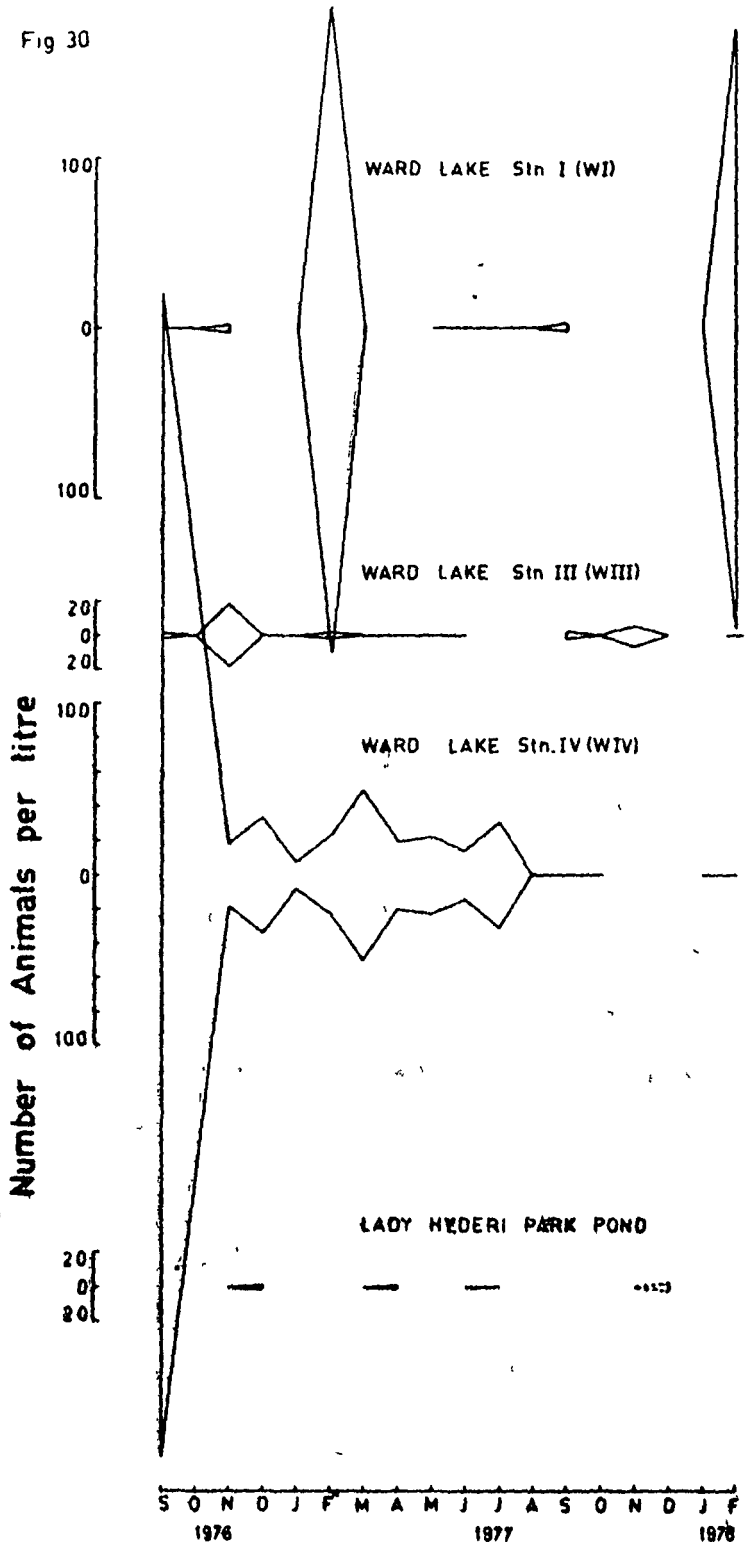
Table-54 : Showing seasonal variation in the numerical density (No./l) of *Simocephalus exspinosus* in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976 to February, 1978).

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	1.00	-	2.00	676.50	-	-
October	0.75	-	1.00	196.50	-	-
November	4.00	-	38.00	33.50	-	1.33
December	-	-	0.67	58.00	-	2.33
1977						
January	1.80	-	0.20	15.40	-	-
February	381.00	-	2.33	44.00	-	-
March	2.50	-	1.00	95.00	0.25	5.00
April	-	-	0.25	37.00	-	1.00
May	0.33	-	1.00	46.00	-	-
June	0.25	-	0.50	27.25	-	0.25
July	0.33	-	-	66.00	0.25	0.50
August	0.67	-	-	2.50	-	-
September	3.50	-	3.50	2.00	-	-
October	-	-	1.00	1.00	-	-
November	0.50	-	5.00	-	-	-
December	-	-	1.00	-	-	3.50
1978						
January	0.50	-	-	1.00	-	-
February	355.00	-	1.00	0.50	-	-

Fig.30

Seasonal variations in the population density (No/l) of Simocephalus exspinosus in the four stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig 30


WARD LAKE Stn I (WI)
WARD LAKE Stn III (WIII)
WARD LAKE Stn.IV (WIV)
LADY HYDERI PARK POND
100
0
100
20
0
20
100
0
100
20
0
20
Number of Animals per litre
S O N D J F M A M J J A S O N D J F
1976
1977
1978

November, 1977.

Simocephalus serrulatus : This species was recorded only in WIV of Ward Lake in December, 1977 forming a population of 0.25 units/l density. They were not recorded in Fish Dale and Hyderi Park ponds (Table-52).

Family Moinidae :

Moina micrura : Moina micrura was recorded only in WIV of Ward Lake and were absent in all the rest of the stations and the two other systems. This species appeared only once during the 1st week of October, 1977 with the density of 1 unit/l, thus resulting in the monthly average value of 0.25 units/l (Table-52).

Family Macrothricidae :

Ilyocryptus spinifer : Ilycryptus spinnifer was recorded only in WIII of Ward Lake (Table-52). They were not found in any of the other sampling stations. In WIII, they were found only during October and November, 1976 with 4 units/l and 3 units/l respectively. In October, 1976 they contributed 7.48% to the total Cladocera while only 2.28% in November, 1976.

Family Bosminidae :

~~Bosmina longirostris~~ : B. longirostris was present in all sampling stations.

WI :Seasonal fluctuations in the population density of B.longirostris in WI have been shown in Table-55 and Fig.31. The highest numerical density of this Bosminidae

was in December, 1977 with 288 units/l while the lowest was in January, 1977 when only 2.2. units/l were found. From September to November, 1976 these organism did not exhibit much difference in population density which was followed by a maxima in December, 1976 (284 units/l). The density became low in January, 1977 only to increase gradually till April, 1977. After a second low value in May, 1977, the count per litre increased once again till higher values of 240 and 275 units/l were observed during September and October, 1977. In December, 1977 the highest value was seen while low densities were observed in November, 1977, January and February, 1978.

WII : In this station B. longirostris was present throughout the study period except in June, 1977. Their highest recorded number was 225 units/l while the lowest was 0.50 units/l observed in September, 1977 and also in August and November, 1977. Both September, 1977 and 1978 showed higher population densities with 198 units/l and 225 units/l. The densities were low from October, 1976 to August, 1977 and also from October, 1977 to February, 1978 (Table-55, Fig.31).

WIII: In WIII the maximum numerical abundance of B.longirostris was in September, 1977 with 15.50 units/l while the lowest number was found in January, 1977 with only 0.40 units/l. Three distinct maxima were observed during

September, 1976, January, 1977 and September, 1977. During the months November and December, 1976, February, July and December, 1977 and also in February, 1978, Bosmina longirostris was not recorded at this station. The winter maxima observed in Station-XII was not recorded here.

WIV : The highest density of Bosmina population was observed in this station (Table-55, Fig.31). Minimum and maximum densities of B. longirostris were 0.20 units/l and 1080 units/l recorded during September, 1977 and November, 1977 respectively. This species was not recorded during the months of September, 1976 to December, 1976, February, March, July and August, 1977 and also in February, 1978.

Fish Dale Pond : Seasonal fluctuations in the population density of B. longirostris have been shown in Table-55, Fig.31. The total range of pupulation density of this species in this system varied from 0.50 -81.15 units/l. The highest was recorded in the month of July, 1977 while the lower limit was those of September, October and November, 1976. Bosmina was not recorded during December, 1976, March, 1977 and November, 1977. April, 1977 to October, 1977 showed higher values with a peak in July, 1977 with 81.15 units/l. After a low density of 1 unit/l in January, 1978 the population density showed increase in February, 1978 with 27units/l.

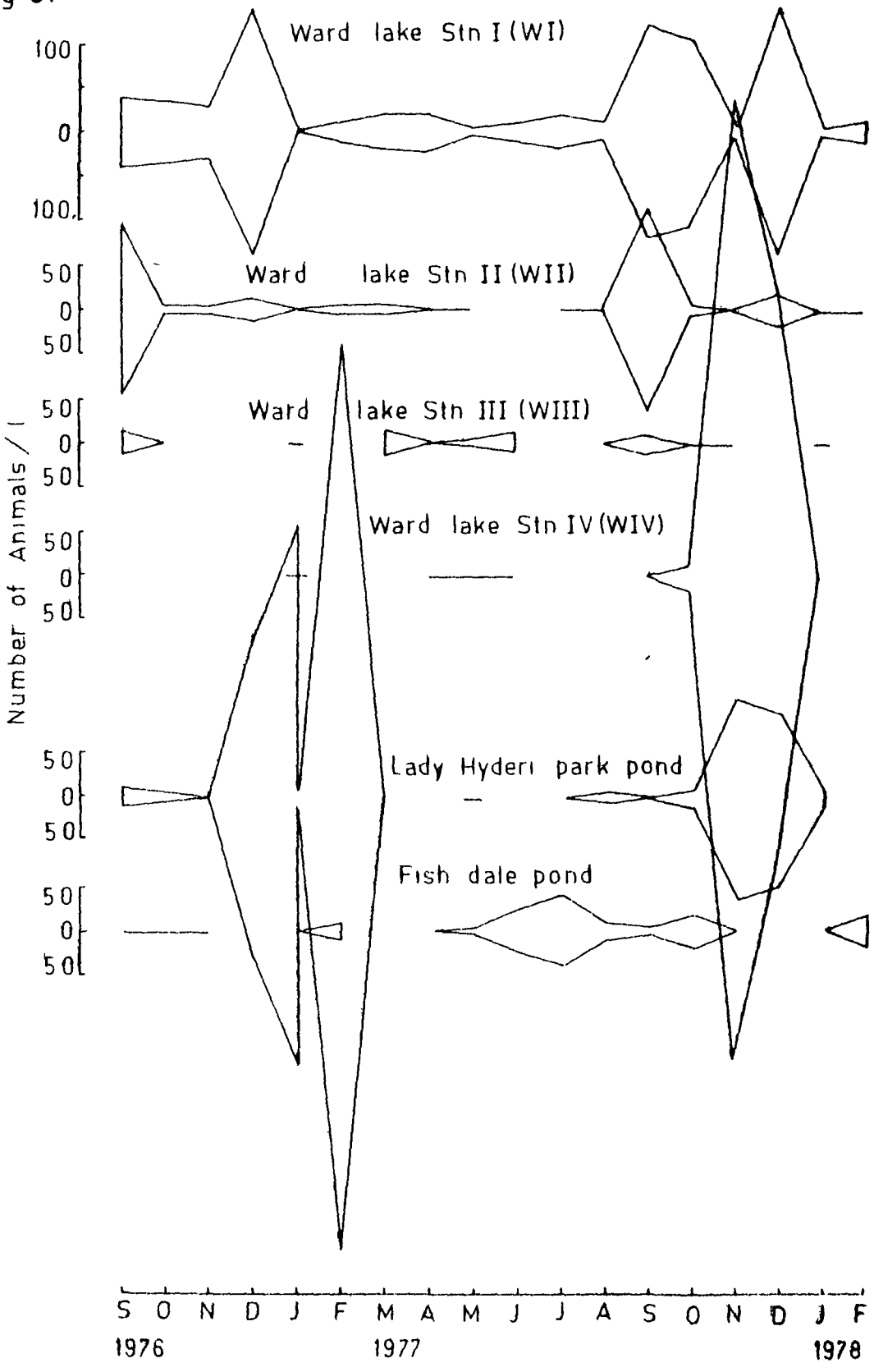
Table-55 : Showing seasonal variation in the numerical density (No./l) of *Bosmina longirostris* in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976 to February, 1978).

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	74.00	198.00	14.75	-	0.50	20.00
October	66.25	11.00	5.50	-	0.50	7.50
November	61.67	8.33	-	-	0.50	3.33
December	283.67	25.33	-	-	-	363.67
1977						
January	2.20	2.25	0.40	0.40	1.00	711.00
February	9.00	4.00	-	-	10.33	32.50
March	24.50	6.25	13.50	-	-	1082.50
April	34.60	3.20	0.50	0.25	2.60	16.00
May	7.67	1.50	3.67	3.33	4.50	-
June	21.00	-	15.25	0.50	49.00	0.25
July	25.00	0.50	-	-	81.50	-
August	17.67	1.00	3.00	-	20.33	4.00
September	240.00	225.00	15.50	0.20	7.50	9.50
October	214.50	4.00	2.00	16.00	24.00	1.50
November	15.00	0.50	0.50	1080.00	1.50	17.50
December	288.00	35.00	-	655.00	-	225.00
1978						
January	5.50	3.00	1.00	1.00	1.00	198.50
February	19.00	3.00	-	-	27.00	17.00

Fig.31

Seasonal variations in the population density (No/l) of Bosmina longirostris in the four stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig. 31


Ward lake Stn I (WI)
Ward lake Stn II (WII)
Ward lake Stn III (WIII)
Ward lake Stn IV (WIV)
Lady Hyderi park pond
Fish dale pond
Number of Animals / l
100
0
100
50
0
50
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Lady Hyderi Park pond : Of the total 18 months sampling period, B. longirostris was almost always present in this system except in the months of May and July, 1977 as shown in Table-55 and Fig.31. The highest density of B.longirostris was in March, 1977 with 1082.50 units/l and the lowest was 0.25 units/l in June, 1977. Three distinct maxima were observed during the study period. The first higher value was seen in January, 1976 with 711.00 units/l, followed by the peak value (1082-5) in March, 1977 while the third higher value was recorded in December, 1977 with 225 units/l. Both the months of December, 1976 and January, 1977 exhibited somewhat higher values. During the rest of the period B.longirostris ranged between 0.25 to 32.50 units1.

Family Chydoridae :

Chydorus sphaericus : C.sphaericus was present in all of the 3 systems and also in all stations of Ward Lake.

WI : In WI C.sphaericus was present throughout the study period (Table-56, Fig.32). In september, 1976 the numerical density was 14.33 units/l which gradully declined to reach 1.33 units/l in December, 1976. From January, 1977 an increasing trend was noticed reaching the value of 29 units/l in February, 1977. March, 1977 marked another low density period with 3.50 units/l followed by an increase in April, 1977 and in May, 1977 the density reached 11.67 units/l which again declined till July, 1977 only to increase further to reach the value of 15 units/l in

October, 1977. From November, 1977 to January, 1978 the population was low in density while February, 1978 showed a distinct maxima with 25.50 units/l. Lowest and highest densities were 1.33 and 29 units/l recorded during December, 1976 and February, 1977 respectively.

WII : In this open water station Chydorus sphaericus was recorded only during September and October, 1976 and also during September, 1977 (Table-56, Fig.32). Highest numerical density was 1 unit/l during September, 1977.

WIII: Seasonal fluctuations in the population density of C. sphaeriens has been presented in Table-56 and Fig.32. This species was present throughout the study period in WIII and their maximum density was 45 units/l in November, 1976. Two other maxima in density were in March, 1977 with 31.25 units/l and November, 1977 with 40 units/l. Lowest numerical abundance was in August, 1977 when a density of 2.75 units/l was recorded.

WIV : In WIV population density of C. spaericus was (Table-56, Fig.32) maximum in September, 1976 with 100 units/l and continued till October, 1976. They disappeared completely in November, 1976 only reappear in December, 1976 when a density of 28.75 units/l was recorded. From January to August, 1977 population density of C. spaericus ranged between 1.75 - 19.25 units/l. August, 1977 exhibited a density of 60 units/l which declined subsequently to

reach the value of 3.50 imots/l in January, 1978. The lowest density, however, was recorded in August, 1977 with only 1.75 units/l.

Fish Dale pond : The numerical density of C.sphaericus in this system is as shown in Table-56 and Fig.32. During period from September, 1976 to December, 1976, October and November showed comparatively higher density with 10.50 and 11.25 units/l respectively. In December, 1976 and January, 1977, the population density was low while February and March, 1977 showed active period of growth and the population continued till June, 1977 only to disappear in July, 1977. C. sphericus reappeared again in the plankton samples in October, 1977 which reached the maximum density in February, 1978 with 24.50 units/l. The lowest value was recorded in June, 1977 with 0.33 units/l.

Lady Hyderi Park pond : The lowest and highest numerical abundance of Chydorus spaericus in this system were those of August, 1977 and November, 1976 with 1.67 and 119.33 units/l respectively. This system showed a higher population density during the major period of the season when compared with other systems. With the exception of August, 1977 when the lowest density was seen, numerical density values ranged between 3.40 - 119.33 units/l.

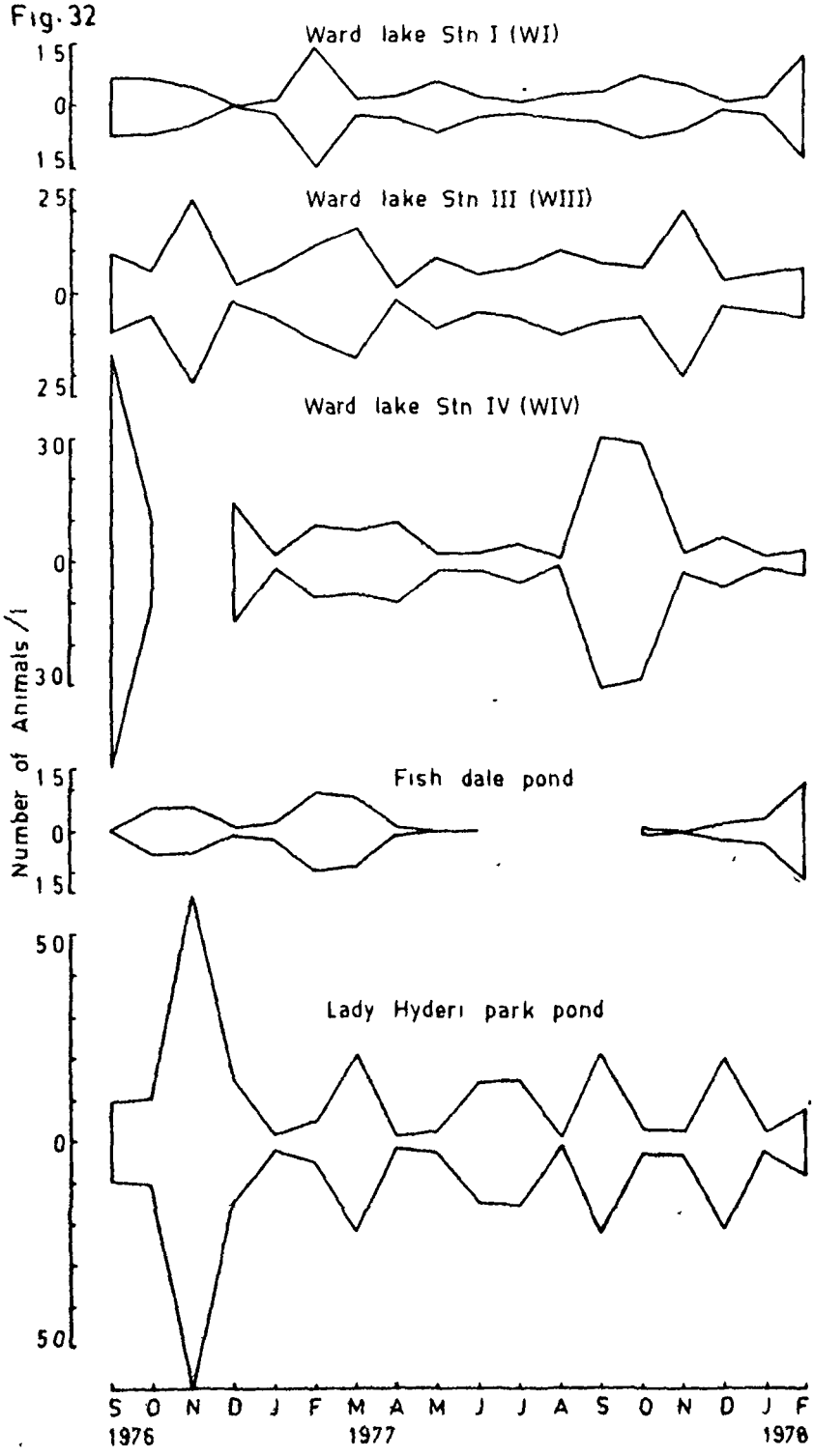
Table-56 : Showing seasonal variation in the numerical density (No./l) of Chydorus sphaericus in the 4 Stations of Ward Lake and Fish Dale and Lady Hyderi Park ponds (September, 1976 to February, 1978).

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	14.33	0.75	18.75	100.00	1.00	19.25
October	12.75	0.50	10.75	19.00	10.50	10.75
November	9.00	-	45.00	-	11.25	119.33
December	1.33	-	4.33	28.75	2.33	29.67
1977						
January	2.80	-	12.20	2.60	4.60	7.50
February	29.00	-	22.67	17.00	19.00	9.50
March	3.50	-	31.25	15.25	17.00	42.75
April	5.20	-	2.75	19.25	2.00	3.40
May	11.67	-	17.00	3.67	0.50	4.50
June	5.00	-	8.75	4.25	0.33	28.50
July	3.33	-	12.00	9.00	-	30.00
August	6.00	-	20.33	1.75	-	1.67
September	6.50	1.00	14.50	60.00	-	43.50
October	15.00	-	12.50	57.00	1.00	6.50
November	11.50	-	40.00	4.50	0.50	6.50
December	2.00	-	5.50	12.00	4.00	41.50
1978						
January	3.50	-	9.00	3.50	6.00	5.00
February	25.50	-	12.00	5.50	24.50	16.00

Fig.32

Seasonal variations in the population density (No/l) of Chydorus sphaericus in the four stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig. 32


Ward lake Stn I (WI)
15
0
15
Ward lake Stn III (WIII)
25
0
25
Ward lake Stn IV (WIV)
30
0
30
Number of Animals /l
Fish dale pond
15
0
15
Lady Hyderi park pond
50
0
50
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Biapertura affinis : Biapertura affinis was recorded in all the three systems and in all stations of Ward Lake (Table-57).

WI : In WI the highest recorded number was 8.0 units/l observed in September, 1977. Although their number was not very high. B.affinis was always present except in November, 1976 and April and May, 1977. Lowest numerical density was found in December, 1976 with 0.33 units/l. and their range of density value between December, 1976 to Mafch, 1977 was 0.33 to 2.5 units/l. From the month of June, 1977 to February, 1978, B. affinis was continuously present ranging from 0.50 to 8.0 units/l (Table-57, Fig.33).

WII : In WII B.affinis was recorded on only 3 occasions namely, November, 1976, February, 1977 and April, 1977 with a maximum density of 0.33 units/l (Table-57,Fig.33).

WIII: Numerical density of B. affinis in WIII has been presented in Table-57 and Fig.33. Highest number of individualsw was observed in September, 1977 with 14 units/l. During the total of 18 months study period commencing on September, 1976, the population density was of a fluctuating nature. The September, 1976 collection marked by 5 units/l increased to 7.5 units/l in March, 1977, though with minor fluctuations. In April, 1977 the density decreased to 4.5 units/l and B. affinis disappeared in May, 1977. Among the remaining months

they were absent in August and October, 1977 and January, 1978. Except in the month of September, 1977 when the highest value of 14.0 units/l was recorded, numerical density of B. affinis ranged between 0.75 to 3 units/l.

WIV : In WIV B. affinis was recorded only during September, 1976 till June, 1977. Highest density of B. affinis was in September, 1976 with 11 units/l and the lowest value was 0.2 units/l recorded in the months of October, 1976 and January, 1977. During their period of occurrence also (September, 1976 - June, 1977). B. affinis was not recorded in the months of November, 1976, February and April, 1977. During the rest of the period the density was never more than 2 units/l (Table-57, Fig.33).

Fish Dale pond : In this system B. affinis was recorded only in October, 1976 with a density of 0.25 units/l (Table-57).

Lady Hyderi Park pond : In this system, the seasonal fluctuations of the numerical density was somewhat different (Table-57, Fig.33). The highest density was recorded in June, 1977 with 8.75 units/l. In course of the 18 months study, they were recorded on 9 occasions with September and October, 1976 showing a density of 0.25 units/l. Densities during January to March, 1977 ranged between 1 to 1.75 units/l while June and July, 1977 showed a density range of 4.0 to 8.75 units/l. January and February, 1978, on

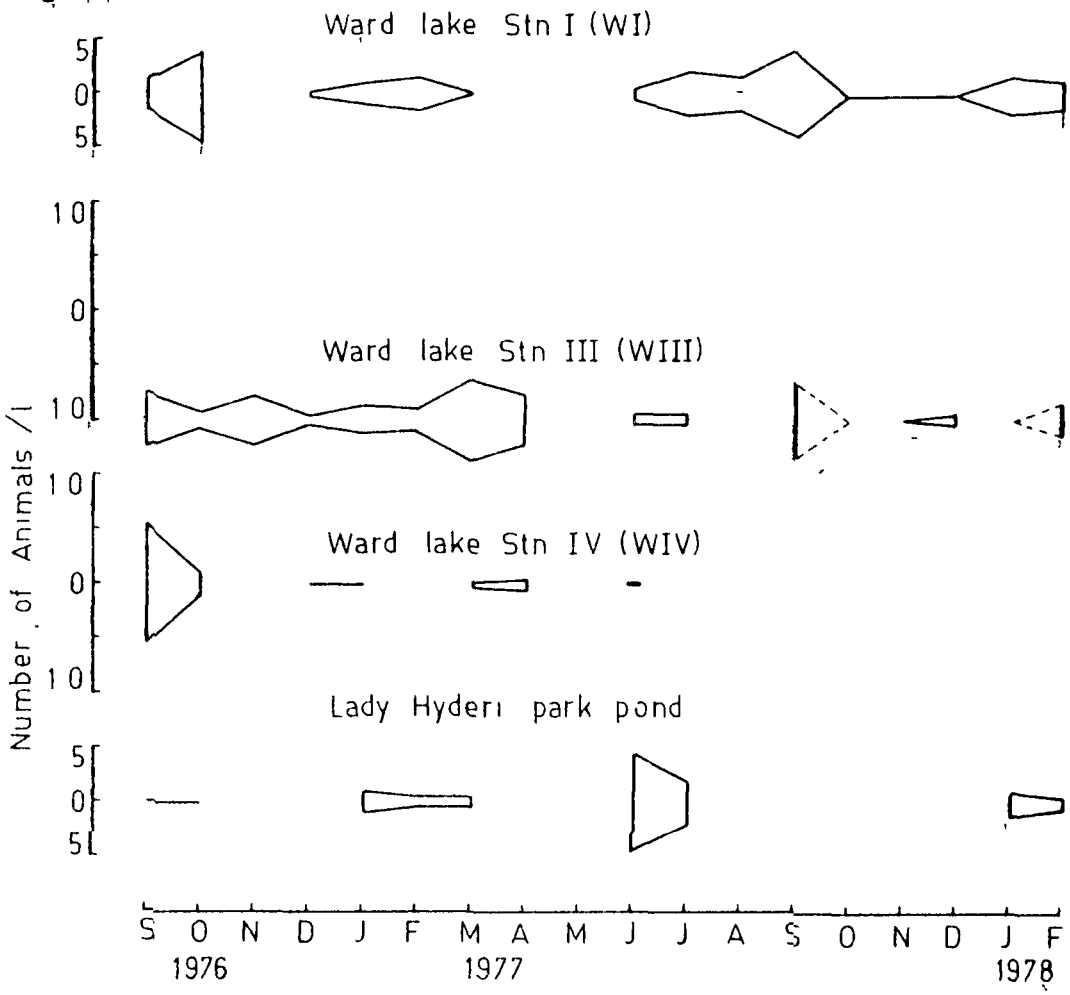
Table-57 : Showing seasonal variation in the numerical density (No./l) of Biapertura affinis in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976 to February, 1978).

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	3.00	-	5.00	11.00	-	0.25
October	7.75	-	1.50	2.00	0.25	0.25
November	-	0.33	4.50	-	-	-
December	0.33	-	1.33	0.25	-	-
1977						
January	2.00	-	2.40	0.20	-	1.75
February	2.50	0.33	2.33	-	-	1.00
March	0.50	-	7.50	0.50	-	11.00
April	-	0.20	4.50	1.00	-	-
May	-	-	-	-	-	-
June	0.75	-	0.75	0.50	-	8.75
July	4.00	-	1.00	-	-	4.00
August	2.67	-	-	-	-	-
September	8.00	-	14.00	-	-	-
October	0.50	-	-	-	-	-
November	0.50	-	0.50	-	-	-
December	0.50	-	1.00	-	-	-
1978						
January	3.50	-	-	-	-	2.00
February	2.50	-	3.00	-	-	1.00

Fig.33

Seasonal variations in the population density (No/l) of *Biapertura affinis* in the four stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig. 33


Ward lake Stn I (WI)
5
0
5
10
0
Ward lake Stn III (WIII)
10
10
0
Ward lake Stn IV (WIV)
10
Lady Hyderi park pond
5
0
5
Number of Animals /l
S O N D J F M A M J J A S O N D J F
1976
1977
1978

the other hand, had the densities of 2.0 and 1.0 units/l respectively.

Camptocercus australis : C. australis was recorded only at WI and WIII and WIV of Ward Lake. This species was absent in Fish Dale and Lady Hyderi Park ponds.

WI : Seasonal fluctuations in the numerical density of C. australis in WI has been presented in Table-58 and Fig.34. The maximum density was observed in December, 1976 with 12.67 units/l while the lowest was 0.33 units/l observed in September, 1976. This species continued from September, 1976 till January, 1977 showing higher densities during the last two months. They were not recorded during February, 1977 and were present continuously from March to August, 1977 with a maximum density of 2.33 units/l (July, 1977). In January, 1978, 8.0 units/l was recorded. They were absent from September to December, 1977 and February, 1978.

WII : C. austrilis was not recorded in this station.

WIII: C. australis was present throughout the study period except September, 1976 and March and October, 1977. With their absence in September, 1976 C. australis continued through October, 1976 till February, 1977 showing highest abundance in January, 1977 with 5 units/l. This population died at the end of February, 1977 and were absent throughout March, 1977. In the month of April, 1977, C. australis reappeared again to continue till

Table-58 : Showing seasonal variation in the numerical density (No./l) of Camptocercus australis in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976 to February, 1978).

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	0.33	-	-	3.50	-	-
October	1.75	-	2.50	4.75	-	-
November	2.33	-	3.00	5.00	-	-
December	12.67	-	4.67	-	-	-
1977						
January	3.20	-	5.00	-	-	-
February	-	-	2.67	-	-	-
March	0.25	-	-	0.25	-	-
April	1.80	-	1.75	0.25	-	-
May	1.00	-	1.33	-	-	-
June	1.00	-	0.75	-	-	-
July	2.33	-	3.00	-	-	-
August	2.00	-	1.33	-	-	-
September	-	-	2.50	-	-	-
October	-	-	-	-	-	-
November	-	-	16.50	-	-	-
December	-	-	6.00	-	-	-
1978						
January	8.00	-	8.00	-	-	-
February	-	-	1.50	-	-	-

September, 1977 with the maximum numerical density of 3 units/l. After a period of absence during October, 1977 C. australis continued from November, 1977 till February, 1978. The peak value of the numerical abundance was 16.50 units/l observed in November, 1977. The lowest number was recorded in June, 1977 with only 0.75 units (Table-56,Fig.34).

WIV : In WIV C. austrilis showed two distinct pulses of the population (Table-58, Fig.34). The first continued from September, 1976 till November, 1976 when the highest seasonal density was 5 units/l recorded in November, 1976. The second population arose in the month of March, 1977 and continued till April, 1977 with a density of 0.25 units/l in both the months.

Lady Hyderi Park pond : C. australis was absent in this pond.

Acroperus harpae : Acroperus harpae was recorded in all the systems except in WII of Ward Lake.

WMI :Numerical density of A. harpae fluctuated during different months in WI (Table-59, Fig.35). Highest population density was seen in September, 1976 with 21.67 units/l which declined to 13.25 units/l in October, 1976 and again increased in November, 1976 to the value of 18.33 units/l. This species was not recorded during December, 1976, September and December, 1977 and also in January, 1978. Acroperus harpae was continuously present from

January to August, 1977 with a density of 3 to 11.50 units/l. During the 18 months study period 2 maxima were observed during February and April, 1977 with 11.50 and 8.60 units/l, although the peak value was in September, 1976 as mentioned earlier.

WII : Acroperus harpae was not recorded in this station.

WIII : Seasonal fluctuations in thepopulation density of A. harpae in WIII have been shown in Table-59 and Fig.35. Lowest and highest numerical densities were those of August, 1977 and November, 1976 with 0.67 and 24.50 units/l respectively. They were not recorded during September, 1976, January and July, 1977 and January, 1978. From October, 1976 A. harpae populations increased to reach the highest value in November, 1976 followed by a declined in December, 1976 only to disappear in January, 1977. In February, 1977 they appeared again with 7.67 units/l which declined in March, 1977 and rose again to reach a density of 24 units/l in April, 1977, followed by a gradual decrease and complete absence in July, 1977. From August to December, 1977, this species was continuously present ranging between 0.67 and 12.50 units/l. A value of 6 units/l was recorded in February, 1978 though they were absent earlier in January, 1978.

WIV : In station WIV A. harpae was recorded only during October, 1976 with a density of 0.25 units/l (Table-59).

Table-59 : Showing seasonal variation in the numerical density (No./l) of *Acroperus harpae* in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976 to February, 1978).

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	21.67	-	-	-	-	5.25
October	13.25	-	22.50	0.25	0.25	0.75
November	18.33	-	24.50	-	-	0.33
December	-	-	8.33	-	-	0.33
1977						
January	3.00	-	-	-	-	-
February	11.50	-	7.67	-	-	-
March	4.75	-	1.75	-	-	0.25
April	8.60	-	24.00	-	-	0.20
May	6.67	-	16.00	-	-	2.00
June	3.50	-	3.25	-	-	1.75
July	6.33	-	-	-	-	2.75
August	6.00	-	0.67	-	-	-
September	-	-	10.00	-	-	2.50
October	3.50	-	5.50	-	-	1.00
November	4.00	-	12.50	-	-	1.00
December	-	-	6.00	-	-	-
1978						
January	-	-	-	-	-	5.00
February	8.50	-	6.00	-	-	-

Fig.34

Seasonal variations in the population density (No/l) of Camptocercus australis in the four stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig.35

Seasonal variations in the population density (No/l) of Acroperus harpae in the four stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig. 34

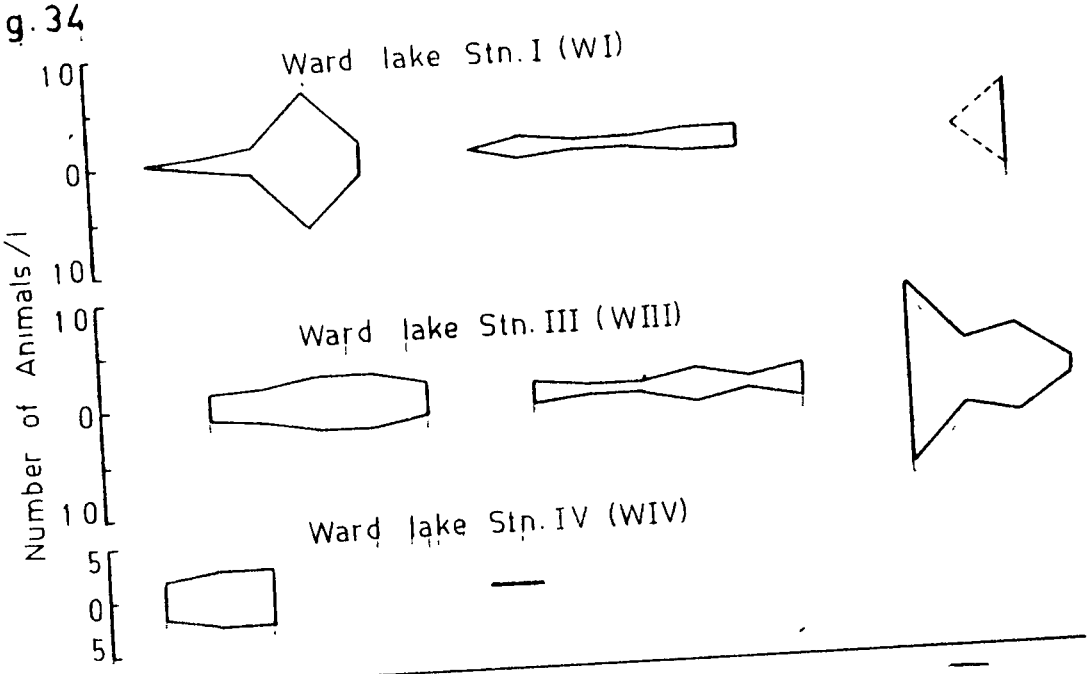
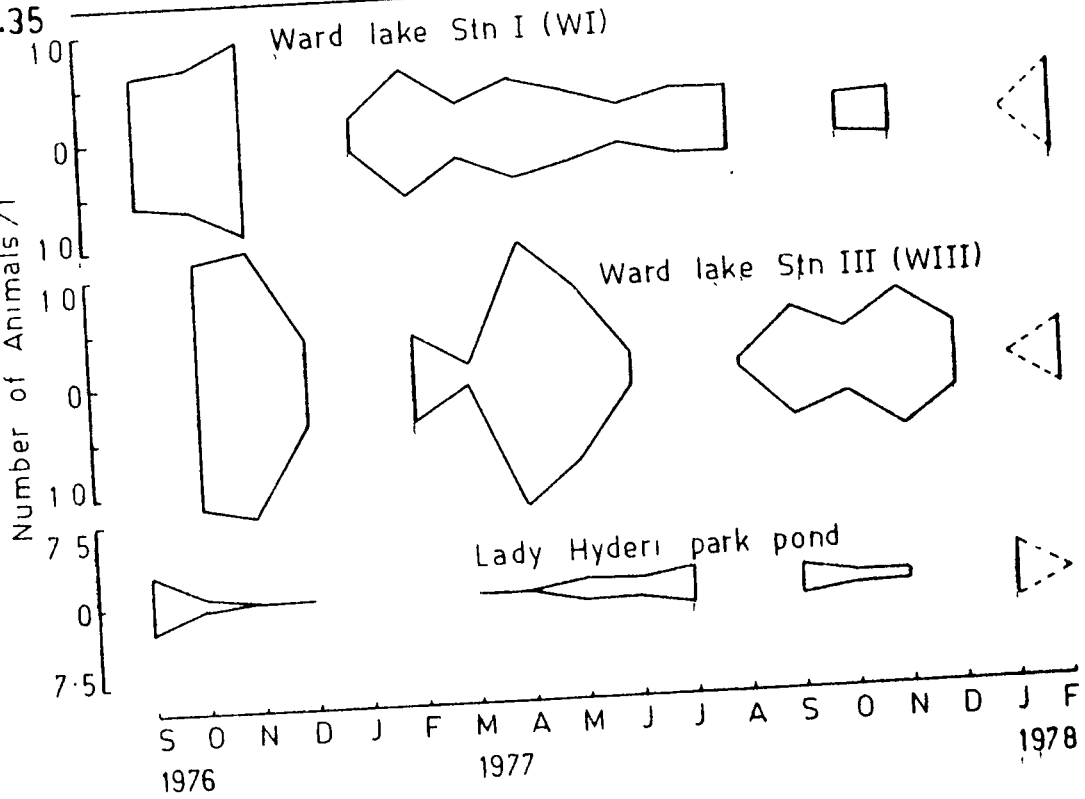

Ward lake Stn. I (WI)
Ward lake Stn. III (WIII)
Ward lake Stn. IV (WIV)
Number of Animals /l
10
0
10
5
0
5

Fig. 35


Ward lake Stn I (WI)
Ward lake Stn III (WIII)
Lady Hyderi park pond
Number of Animals /l
10
0
10
7·5
0
7·5
S O N D J F M A M J J A S O N D J F
1976
1977
1978

Fish Dale pond : In this pond also A. harpae was only found in October, 1976 with 0.25 units/l.

Lady Hyderi Park pond : In this system A. harpae was absent during January, February, August and December, 1977 and February, 1978. The numerical density was never very high and the highest value was 5.25 units/l in September, 1976 followed by gradual decline reaching 0.33 units/l in December, 1976 and subsequently disappeared from plankton in January and February, 1977. In March, 1977, the density was 0.25 units/l which gradually increased to reach 2.75 units/l in July, 1977 only to disappear in August, 1977. During September, 1977 the numerical density observed was 2.50 units/l followed by 1 unit/l during October and November, 1977. This species disappeared in December, 1977 only to reappear again in January, 1978 with 5 units/l. The lowest and highest numerical densities were 0.2 units/l in August, 1977 and 5.25 units/l in September, 1976 respectively (Table-59, Fig.35).

Pleuroxus similis : P. similis was recorded in all the 3 systems except in the WII of Ward Lake.

WI : In WI, Pleuroxus similis was only present during the months of January and February, 1977 forming a maximum density of 0.75 unit/l.

WIII : In WIII of Ward Lake, Pleuroxus similis showed a maximum density of 7.33 units/l in February, 1977 (Table-60).

Table-60 : Showing seasonal variation in the numerical density (No./l) of Pleuroxus similis in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976 to February, 1978).

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WVI		
1976						
September	-	-	-	-	-	-
October	-	-	0.25	-	-	-
November	-	-	-	-	0.50	-
December	-	-	1.33	-	0.67	4.33
1977						
January	0.60	-	4.00	-	-	-
February	0.75	-	7.33	-	-	-
March	-	-	-	0.75	-	-
April	-	-	-	-	-	-
May	-	-	-	0.33	-	-
June	-	-	-	-	-	-
July	-	-	-	0.50	-	-
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	-	-	-	-	-	-
November	-	-	-	-	-	-
December	-	-	-	-	-	-
1978						
January	-	-	-	-	-	-
February	-	-	-	-	-	

This species was also recorded in October, 1976 (0.25 units/l), December, 1976 (1.33 units/l) and January, 1977 (4 units/l).

WIV : Pleuroxus similis occurred in WIV only in March, May and July, 1977 (Table-60). The population was never more than 0.75 units in density.

Fish Dale pond : P. similis occurred only during November and December, 1976. The density of population never exceeded 0.67 units/l (Table-60).

Lady Hyderi Park pond : Pleuroxus similis was recorded during December, 1976 and the numerical density observed was 4.33 units/l (Table-60).

Alonella excisa : This species was present in all stations of Ward Lake and also in Fish Dale and Lady Hyderi Park ponds.

WI : Data on the population fluctuations of A. excisa during different months of the study period have been shown in Table-61 and Fig.36. Minimum and maximum densities of Alonella in WI were in September, 1976 with 17.33 units/l and in November, 1977 with 0.50 units/l respectively. Alonella excisa was absent during October, 1976, April, June, July and September, 1977. This species was distinctly higher in numbers during September, November and December, 1976. During the rest of the p riod Alonella population ranged between 0.50 to 6.50 unit/l.

WII : In WII Alonella excisa was only recorded during November, 1976

and March, 1977 with 1 unit/l and 0.25 unit/l respectively (Table-61).

WIII: Alonella excisa was always present in this station except in October and November, 9177. The highest density of 21.25 units/l was recorded in September, 1978 which declined to 4.75 unit/l in October, 1976 only to increase again in November, 1976 followed by a decline in December, 1976. In the year 1977, the number of these organisms varied between 1-7/1 except in the month of September, 1977 when 12.5 unit/l was recorded. During January and February, 1978 the density values were 6 units/l and 2 units/l respectively (Table-61, Fig.36).

Fish Dale pond : In this station A. excisa was only recorded in the month of March, 1977 with an average density of 3 units/l (Table-61).

Lady Hyderi Park pond : In this system the highest number of Alonella excisa was in June, 1977 with 21.75 units/1, while the lowest value was those in September, 1976 and November, 1976 with 0.50 units/l (Table-61, Fig.36). During the total of 18 months sampling A. excisa was recorded during 10 months and were absent during October and December, 1976, February, April, October and December, 1977 and also during January and February, 1978. They were present in alternate months starting with September, 1976 till April, 1977. During March, 1977 to

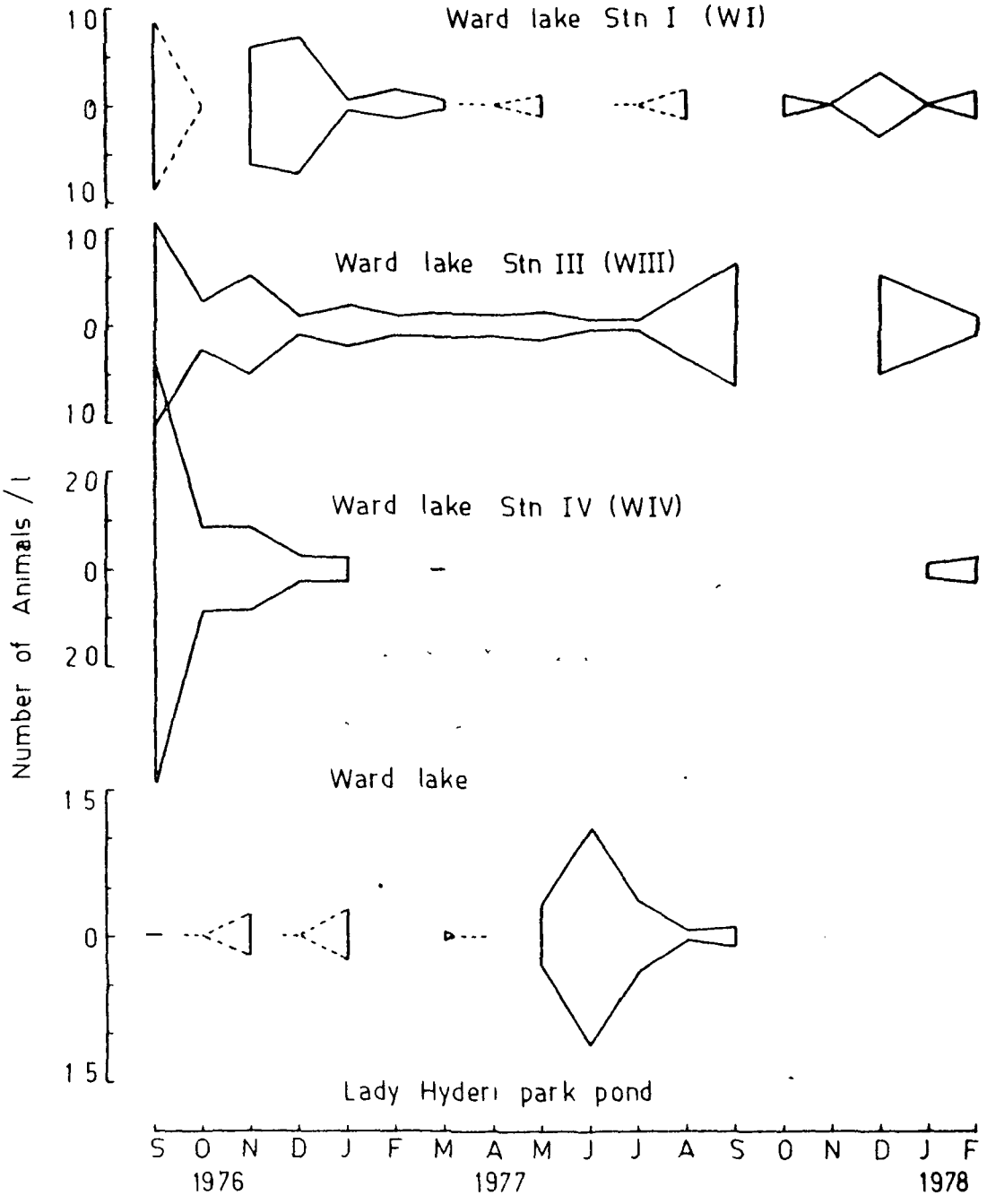
Table-61 : Showing seasonal variation in the numerical density (No./l) of Alonella excisa in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond. (September, 1976 to February, 1978)

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	17.33	-	21.25	87.00	-	0.50
October	-	-	4.75	16.75	-	-
November	12.33	1.00	10.00	17.00	-	4.33
December	14.33	-	1.67	5.50	-	-
1977						
January	0.30	-	3.80	5.20	-	4.75
February	3.00	-	2.00	-	-	-
March	0.75	0.25	2.50	0.50	-	0.80
April	-	-	2.25	-	-	-
May	2.33	-	3.00	-	3.00	6.50
June	-	-	1.00	-	-	21.75
July	-	-	1.00	-	-	6.75
August	3.33	-	6.67	-	-	1.00
September	-	-	12.50	-	-	2.00
October	2.00	-	-	-	-	-
November	0.50	-	-	-	-	0.50
December	6.50	-	10.00	-	-	-
1978						
January	1.00	-	6.00	3.50	-	-
February	2.50	-	2.00	4.00	-	-

Fig.36

Seasonal variations in the population density (No/l) of Alonella excisa in the four stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond during September, 1976 to February, 1978.

Fig. 36


Ward lake Stn I (WI)
10
0
10
Ward lake Stn III (WIII)
10
0
10
Ward lake Stn IV (WIV)
20
0
20
Ward lake
15
0
15
Number of Animals / l
Lady Hyderi park pond
S O N D J F M A M J J A S O N D J F
1976
1977
1978

September, 1977 Alonella excisa was present continuously and showed the peak density in July, 1977 (21.75 units/l).

Alonella nana : As shown in Table-52, Alonella nana was recorded only WIV of Ward Lake. This species never appeared in other stations of Ward Lake nor in Fish Dale and Lady Hyderi Park ponds. In WIV also, A. nana appeared only in the month of November, 1977 with a density of 0.25 units/l.

Alona sp. : Alona sp. appeared only in WIV of Ward Lake, while absent in all other stations and systems. This species was recorded in December, 1976 in two out of the four samples collected in that month. The average density was 0.50 units/l (Table-52).

STRUCTURE (SIZE GROUP, FEMALES WITH AND WITHOUT EGG, EGG/BROOD, GAMOGENESIS AND SEX RATIO) OF THE FIELD POPULATIONS OF DIFFERENT CLADOCERAN SPECIES.

Results of the size group, fecundity, sex ratio and the ratio of egg bearing and non egg bearing females are presented. Same species appearing in different stations was analysed separately. Thus the present results are based on the detailed analysis of the population structure of the daphnid, Simocephalus exspinosus, a bosminid, Bosmina longirostris and four chydorid species namely, Chydorus sphaericus, Pleuroxus similis, Acroperus harpae and Alonella excisa. Size Group-I represented preadult instars in all species.

Simocephalus exspinosus :

Detailed analysis of the population structure of Simocephalus exspinosus was conducted at WIV. The smallest animal recorded was 0.58 mm in length while the maximum length recorded was 2.025 mm. The total length range was grouped into five size groups. Thus Group-I which represented preadult stages ranged between 0.55 - 0.85 mm while the length of Group-II, III, IV and V ranged between 0.85 - 1.15 mm , 1.15 - 1.45 mm, 1.45 - 1.75 mm and 1.75 - 2.025 mm respectively.

WIV :Data collected during the 12 months study on the population structure of Simocephalus exspinosus at

WIV has been presented in Table-62 and Fig.37. Percentage occurrence of different size groups varied during different seasons. Group-I (juvenile) was more during September, 1976 and July, 1977 contributing 41 and 42% of the analysed specimens (Fig.37b). The higher incidence of Group-I generally coincided with higher field density of the species (Fig.37a). Contributions of the members of Group-II never exceeded 31% of the total except in August, 1977 when this group formed 76% of the total. Highest percentage occurrence of Group-III (1.15 -1.45 mm) was in March, 1977 forming 37% of the total. Percentage contribution of Group-IV ranged between 9 to 59% of the animals studied. Group-V (1.75 to 2.2025 mm) was not recorded continuously and they contributed a maximum of 18% in February, 1977.

During the 12 month study period (September, 1976 to August, 1977), females with empty brood pouch were always recorded in the field population (Fig.37c) though with varied density (Table-62). Maximum incidence of non-ovigerous mothers were recorded in August, 1977 forming 53% of the total while their lowest contribution was only 2%, recorded during September, 1976.

Fluctuations in the mean egg/brood for all size groups has been shown in Fig.37a. Maximum monthly average

Table-62 : Showing the details of population structure of Simocephalus exspinosus in Station-IV (WIV) of Ward Lake (September, 1976 to August, 1977).

Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Annual mean egg/brood/ group
I (0.55-0.85 mm)	41	28	34	4	2	4	8	29	4	7	42	-	
II (0.85-1.15 mm)													
Females with egg	14	16+4*	22+3*	22	8	8	26	7	15	7	12	32	
Females without egg	2	7	6	-	-	-	3	7	-	-	2	44	
Eggs per brood	5.2	5.3	6	4.5	5.5	6	8	6	5.7	8	8	2.5	5.90
III (1.15-1.45 mm)													
Females with egg	27	22+2*	11+3*	25	15+4*	6	27+4*	21	19	18	17	7	
Females without egg	-	1	2	4	6	-	6	8	17	9	2	5	
Eggs per brood	6.5	7.5	8	3.1	8	8	12	5.9	4.9	4	4.2	4	6.34
IV (1.45-1.75 mm)													
Females with egg	16	15	14	37+2*	27+11*	44	8	21	37+2*	37+6*	8	8	
Females without egg	-	2	2	4	25	15	12	7	4	9	1	4	
Eggs per brood	6	10.7	7	6.7	5.7	7.9	8	6.7	8.1	5.4	2	8	6.85
V (1.75-2.20 mm)													
Females with egg	-	3	3	2	2	3	6	-	2	5	8	-	
Females without egg	-	-	-	-	-	15	-	-	-	2	6	-	
Eggs per brood	-	4	18	12	12	12	6.5	-	8	12	8	-	10.28
Total females with egg	57	56+6*	50+6*	86+2*	50+15*	73	67+4*	49	73+2*	73	47	47	
Total females without egg	2	10	10	8	33	23	21	22	21	20	11	53	
Total juvenile (Group-I)	41	28	34	4	2	4	8	29	4	7	42	-	
Mean egg/brood(all size gr.)	5.9	6.9	9.7	9.6	6.4	8.5	8.1	6.2	6.9	7.4	5.6	4.8	7.16(mean
Actual field density(No./l)	675.5	196.5	33.5	58	15.4	44	95	37	46	27.2	66	2.5	for all sizegr.)
Total specimens analysed	100	100	100	100	100	100	100	100	100	100	100	50	

Values for juveniles, females with and without eggs are as percentages and the egg/brood given as Nos.

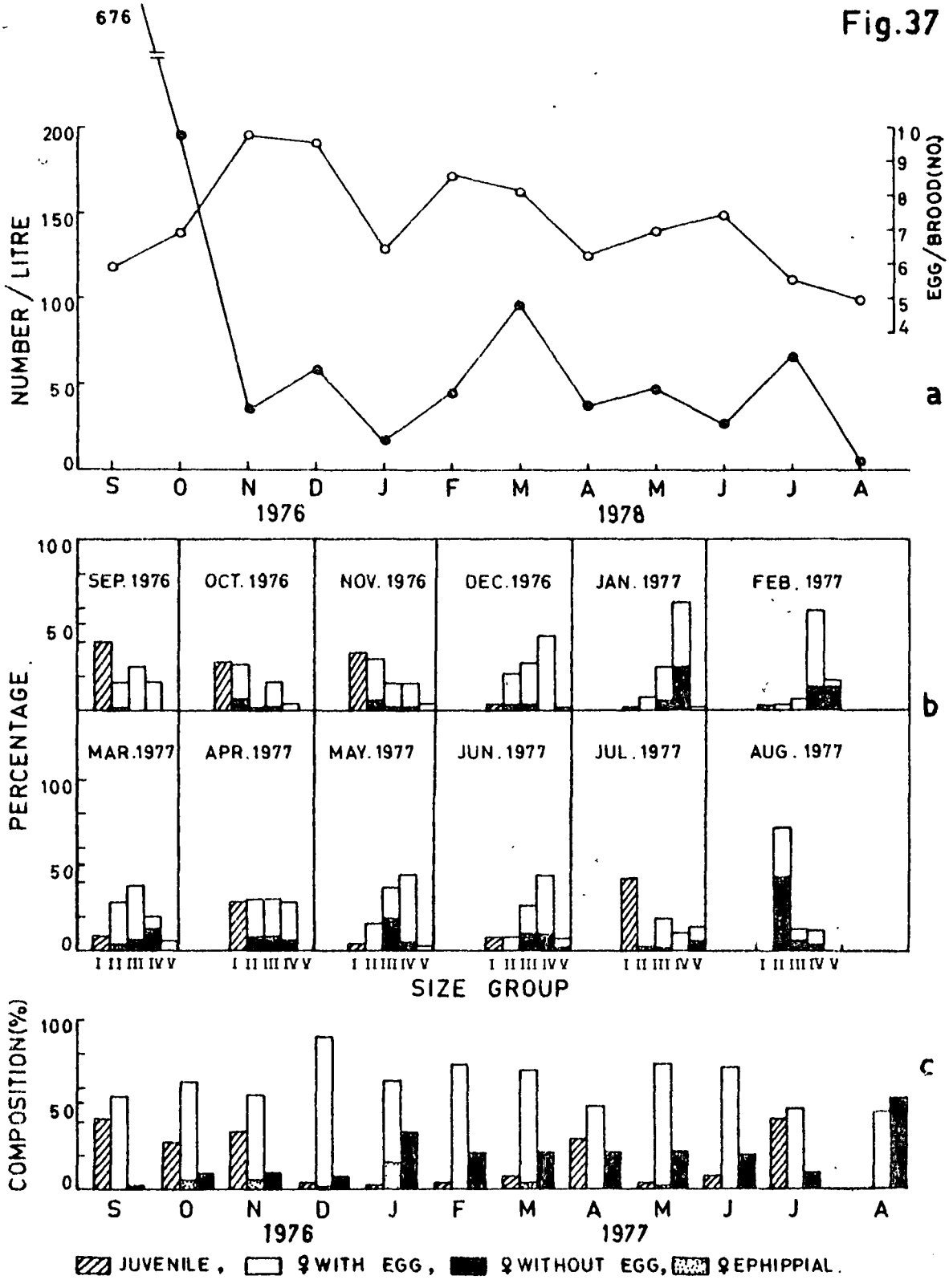
(Percentage figures given are rounded off to the nearest whole number; * = female with ephippium)

Fig.37

Showing population structure of Simocephalus exspinosus in Station-IV (WIV) of Ward Lake.

a. Seasonal variations in brood size and population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.37


676
200
150
100
50
0
NUMBER / LITRE
10
9
8
7
6
5
4
EGG/BROOD(NO.)
a
S O N D J F M A M J J A
1976
1978
100
50
PERCENTAGE
SEP. 1976
OCT. 1976
NOV. 1976
DEC. 1976
JAN. 1977
FEB. 1977
MAR. 1977
APR. 1977
MAY. 1977
JUN. 1977
JUL. 1977
AUG. 1977
b
I II III IV V
SIZE GROUP
COMPOSITION(%)
c
S O N D J F M A M J J A
1976
1977
JUVENILE, ♀WITH EGG, ♀WITHOUT EGG, ♀EPHIPPIAL.

egg/brood for all size group was 9.75 recorded during December, 1976 while the least productive month was August, 1977 with 4.83 eggs/brood. The annual mean egg for all size groups was 7.16/brood. Annual mean egg/ brood for the different size groups showed variations. Among the adult size groups, Group-V was the most productive with 10.28 eggs while the range of variation in egg production was 5.08 to 10.28/brood in different size groups.

Females with ephippium were recorded during November and December, 1976 and January, March and May, 1977 forming a maximum of 15% of the 100 animals analysed. However, no male specimen was recorded during the entire study period.

Bosmina longirostris :

WI :Data on the structure analysis of Bosmina population at WI of Ward Lake have been presented in Table-63 and Fig.38. Of the 5 size groups, Group-I was only represented in September, 1976 forming 1% of the total count. Groups-II and III (0.23 to 0.40 mm) were present throughout the study period except in January, 1977. Highest percentage contribution of Group-II was 42% while that of Group-III was 68%. Group-IV was not recorded in September, 1976 and July, 1977 and its maximum abundance was in January, 1977

forming 76% of the total. Contributions of Group-V (0.50 to 0.59 mm) ranged between 1 to 24% during the annual cycle. This group appeared in 6 out of the 12 months study period. Appearence of Group-V generally coincided with lower field densities of B. longirostris (Fig.38 a,b).

Non egg bearing females belonging to adult size groups formed 13-50% during different months of the annual cycle (Fig.38C). However, mature females with egg ranged between 50 to 67% during the annual cycle. Maximum number of non-ovigerous mothers were recorded in February, 1977 when the actual field density of B. longirostris was 9 animals/l (Fig.38a).

The mean number of eggs/brood varied between different size categories and ranged from 1.96 to 2.0/ brood. Both Groups-III and IV contained lower number of eggs in comparison to Groups-II and V. Mean egg production for all size groups also showed variation during different months and ranged between 1.88 to 2.0 eggs/brood. This reduced value of 1.88 was observed in December, 1976. Annual mean egg computed for all size groups was 1.81/ brood.

During the present study no male or ephippial females were recorded and the present B. longirostris population

Table-63 : Showing the details of population structure of Bosmina longirostris in Station-I (WI) of Ward Lake (September, 1976 to August, 1977).

Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Annual mean egg/brood/group
I (0.18-0.23 mm)	1	-	-	-	-	-	-	-	-	-	-	-	
II (0.23-0.32 mm)													
Females with egg	29	7	6	7	-	8	-	9	11	4	19	9	
Females without egg	13	3	30	1	-	13	4	9	12	4	13	27	
Eggs per brood	2	2	2	2	-	2	-	2	2	2	2	2	2.00
III (0.32-0.40 mm)													
Females with egg	41	31	48	43	-	29	25	41	16	42	68	41	
Females without egg	13	23	5	20	-	28	32	8	12	26	-	7	
Eggs per brood	2	2	1.98	1.82	-	2	2	2	2	1.90	1.93	2	1.97
IV (0.40-0.50 mm)													
Females with egg	-	18	6	14	48	13	18	28	20	7	-	16	
Females without egg	-	9	6	12	28	9	12	4	16	7	-	-	
Eggs per brood	-	2	2	1.93	1.94	2	2	1.92	2	1.86	-	2	1.96
V (0.50-0.59 mm)													
Females with egg	-	-	-	-	21	-	9	-	13	2	-	-	
Females without egg	3	-	-	3	3	-	-	1	-	4	-	-	
Eggs per brood	-	-	-	-	2	-	2	-	2	2	-	-	2.00
Total famels with egg	70	65	59	64	69	50	52	78	60	55	87	66	
Total females without egg	29	35	41	36	31	50	48	22	40	45	13	34	
Total juvenile (Group-I)	1	-	-	-	-	-	-	-	-	-	-	-	
Mean egg/brood(all size gr.)	2	2	1.97	1.88	1.97	2	2	1.97	2	1.94	1.96	2	1.81(mean
Actual field density(No/l)	74	66.2	61.7	283.7	2.2	9	24.5	34.6	7.7	21.0	25	17.7	for all size gr
Total specimens analysed	100	100	100	100	100	100	100	80	88	100	100	100	

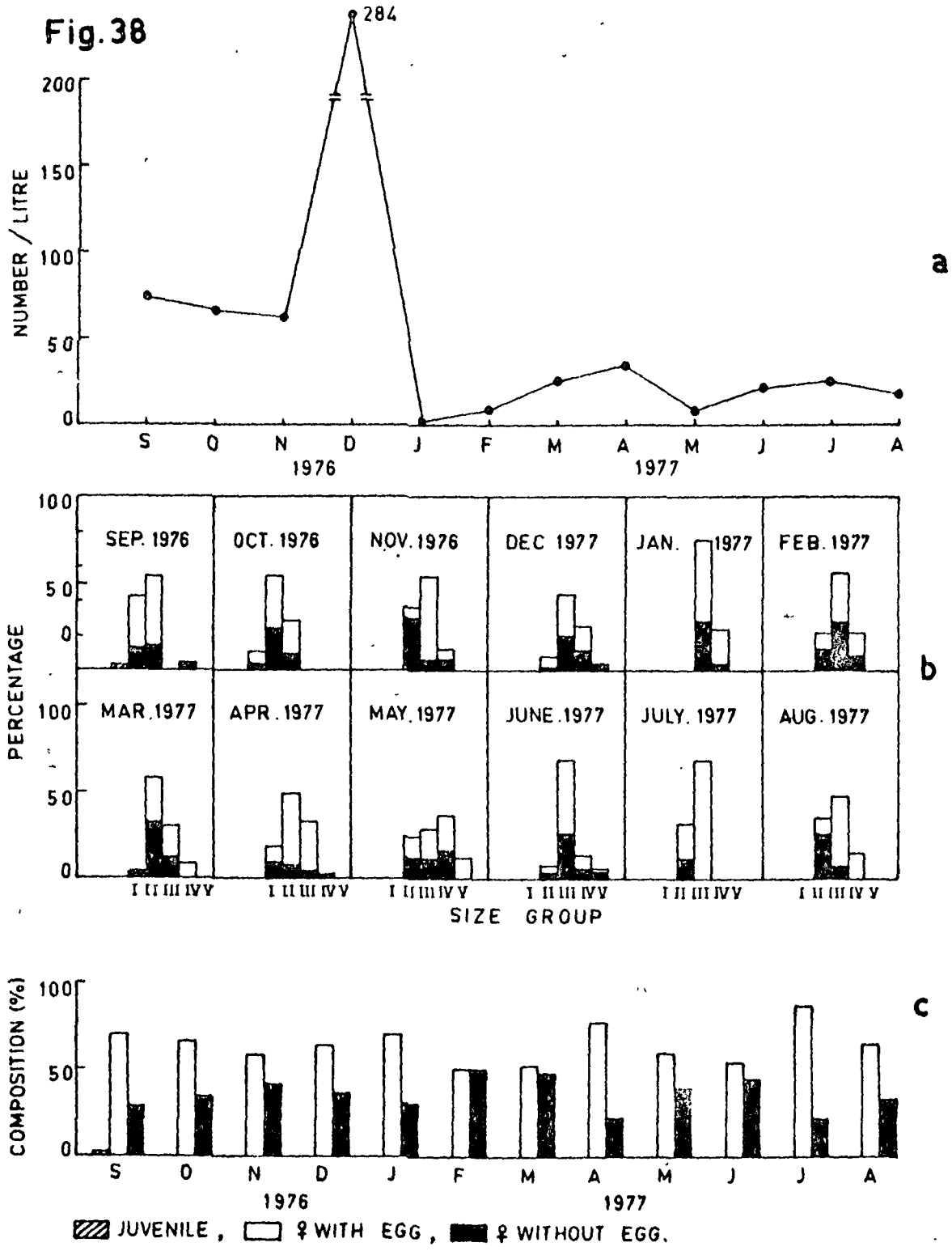
Values for juveniles, females with and without eggs are as percentages and the egg/brood given as Nos. (Percentage figures given are rounded off to the nearest whole number).

Fig.38

Showing population structure of Bosmina longirostris in Station-I (WI) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.38


284
200
150
100
50
0
NUMBER / LITRE
a
S O N D J F M A M J J A
1976
1977
100
50
0
SEP. 1976
OCT. 1976
NOV. 1976
DEC 1977
JAN. 1977
FEB. 1977
MAR. 1977
APR. 1977
MAY. 1977
JUNE. 1977
JULY. 1977
AUG. 1977
PERCENTAGE
b
I II III IV V
SIZE GROUP
COMPOSITION (%)
c
JUVENILE , ♀ WITH EGG , ♀ WITHOUT EGG.

was entirely formed a parthenogenetic females.

WII: In Table-64 details of the population structure of Bosmina longirostris has been shown. In Fig. 39a, b and c the population density, size group and the percentage contributions of female with and without eggs have been shown. Among the 5 size groups, Groups-I and V were present in few occasions only with Group-I contributing a maximum of 4% while Group-V formed the maximum of 35% of the analysed specimens. Thus the majority of the animals ranged between 0.23 to 0.50 mm representing Groups-II, III and IV. In September, 1976 Group-II formed a maximum of 68% of the analysed animals while in both May and August, 1977, this group was not represented in the counted animals. Range of percentage contribution of Group-III was 0 to 61%, the higher value being recorded in October, 1976. Maximum abundance of Group-IV (0.40 - 0.50 mm) was seen in August, 1977 when all of the 9 analysed specimens belonged to this group making 100% contribution.

Distribution of non egg bearing females varied between different groups as well as during different seasons. Total number of females without eggs ranged

Table-64 : Showing the details of population structure of Bosmina longirostris in Station-II (WII) of Ward Lake (September, 1976 to August, 1977).

Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Annual mean egg/brood/ group
I (0.18-0.23 mm)	1	3	-	-	3	4	-	-	-	-	-	-	
II (0.23-0.32 mm)													
Females with egg	45	16	26	14	33	21	23	40	-	5	10	-	
Females without egg	23	6	17	24	33	2	1	23	-	45	40	-	
Eggs per brood	1.83	2	2	1.86	2	2	1.86	2	-	2	2	-	1.96
III (o.32-0,40 mm)													
Females with egg	18	33	21	22	-	18	34	19	-	15	30	-	
Females without egg	11	28	33	16	-	6	24	18	-	-	20	-	
Eggs per brood	2	2	2	1.75	-	2	1.79	2	-	2	2	-	1.95
IV (0.40-0.50 mm)													
Females with egg	2	8	3	4	9	13	9	-	65	-	-	30	
Females without egg	-	6	-	20	22	24	6	-	35	-	-	70	
Eggs per brood	2	2	2	2	2	2	2	-	2	-	-	2	2.00
V (0.50-0,59 mm)													
Females with egg	-	-	-	-	-	8	-	-	-	-	-	-	
Females without egg	-	-	-	-	-	4	3	35	-	-	-	-	
Eggs per brood	-	-	-	-	-	2	-	-	-	-	-	-	2.00
Total females with egg	65	57	50	40	42	60	66	59	65	20	40	30	
Total females without egg	34	40	50	60	55	36	34	41	35	80	60	70	
Total juvenile (Group-I)	1	3	-	-	3	4	-	-	-	-	-	-	
Mean egg per brood(all size group)	1.94	2	2	1.87	2	2	1.88	2	2	2	2	2	1.97 (mean for all size groups)
Actual field density(No/l)	198	11	8.3	25.3	2.25	4	6.25	3.2	1.5	-	0.5	1	
Total specimens analysed	100	100	100	100	50	100	100	100	15	20	20	9	

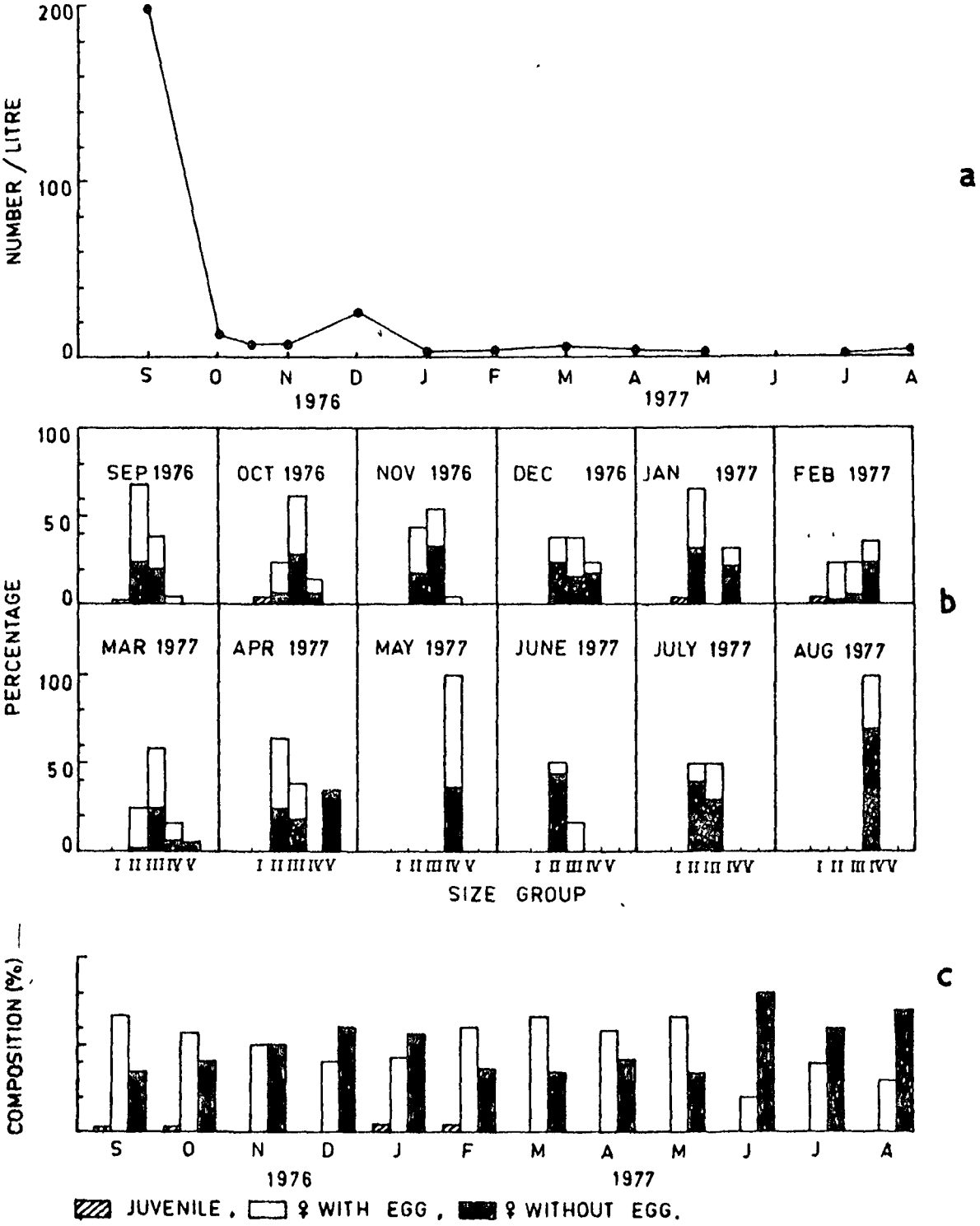
Values for juveniles, females with and without eggs are as percentages and the egg/brood given as Nos. (Percentage figures given are rounded off to the nearest whole number).

Fig.39

Showing population structure of Bosmina longirostris in Station-II (WII) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.39


a
NUMBER / LITRE
200
100
0
S O N D J F M A M J J A
1976
1977
b
PERCENTAGE
100
50
0
SEP 1976
OCT 1976
NOV 1976
DEC 1976
JAN 1977
FEB 1977
MAR 1977
APR 1977
MAY 1977
JUNE 1977
JULY 1977
AUG 1977
I II III IV V
SIZE GROUP
c
COMPOSITION (%)
S O N D J F M A M J J A
1976
1977
JUVENILE , ♀ WITH EGG , ♀ WITHOUT EGG.

between 34 to 80% of the animals analysed. Females with eggs formed a minimum of 30% to a maximum of 66% of the total during different seasons while contributions of juveniles (Group-I) ranged between 0 - 4% of the total count. It can be seen from the table (Table-64) that *non-ovigerous females as well as* older females were more during low population density periods.

Annual mean eggs per brood showed variation in the 4 adult size groups and the value ranged between 1.95 to 2.0 eggs/brood while the annual mean value for all size groups was 1.97 eggs. Again mean egg/brood for all size classes varied between 1.88 to 2.0 during different study months.

In this station also B. longirostris population of formed only of parthenogenetic females.

Results on the structure analysis of B.longirostris population at Fish Dale pond are given in Table-65 and Fig.40. Maximum percentage composition of Group-I animals were in April and June, 1977 forming 40% of the analysed specimens (Table-65). In this pond specimens belonging to Group-II (0.23 - 0.32 mm) and III (0.32 to 0.40 mm) were present during the greater

Table-65 : Showing the details of population structure of Bosmina longirostris in Fish Dale pond (September, 1976 to February, 1977)

Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Annual mean egg/brodd/ group
I (0.18-0.23 mm)	10	-	-	-	-	2	-	40	-	40	3	11	
II (0.23-0.32 mm)													
Females with egg	47	26	-	13	6	12	-	17	28	33	32	24	
Females without egg	-	8	-	26	-	-	-	7	11	16	9	13	
Eggs per brood	1.85	2	-	2	2	2	-	2	2	2	2	2	1.98
III (0.32-0.40 mm)													
Females with egg	33	8	31	22	11	31	-	18	35	5	50	17	
Females without egg	10	-	42	39	8	43	-	5	26	6	2	10	
Eggs per brood	1.76	2	2	2	1.75	1.90	-	1.95	1.97	2	2	1.82	1.92
IV (0.40-0.50 mm)													
Females with egg	-	34	9	-	39	7	30	2	-	-	3	22	
Females without egg	-	24	18	-	15	5	70	5	-	-	-	-	
Eggs per brood	-	2	2	-	2	2	2	2	-	-	2	1.77	1.97
V (0.50-0.59 mm)													
Females with egg	-	-	-	-	21	-	-	5	-	-	-	1	
Females without egg	-	-	-	-	-	-	-	1	-	-	1	2	
Eggs per brood	-	-	-	-	1.95	-	-	1.80	-	-	-	2	1.92
Total females with egg	80	68	40	35	66	50	30	42	63	38	85	64	
Total females without egg	10	32	60	65	34	48	70	18	37	22	12	25	
Total juvenile (Group-I)	10	-	-	-	-	2	-	40	-	40	3	11	
Mean egg/brood(all size gr.)	1.8	2	2	2	1.92	1.96	2	1.93	1.98	2	2	1.89	1.96(mean for all size
Actual field density(No/l)	0.5	0.5	0.5	-	1	10.3	-	2.6	4.5	49	81.5	20.3	
Total specimens analysed	50	20	25	18	50	100	10	100	100	100	100	100	

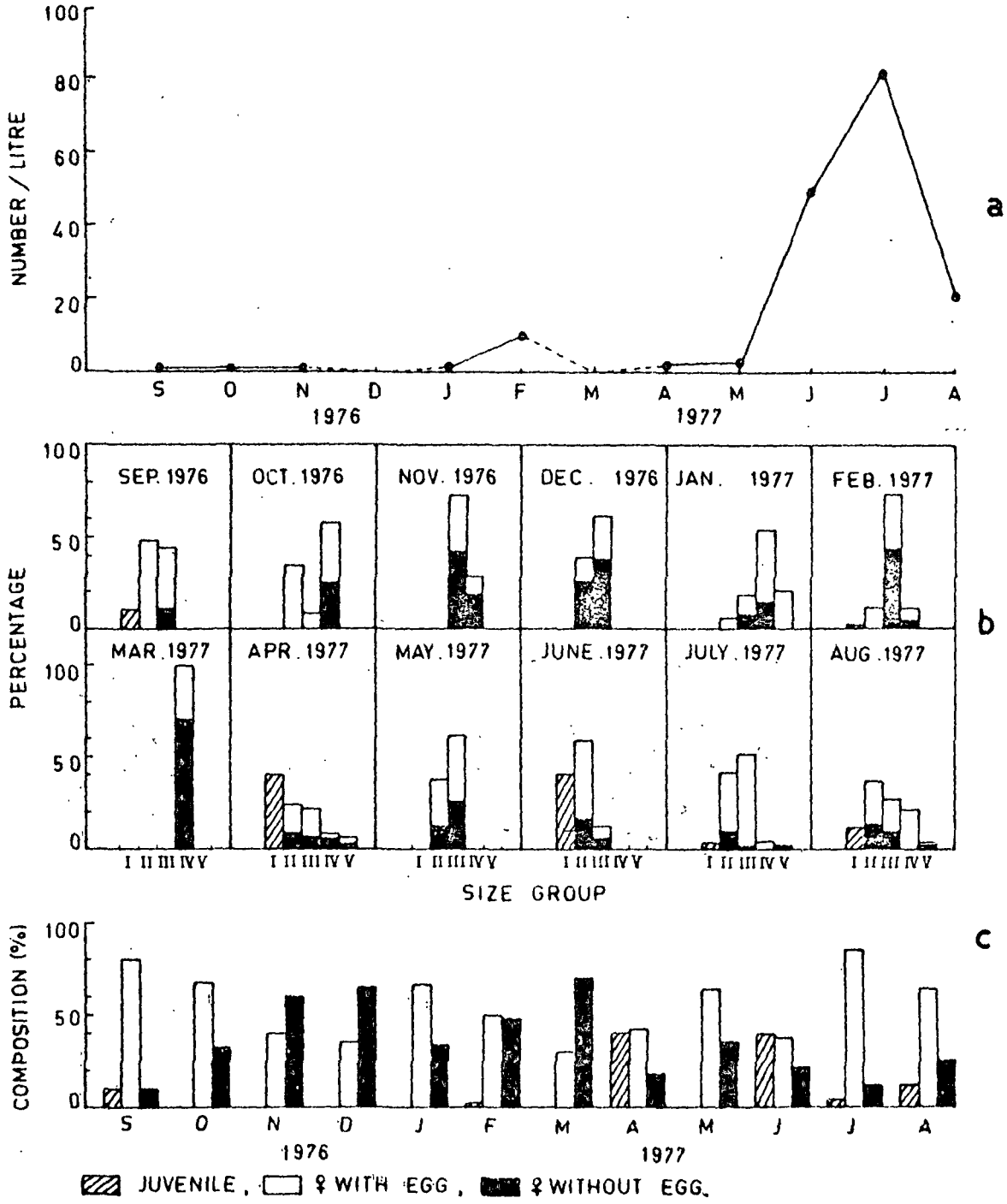
Values for juveniles, females with and without eggs are as percentages and the egg/brood given as N
(Percentage figures given are rounded off to the nearest whole number).

Fig.40

Showing population structure of Bosmina longirostris in Fish Dale pond.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.40


NUMBER / LITRE
100
80
60
40
20
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
SEP. 1976
OCT. 1976
NOV. 1976
DEC. 1976
JAN. 1977
FEB. 1977
MAR. 1977
APR. 1977
MAY. 1977
JUNE. 1977
JULY. 1977
AUG. 1977
I II III IV V
SIZE GROUP
b
COMPOSITION (%)
c
JUVENILE, ♀ WITH EGG, ♀ WITHOUT EGG.

part of the study period. While Group-IV and V were present sporadically. The annual range of percentage contribution of Groups-II, III, IV and V were 0 -49% , 0 - 73% , 0 - 100% and 0 - 21% respectively (Table-65).

Maximum number of total non egg bearing females were recorded in March, 1977 forming females ranged between 30 to 80% of the total. Total juveniles contribued a maximum of 40% of the total though this group was absent in mahy instances (Fig.40c).

Annual mean number of egg varied between 1.92 to 1.98 in different size group and the mean egg/brood for all size groups varied between 1.80 to 2.0 eggs/ brood during different seasons. The calculated annual mean value of egg production was 1.96 for B.longirostris at Fish Dale pond.

Gamogenetic mothers as well as males were not seen in the analysed samples and only ephippial females formed the bulk.

Chydorus sphaericus :

Detailed analysis of the field populations of Chydorus sphaericus was conducted in WI, WIII and WIV of Ward Lake as well as in Lady Dyderi Park pond. The size of this species varied from a minimum of 0.16 mm to a maximum of 0.56 mm

and this length range was divided into 6 size categories. Length range of the different size groups are as follows: Group-I (juvenile) : 0.16 - 0.21 mm, Group-II: 0.22-0.26 mm, Group-III: 0.26 - 0.31 mm, Group-IV: 0.31 - 0.36 mm, Group-V: 0.36 - 0.41 mm and Group-VI : 0.41 - 0.56 mm.

WI : In WI Group-I animals were present during 5 out of the 12 months study period and their maximum abundance was in August, 1977 forming 17% of the specimens analysed (Table-66, Fig.41). Contributions of Group-II ranged between 0-40% while that of Group-III varied between 0 - 83% of the total. Group-IV animals (0.31 - 0.36 mm) was present in 11 out of the 12 months of study and in one instance formed 100% of the 31 animals studied. Group-V was represented only during 4 months while Group-VI was absent during the entire study. Thus in this station length of C.sphaericus did not exceed 0.41 mm. Further, appearence of Group-V generally coincided with lower population densities of C. sphaericus (Table-66, Fig.41a).

Female with empty brood pouch was always recorded ranging from 6 - 39% during different seasons. Total juveniles and females with eggs varied between 0-17% and 61-90% respectively (Fig.41c). Distributions of ovigerous and nonovigerous females in different size

Table-66 : Showing the details of population structure of Chydorus sphaericus in Station-I (WI) of Ward Lake during September, 1976 to August, 1977. (Values for juveniles, females with and without eggs are as percentages and the egg/brood given as numbers; percentage figures given are rounded off to the nearest whole number).

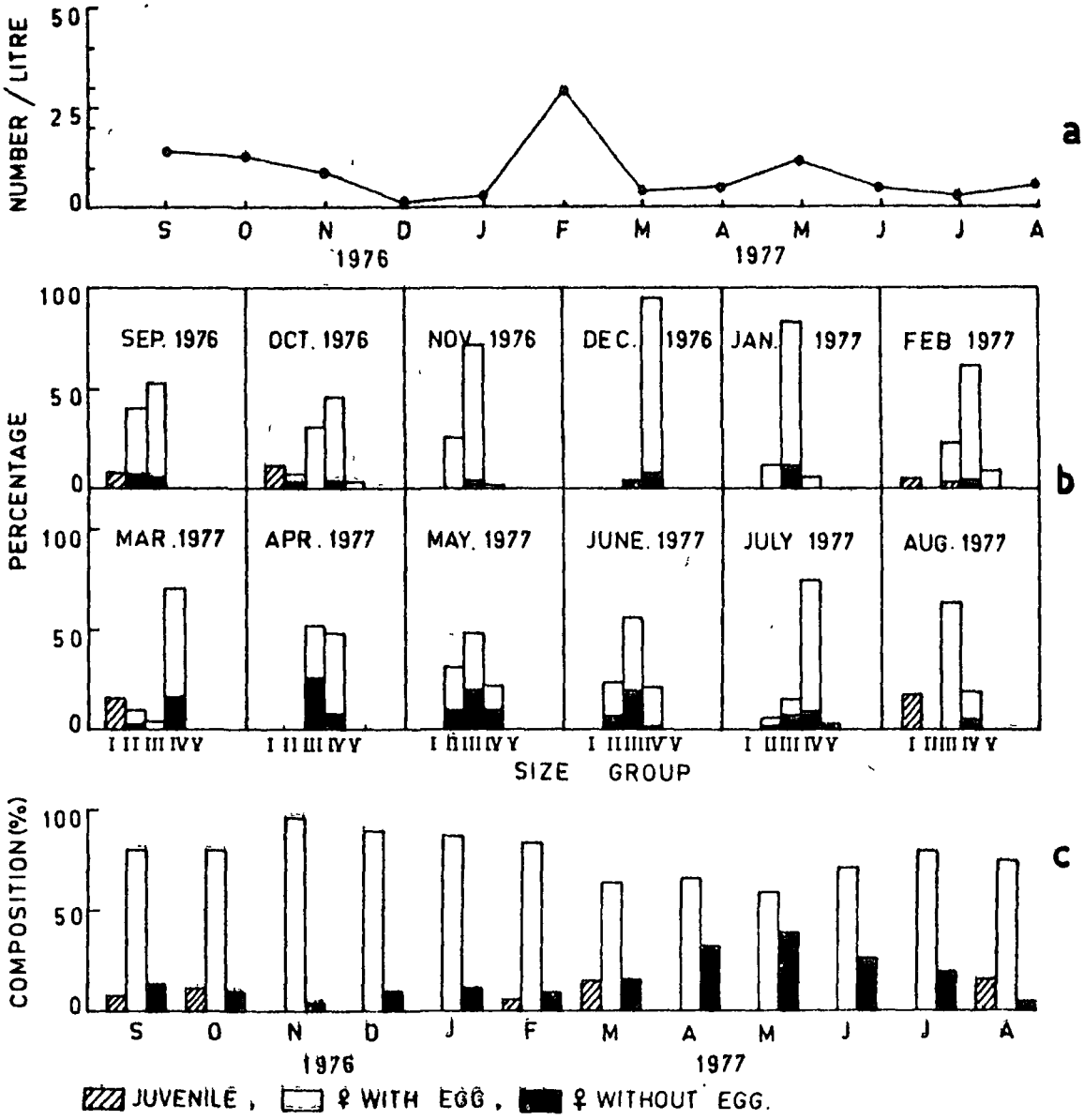
Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Annual mean egg/brood/group
I (0.16-0.21 mm)	7	12	-	-	-	6	16	-	-	-	-	17	
II (0.21-0.26 mm)													
Females with egg	33	3	-	-	12	-	6	-	21	16	5	-	
Females without egg	7	4	-	-	-	-	3	-	10	7	1	-	
Eggs per brood	2	2	-	-	2	-	2	-	2	2	2	-	2.00
III (0.26-0.31 mm)													
Females with egg	47	31	26	-	71	19	4	26	29	37	9	64	
Females without egg	6	-	-	3	12	5	-	26	19	19	7	-	
Eggs per brood	2	2	2	-	1.98	2	2	2	2	2	2	2	1.99
IV (0.31-0.36 mm)													
Females with egg	-	42	68	90	5	56	54	41	11	19	66	13	
Females without egg	-	4	4	7	-	5	17	7	10	2	9	6	
Eggs per brood	-	2	2	2	2	2	2	2	2	2	2	2	2.00
V (0.36-0.41 mm)													
Females with egg	-	4	2	-	-	9	-	-	-	-	-	-	
Females without egg	-	-	-	-	-	-	-	-	-	-	3	-	
Eggs per brood	-	2	2	-	-	2	-	-	-	-	-	-	2.00
VI (0.41-0.56 mm)													
Females with egg	-	-	-	-	-	-	-	-	-	-	-	-	
Females without egg	-	-	-	-	-	-	-	-	-	-	-	-	
Eggs per brood	-	-	-	-	-	-	-	-	-	-	-	-	-
Total females with egg	80	80	96	90	88	84	64	67	61	72	80	77	
Total females without egg	13	8	4	10	12	10	20	33	39	28	20	6	
Total juvenile (Group-I)	7	12	-	-	-	6	16	-	-	-	-	17	
Mean egg per brood(allsize gr)	2	2	2	2	1.99	2	2	2	2	2	2	2	1.99(mean for all groups)
Actual field density(No/l)	14.3	12.7	9.0	1.3	2.8	29.0	3.5	5.2	11.7	5.0	3.3	6.0	
Total specimens analysed	100	100	100	31	40	100	100	100	100	100	40	100	

Fig.41

Showing population structure of Chydorus sphaericus in Station-I (WI) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.41


NUMBER / LITRE
50
25
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
100
50
0
SEP. 1976
OCT. 1976
NOV. 1976
DEC. 1976
JAN. 1977
FEB 1977
MAR. 1977
APR. 1977
MAY. 1977
JUNE. 1977
JULY 1977
AUG. 1977
I II III IV V
SIZE GROUP
b
COMPOSITION (%)
100
50
0
S O N D J F M A M J J A
1976
1977
c
JUVENILE , ♀ WITH EGG , ♀ WITHOUT EGG.

groups have been shown in Fig.41b.

Eggs/brood recorded during the present study was 2.0/brood except in January, 1977 when a mean of 1.98/brood was seen in Group-III. Value of the annual mean egg/brood for all size groups was found to be 1.99/brood.

During the entire study period no male or ephippial female was seen among the studied specimens.

WIII: Results of the different population parameters of Chydorus sphaericus have been presented in Table-67 and Fig.42. Seasonal distribution of different size groups of this species has been shown in Fig.42b. Group-I (juvenile) was seen only in the samples of October, 1976 and February and August, 1977 forming a maximum of 6% in August, 1977. Group-II was present during 6 out of the 12 months and ranged between 0-29% of the analysed animals. Groups-III, IV and V were the dominant groups occurring almost throughout the study period. Percentage contributions of these groups varied between 0-44% , 17-68% and 2-72% during different seasons. Group-VI, on the other hand, appeared during April to July, 1977 forming a maximum of 10% of the total. Egg production ranged from 1.98 to 2.0/brood in different size groups.

Table-67 : Showing the details of population structure of Chydorus sphaericus in Station-III (WIII) of Ward Lake during September, 1976 to August, 1977.

(Values for juveniles, females with and without eggs are as percentages and the egg/brood given as numbers; percentage figures given are rounded off to the nearest whole number).

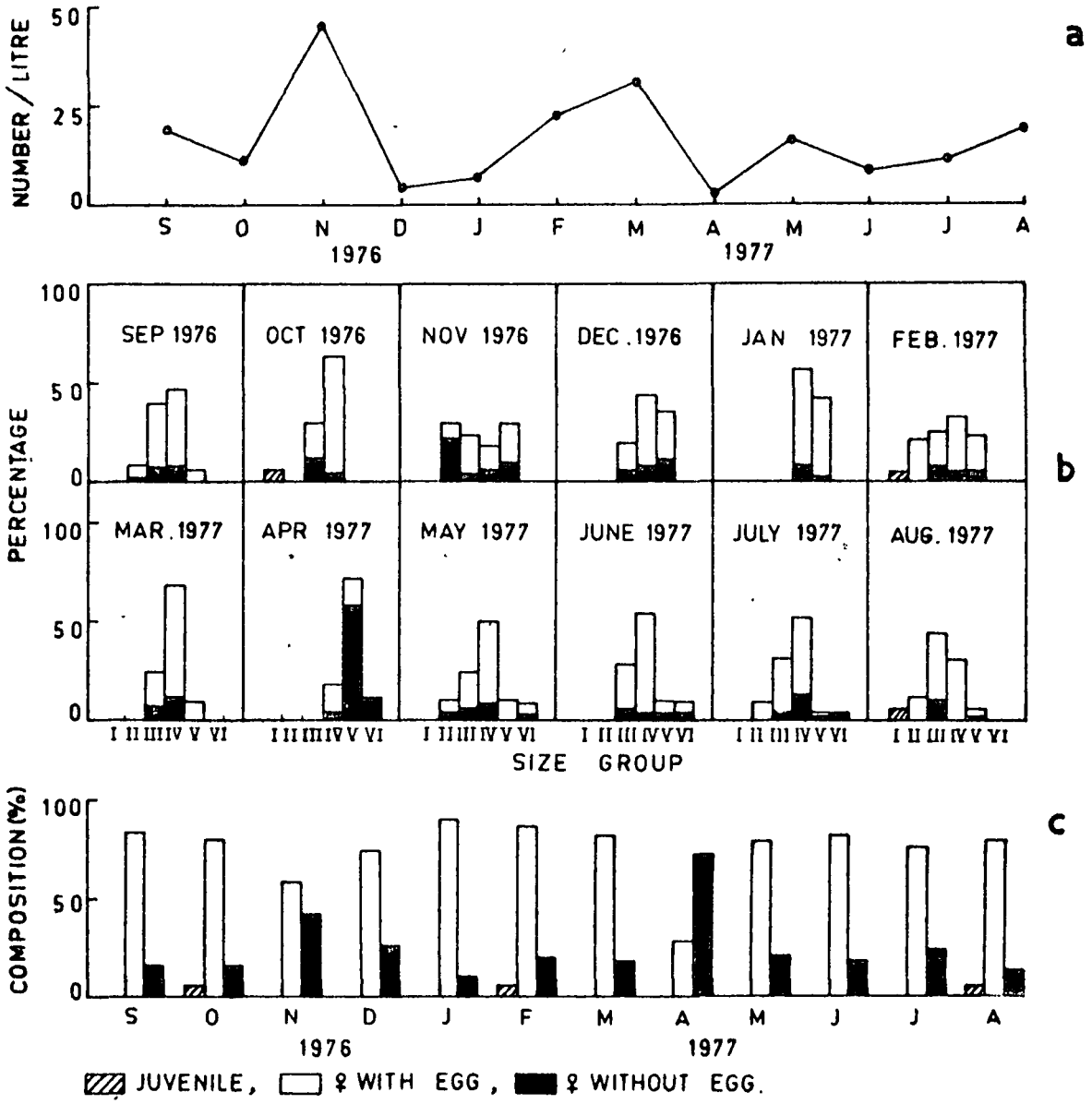
Size Group and categories	1976				1977								Annual mean egg/brood/group
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	
I (0.16-0.21 mm)	-	5	-	-	-	5	-	-	-	-	-	6	
II (0.21-0.26 mm)													
Females with egg	7		7	-	-	22	-	-	7	-	9	12	
Females without egg	1		22	-	-	-	-	-	3	-	-	1	
Eggs per brood	2	-	2	-	-	2	-	-	2	-	2	2	2.00
III (0.26-0.31 mm)													
Females with egg	32	17	20	13	-	19	17	-	18	23	26	34	
Females without egg	7	13	4	6	-	7	6	-	5	5	5	10	
Eggs per brood	2	2	2	2	-	2	2	-	2	2	1.96	2	1.99
IV (0.31-0.36 mm)													
Females with egg	39	61	12	37	50	26	56	13	42	49	39	30	
Females without egg	8	3	6	7	7	6	12	4	9	4	13	1	
Eggs per brood	2	2	2	2	2	2	2	1.85	2	2	2	2	1.98
V (0.36-0.41 mm)													
Females with egg	6	2	18	24	41	19	9	14	9	3	2	4	
Females without egg	-	-	11	13	2	6	-	58	-	6	2	2	
Eggs per brood	2	2	2	2	2	2	2	2	2	2	2	2	2.00
VI (0.41-0.56 mm)													
Females with egg	-	-	-	-	-	-	-	-	3	7	-	-	
Females without egg	-	-	-	-	-	-	-	11	4	3	4	-	
Eggs per brood	-	-	-	-	-	-	-	-	2	2	-	-	2.00
Total females with egg	84	79	57	74	91	86	82	27	79	82	76	80	
Total females without egg	16	16	43	26	9	19	18	73	21	18	24	14	
Total juvenile (Group-I)	-	5	-	-	-	5	-	-	-	-	-	6	
Mean egg per brood(all size group)	2	2	2	2	2	2	2	1.78	2	2	1.99	2	1.98 (mean for all size groups)
Actual field density(NO./l)	18.7	10.7	45.0	4.3	12.2	22.7	31.2	2.7	17.0	8.7	12.0	20.3	
Total specimens analysed	100	100	100	100	100	100	100	100	100	100	100	100	

Fig.42

Showing population structure of Chydorus sphaericus in Station-III (WIII) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.42


a
NUMBER / LITRE
50
25
0
S O N D J F M A M J J A
1976
1977
b
PERCENTAGE
100
50
0
SEP 1976
OCT 1976
NOV 1976
DEC. 1976
JAN 1977
FEB. 1977
MAR. 1977
APR 1977
MAY 1977
JUNE 1977
JULY 1977
AUG. 1977
I II III IV V VI
SIZE GROUP
c
COMPOSITION (%)
100
50
0
S O N D J F M A M J J A
1976
1977
JUVENILE, ♀ WITH EGG, ♀ WITHOUT EGG.

The appearence of matured females without eggs varied between different groups. In the month of April, 1977 all the 5 adult size groups had higher incidence of non-egg bearing females (Fig.42b) resulting in a total of 73% while egg bearing mothers formed only 27% (Fig.42c). This further coincided with lower field density of the species (Fig.42a) . During the one year study period egg bearing females formed a maximum of 91% while the juveniles (Group-I) formed a maximum of 6% of the analysed specimens.

No male or ephippial females were recorded throughout the study period.

WIV : In WIV Group-I (juveniles) appeared in 4 out of the 12 months study period (Table-68, Fig.43b,c). This group formed a maximum of 28% of the analysed sample. Group-II was seen in the samples of September to December, 1976 and January, May and July, 1977 forming a maximum of 51% in May, 1977 (Table-68). Groups-IV and V were the dominant size groups appearing throughout the study period except in May, 1977 when Group-V was absent. Group-III was discontinuous in its distribution while Group-VI was recorded only during October and December, 1976 and March, 1977 forming 90% during the last mentioned month . Ranges

Table-68 : Showing the details of population structure of Chydorus sphaericus in Station-IV (WIV) of Ward Lake during September, 1976 to August, 1977. (Values for juveniles, females with and without eggs are as percentage and the egg/brood given as numbers; percentage figures given are rounded off to the nearest whole number).

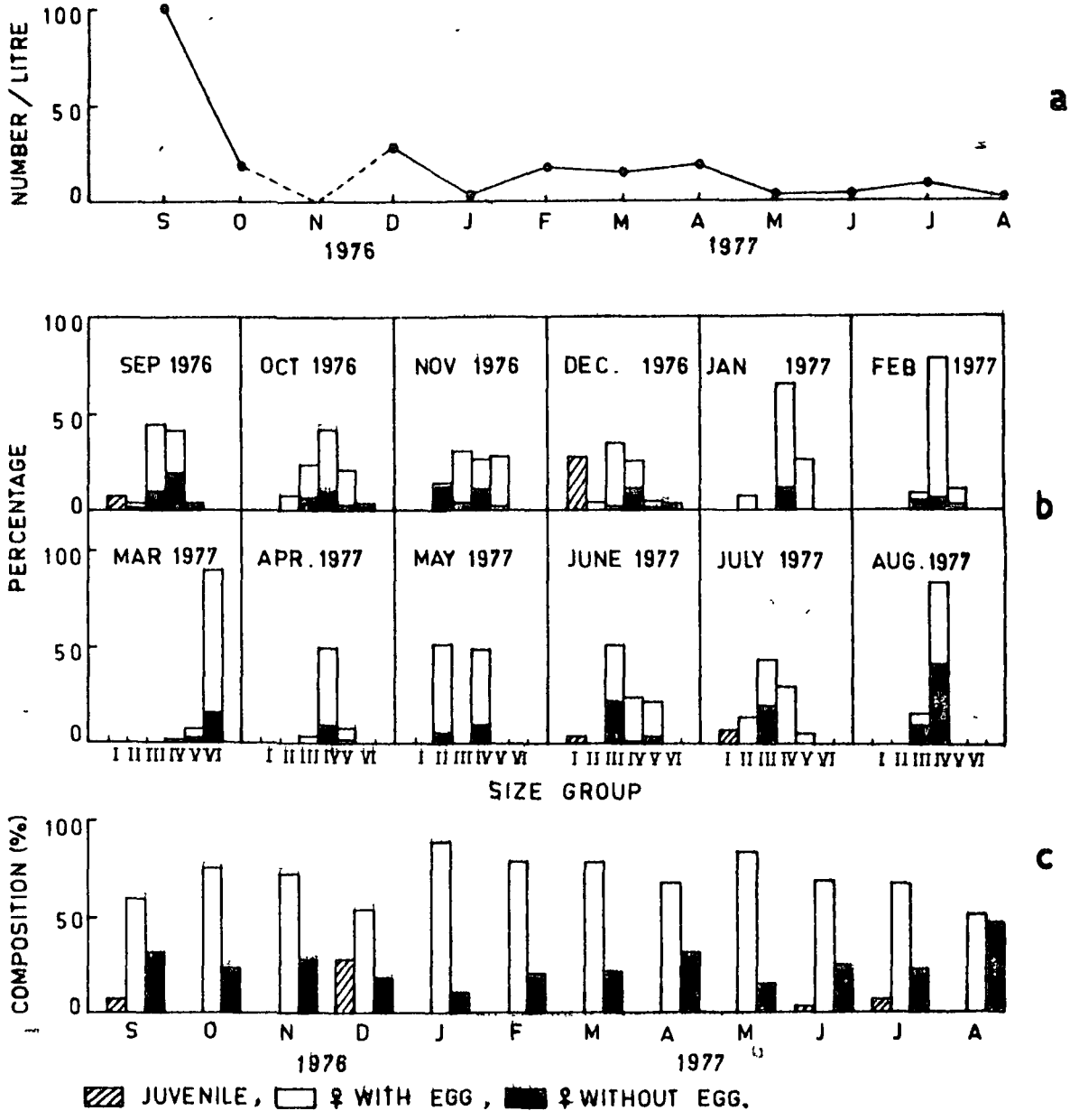
Size Group and categories	1976				1977								Annual mean egg/brood/ group
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	
I (0.16-0.21 mm)	7	-	-	28	-	-	-	-	-	4	7	-	
II (0.21-0.26 mm)													
Females with egg	2	7	2	3	6	-	-	-	45	-	14	-	
Females without egg	1	-	12	-	-	-	-	-	6	-	-	-	
Eggs per brood	2	2	2	2	2	-	-	-	2	-	2	-	2.00
III (0.26-0.31 mm)													
Females with egg	35	17	27	33	-	4	-	9	-	29	25	10	
Females without egg	10	7	4	2	-	5	-	9	-	22	19	7	
Eggs per brood	2	2	2	2	-	2	-	2	-	2	2	2	2.00
IV (0.31-0.36 mm)													
Females with egg	23	31	16	13	56	72	2	51	39	23	29	42	
Females without egg	19	11	11	13	11	7	-	19	10	1	-	41	
Eggs per brood	2	2	2	2	2	2	1	2	2	2	2	2	1.92
V (0.36-0.41 mm)													
Females with egg	-	18	27	4	27	3	4	7	-	18	6	-	
Females without egg	3	3	1	1	-	9	4	5	-	4	-	-	
Eggs per brood	-	2	2	2	2	2	1.5	2	-	2	2	-	1.94
VI (0.41-0.56 mm)													
Females with egg	-	2	-	-	-	-	73	-	-	-	-	-	
Females without egg	-	4	-	3	-	-	17	-	-	-	-	-	
Eggs per brood	-	2	-	-	-	-	2	-	-	-	-	-	2.00
Total females with egg	60	75	72	53	89	79	79	67	84	70	68	52	
Total females without egg	33	25	28	19	11	21	21	33	16	26	25	48	
Total juvenile (Group-I)	7	-	-	28	-	-	-	-	-	4	7	-	
Mean egg/brood(all size gr.)	2	2	2	2	2	2	1.92	2	2	2	2	2	1.99(mean for all size gr.)
Actual field density(NO/l)	100	19	-	28.7	2.6	17.0	15.2	19.2	3.7	4.2	9.0	1.7	
Total specimens analysed	100	100	29	100	100	100	100	100	50	50	100	42	

Fig.43

Showing population structure of Chydorus sphaericus in Station-IV (WIV) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.43


a
NUMBER / LITRE
100
50
0
S O N D J F M A M J J A
1976
1977
b
PERCENTAGE
SEP 1976
OCT 1976
NOV 1976
DEC. 1976
JAN 1977
FEB 1977
MAR 1977
APR. 1977
MAY 1977
JUNE 1977
JULY 1977
AUG. 1977
I II III IV V VI
SIZE GROUP
c
COMPOSITION (%)
JUVENILE, ♀ WITH EGG, ♀ WITHOUT EGG.

of contribution of Groups-III, IV, V and VI were 0 - 51%, 2 - 83%, 0 - 28% and 0 - 90% during different months of the annual cycle (Table-68).

Total adult females with empty brood pouch formed a maximum of 48% in August, 1977 and appeared throughout the season in the counted animals. Total juveniles formed a maximum of 28% in December, 1976 while the remaining fractions were formed by females with egg.

Egg/brood was generally 2.0 in different size groups though due to the appearence of 1.0 egg/brood during some months in a few animals, the annual mean egg/brood/group ranged between 1.92 to 2.0/brood and the calculated annual mean for all size group was 1.99 egg/brood.

This population of C.sphaericus at WIV was also formed entirely of parthenogenetic individuals.

Lady Hyderi Park pond :

Information gathered on the population structure of Chydorus sphaericus at Lady Hyderi Park pond has been documented in Table-69 and Fig.44. In this pond also Groups-III and IV dominated the analysed sample. Ranges of contributions of different size groups during the annual cycle were as

Table-69 : Showing the details of population structure of Chydorus sphaericus in Lady Hyderi Park pond during Septamber, 1976 to August, 1977. (Values for juveniles, females with and without eggs are as percentage and the egg/brood given as numbers; percentage figures given are rounded off to the nearest whole number).

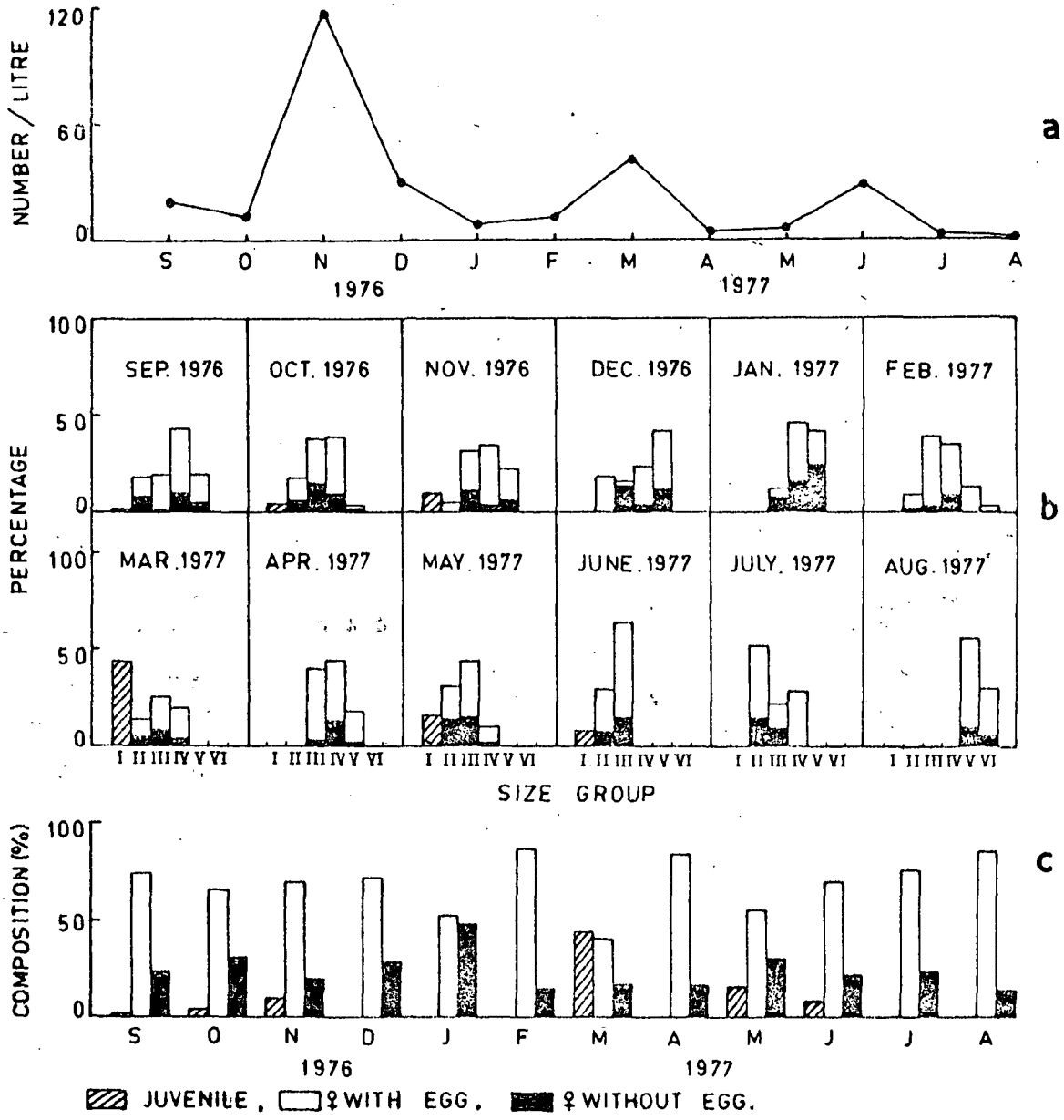
Size Group and categories	1976				1977								Annual mean egg/brood/ group
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	
I (0.16-0.21 mm)	1	3	9	-	-	-	43	-	16	7	-	-	
II (0.21-0.26 mm)													
Females with egg	11	12	5	18	-	7	8	-	17	22	36	-	
Females without egg	8	6	-	-	-	2	5	-	14	7	15	-	
Eggs per brood	2	2	2	2	-	2	2	-	2	2	1.67	-	1.96
III (0.26-0.31 mm)													
Females with egg	17	23	21	2	4	36	17	37	29	49	13	-	
Females without egg	1	15	11	14	8	3	8	2	15	15	9	-	
Eggs per brood	2	2	2	1.5	1.5	2	2	2	1.82	2	1.33	-	1.83
IV (0.31-0.36 mm)													
Females with egg	33	30	29	21	30	26	15	30	9	-	27	-	
Females without egg	10	9	4	3	16	9	4	13	-	-	-	-	
Eggs per brood	2	2	2	1.33	1.80	2	2	2	2	-	2	-	1.91
V (0.36-0.41 mm)													
Females with egg	14	2	17	31	17	13	-	17	-	-	-	56	
Females without egg	5	1	5	11	25	-	-	1	-	-	-	10	
Eggs per brood	2	2	2	2	2	2	-	1	-	-	-	1.33	1.79
VI (0.41-0.56 mm)													
Females with egg	-	-	-	-	-	4	-	-	-	-	-	29	
Females without egg	-	-	-	-	-	-	-	-	-	-	-	5	
Eggs per brood	-	-	-	-	-	2	-	-	-	-	-	2	2.00
Total females with egg	75	66	71	72	51	86	40	84	55	71	76	85	
Total females without egg	24	31	20	28	49	14	17	16	29	22	24	15	
Total juvenile (Group-I)	1	3	9	-	-	-	43	-	16	7	-	-	
Mean egg/brood(all size gr)	2	2	2	1.70	1.84	2	2	1.67	1.93	2	1.75	1.45	1.86 (Mean for all size gr.)
Actual field density (No./l)	19.2	10.7	19.3	29.7	7.5	9.5	42.7	3.4	4.5	28.5	30.0	1.7	
Total specimens analysed	100	100	100	100	100	100	100	31	50	100	100	50	

Fig.44

Showing population structure of Chydorus sphaericus in the Lady Hyderi Park pond.

a. Seasonal variations in population density (No./l)
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.44


NUMBER / LITRE
120
60
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
100
50
0
SEP. 1976
OCT. 1976
NOV. 1976
DEC. 1976
JAN. 1977
FEB. 1977
MAR. 1977
APR. 1977
MAY. 1977
JUNE. 1977
JULY. 1977
AUG. 1977
I II III IV V VI
SIZE GROUP
b
COMPOSITION (%)
100
50
0
S O N D J F M A M J J A
1976
1977
JUVENILE, ♀WITH EGG, ♀WITHOUT EGG.
c

follows:

Group-I : 0 - 43%, Group-II : 0 - 51%, Group-III : 0- 64% , Group-IV : 0 - 46%, Group-V : 0 - 66% and Group-VI : 0 -34%.

Total nonegg bearing females ranged between 14-49% during different study months, while total juveniles formed a maximum of 43% in March, 1977. The remaining fractions were formed by egg bearing females.

Egg/brood showed slight variation during different study months in different groups. The calculated annual mean egg/brood/group varied between 1.79 to 2.0 eggs/brood while the calculated annual mean for all size group was 1.86 eggs/ brood.

No sexual females as well as males were seen in the specimens analysed during different months.

Pleuroxus similis :

Detailed analysis of the populations struction of Pleuroxus similis was conducted in WIII of Ward Lake and the results are shown in Table-70 and Fig.45. In WIII, Pleuroxus similis ranged from a minimum of 0.40 mm to a maximum of 0.90 mm in length. The five size groups were Group-I (juvenile): 0.40 - 0.45 mm, Group-II: 0.45 - 0.58 mm, Group-III: 0.58-0.70 mm , Group-IV: 0.70 - 0.80 mm and Group-V: 0.80 - 0.90 mm.

WIII : Group-I was only present during March and April, 1977

contributing 7 and 9% respectively, while no analysis could be conducted during September and November, 1976 due to their non availability . Group-II contributed a maximum of 19% in April, 1977 of which 10% of the females were without eggs while 74% was the highest contributions of Group-III in August, 1977. Minimum and maximum percentage contribution of Group-IV were 17% and 80% respectively. Maximum abundance of Group-V was in June, 1977 forming 54%. Thus Groups-III and IV showed dominance during the greater part of season.

Total number of females with and without eggs varied during different seasons (Fig.45c). Ovigerous females were more during January and February, 1977 forming 71 and 69% of the total observations while the rest was formed by mature females without eggs. On the other hand percentages of females without eggs were more in June, 1977 with 68% of the total when the count/litre was also low (Fig.45a). However, in August, 1977 also nongravid females were more in the counted sample.

The analysed population P. similis was entirely formed of parthenogenetic females and egg/brood always 2 in number.

Table-70 : Showing the details of the population structure of *Pleuroxus similis* in Station-III (WIII) of Ward Lake (September, 1976 to August, 1977).

Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Annual mean egg/brood/ group
I (0.40-0.45 mm)	-	-	-	-	-	-	7	9	-	-	-	-	
II (0.45-0.58 mm)													
Females with egg	-	-	-	-	7	11	4	9	-	-	-	-	
Females without egg	-	-	-	-	4	6	13	10	-	-	-	9	
Eggs per brood	-	-	-	-	2	2	2	2	-	-	-	-	2.00
III (0.58-0.70 mm)													
Females with egg	-	10	-	11	21	19	6	21	5	11	-	27	
Females without egg	-	21	-	33	8	19	17	9	15	35	-	47	
Eggs per brood	-	2	-	2	2	2	2	2	2	2	-	2	2.00
IV (0.70-0.80 mm)													
Females with egg	-	43	-	11	38	14	37	14	48	-	-	8	
Females without egg	-	27	-	22	15	5	2	12	32	-	-	9	
Eggs per brood	-	2	-	2	2	2	2	2	2	-	-	2	2.00
V (0.80-0.90 mm)													
Females with egg	-	-	-	23	5	25	11	13	-	21	-		
Females without egg	-	-	-	-	2	1	4	3	-	33	-	-	
Eggs per brood	-	-	-	2	2	2	2	2	-	2	-	-	2.00
Total juvenile (Group-I)	-	-	-	-	-	-	7	9	-	-	-	-	
Total females with egg	-	53	-	45	71	69	57	57	53	32	-	35	
Total females without egg	-	47	-	55	29	31	36	34	47	68	-	65	
Mean egg/brood(all size gr.)	-	2	-	2	2	2	2	2	2	2	-	2	2.00 (mean for all size group)
Actual field density(No./l)	-	0.3	-	1.3	4.0	7.3	-	-	-	-	-	-	
Total specimens analysed	-	16	-	39	100	100	23	25	24	13	-	23	

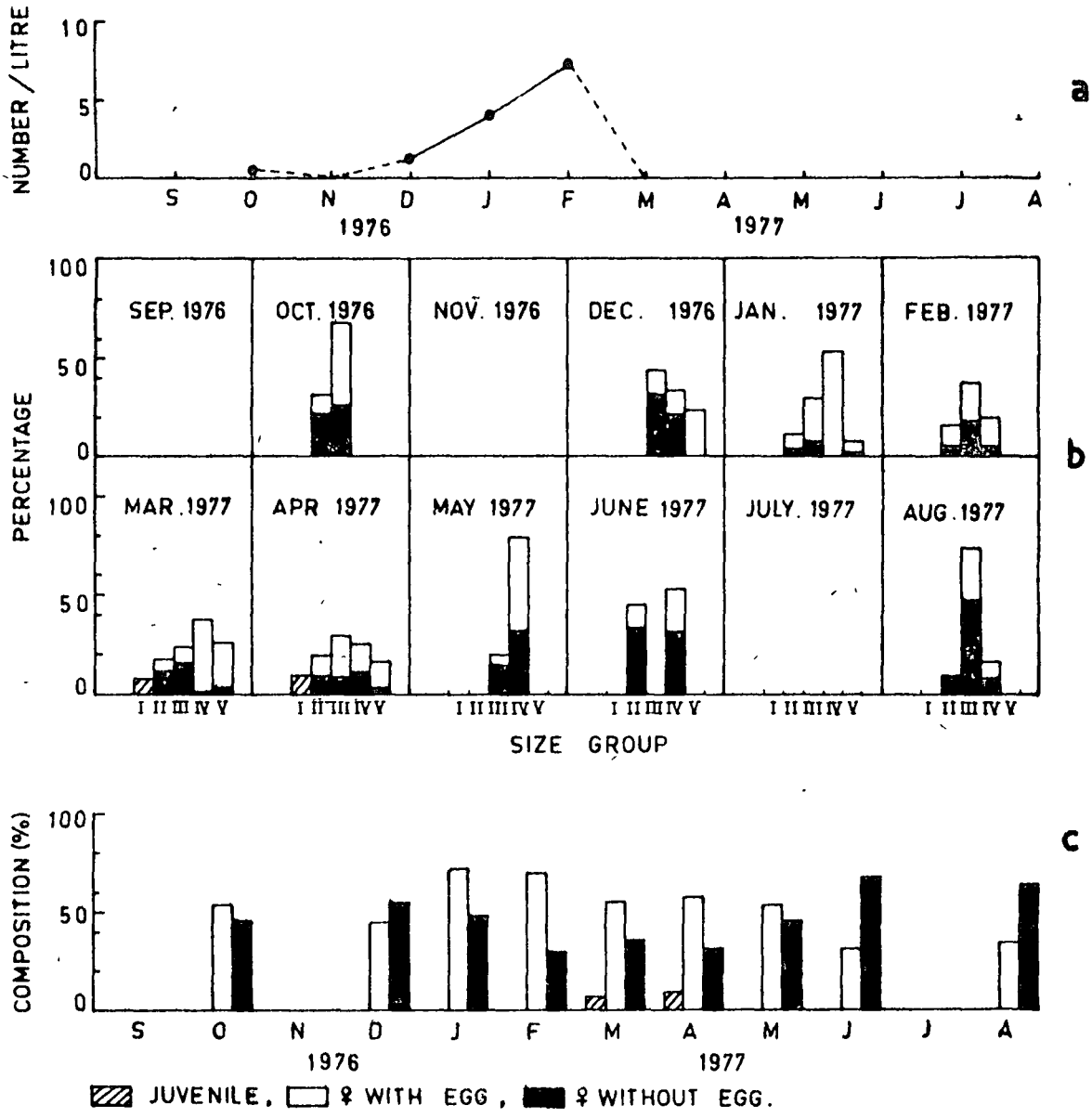
Values for juveniles, females with and without eggs are as percentages and the egg/brood given as numbers (Percentage figures given are rounded off to the nearest whole number).

Fig.45

Showing population structure of Pleuroxus similis in Station-III (WIII) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.45


NUMBER / LITRE
10
5
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
100
50
0
SEP. 1976
OCT. 1976
NOV. 1976
DEC. 1976
JAN. 1977
FEB. 1977
MAR. 1977
APR 1977
MAY 1977
JUNE 1977
JULY. 1977
AUG. 1977
I II III IV V
SIZE GROUP
b
COMPOSITION (%)
c
JUVENILE, ♀ WITH EGG, ♀ WITHOUT EGG.

Acroperus harpae :

Structure analysis of Acroperus harpae was conducted in WI and WIII of Ward Lake. This species ranged between 0.30 to 0.98 mm in size and the length ranges of the 5 size groups were as follows :

Group-I (juvenile): 0.30 - 0.45 mm, Group-II: 0.45 - 0.58 mm, Group-III: 0.58 - 0.70 mm, Group-IV: 0.70 - 0.85 mm and Group-V: 0.85 - 0.90 mm.

WI : Information gathered on the population structure of Acroperus harpae are furnished in Table-71 and Fig.46. In this station of Ward Lake, Juveniles (Group-I) were recorded only in September, 1976 forming 15% of the sample analysed. Group-II was most abundant in September, 1976 forming 83% of the total of which 27% was the contribution of females without eggs. Group-II formed a maximum of 83% and was present throughout the study period. Contributions of Group-III ranged from 2 -51% during different study months. Group-IV specimens (0.70 - 0.85 mm) were absent during September, 1976 and July till August, 1977. Group-V, on the other hand, was not represented in the samples of September, November and December, 1976 and May to August, 1977. Ranges

Table-71 : Showing the details of the population structure of Acroperus harpae in Station-I (WI) of Ward Lake (September, 1976 to August, 1977).

Size Group and categories	1976				1977								Annual mean egg/brood/ group
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	
I (0.30-0.45 mm)	15	-	-	-	-	-	-	-	-	-	-	-	
II (0.45-0.58 mm)													
Female with egg	56	-	-	8	6	-	-	-	15	11	31	41	
Female without egg	27	11	16	6	-	7	13	19	4	6	18	12	
Eggs per brood	2	-	-	2	2	-	-	-	2	2	2	2	2.00
III (0.58-0.70 mm)													
Female with egg	2	27	15	11	14	-	6+7*	-	24	24	37	36	
Female without egg	-	10	13	6	3	7	20	13	7	18	14	11	
Eggs per brood	2	2	2	2	2	-	1.83	-	2	2	2	2	1.98
IV (0.70-0.85 mm)													
Female with egg	-	42	43	51	41	19	15	46	35	25	-	-	
Female without egg	-	5	13	24	20	34	25	10	15	16	-	-	
Eggs per brood	-	-	2	2	2	2	2	2	1.96	2	-	-	1.99
V (0.85-0.98 mm)													
Female with egg	-	5	-	-	13	31	14	12	-	-	-	-	
Female without egg	-	-	-	-	3	2	-	-	-	-	-	-	
Eggs per brood	-	2	-	-	2	2	2	2	-	-	-	-	2.00
Total females with egg	58	72	58	70	74	50	21+7*	58	74	60	68	77	
Total females without egg	27	28	42	30	25	50	72	42	26	40	32	23	
Total juvenile (Group-I)	15	-	-	-	-	-	-	-	-	-	-	-	
Mean egg/brood(all size gr)	2	2	2	2	2	2	1.97	2	1.96	2	2	2	1.99 (mean for all size group)
Actual field density(No./l)	21.7	13.2	18.3	-	3.0	11.5	4.7	8.6	6.7	3.5	6.3	6.0	
Total specimens analysed	100	100	100	20	60	100	100	100	100	27	50	75	

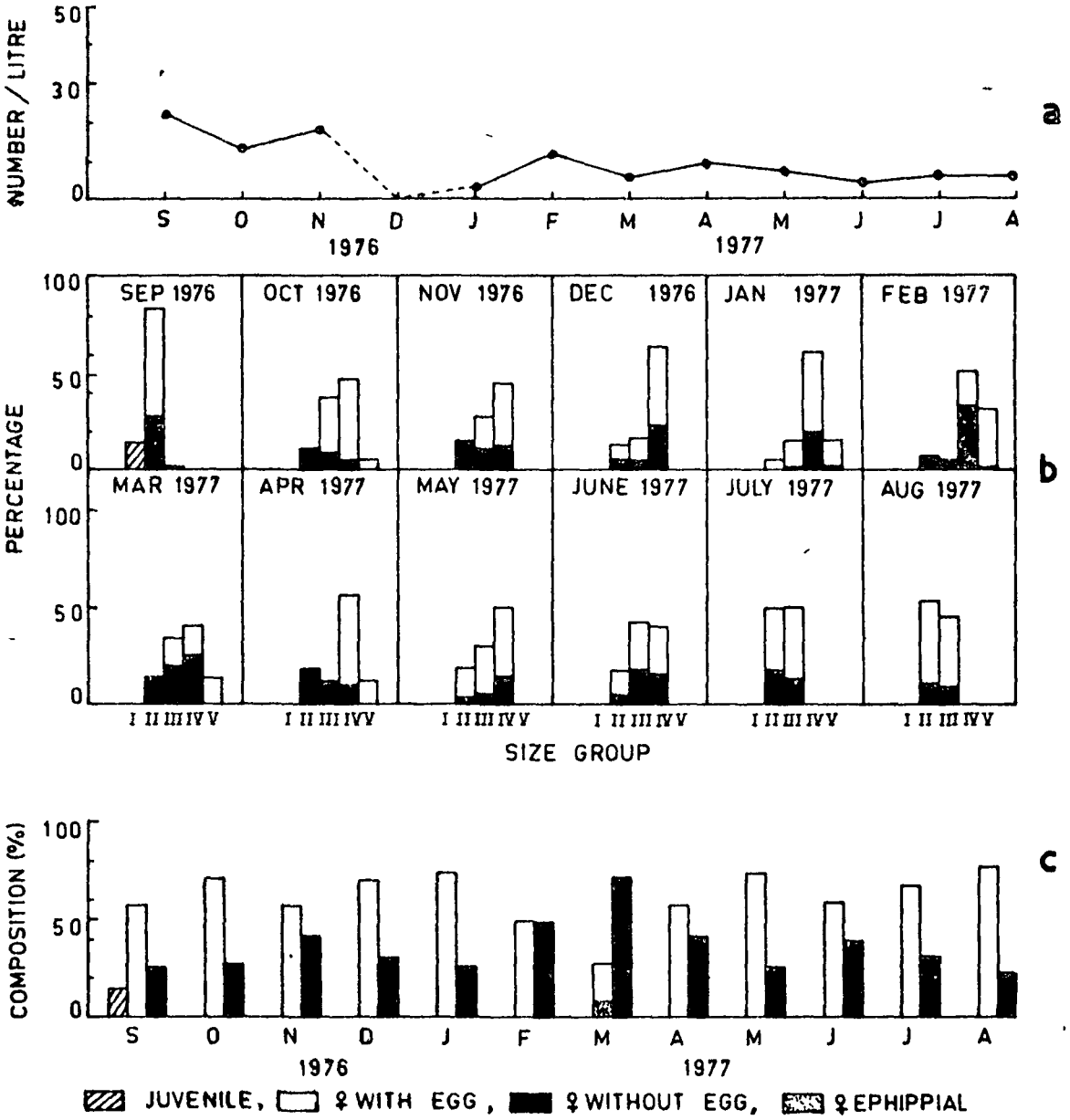
Values for juveniles, females with and without eggs are as percentages and the egg/brood given as numbers (Percentage figures given are rounded off to the nearest whole number; * = ephippial Q_4)

Fig.46

Showing population structure of Acroperus harpae in Station-I (WI) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seascnal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.46


NUMBER / LITRE
50
30
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
100
50
0
SEP 1976
OCT 1976
NOV 1976
DEC 1976
JAN 1977
FEB 1977
MAR 1977
APR 1977
MAY 1977
JUNE 1977
JULY 1977
AUG 1977
I II III IV V
SIZE GROUP
b
COMPOSITION (%)
100
50
0
S O N D J F M A M J J A
1976
1977
c
JUVENILE, ♀ WITH EGG, ♀ WITHOUT EGG, ♀ EPHIPPIAL

of percentage occurrence were 0 - 75% for Group-IV and 0 - 33% for Group-V.

Seasonal variation in the percentage contribution of egg bearing and non egg bearing females appearing in different groups are shown in Fig.46b while the total percentage composition of egg bearing and non-egg bearing females as well as juveniles (Group-I) have been shown in Fig.46c. Maximum number of non-egg bearing females were recorded in March, 1977 forming 72% of the analysed sample.

Mean egg/brood varied between groups ranging from 1.98 - 2.0/brood while the annual mean egg/brood for all sizes was 1.99. However, in general 2 eggs/brood was recorded in majority of the specimens irrespective of size groups.

Seven ephippial females were seen in the 100 animals analysed during March, 1977, though no male specimens were recorded throughout the 12 months period. Thus, with the exception of March, 1977, the population was entirely formed of parthenogenetic females.

WIII: Table-72 represents the data gathered on the population structure of Acroperus harpae in WIII. Seasonal

Table-72 : Showing the details of the population structure of Acroperus harpae in Station-III (WIII) of Ward Lake (September, 1976 to August, 1977).

Size Group and categories	1976				1977								Annual mean egg/brood group
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	
I (0.30-0.45 mm)	41	4	-	-	-	-	-	-	-	-	16	-	
II (0.45-0.58 mm)													
Female with egg	33	1	11	1	-	3	11	15	4	-	-	-	
Female without egg	18	4	2	3	-	-	3	-	9	3	-	-	
Eggs per brood	1.78	2	2	2	-	2	2	2	2	-	-	-	1.97
III (0.58-0.70 mm)													
Female with egg	4	16	3	28	-	33	19	22	27	19	2	-	
Female without egg	4	5	4	13	-	11	10	9	10	60	15	-	
Eggs per brood	2	1.94	1.67	2	-	2	2	2	2	2	2	-	1.96
IV (0.70-0.85 mm)													
Female with egg	-	57	14	33	65	38	38	42	22	6	18	26	
Female without egg	-	9	9	13	35	13	19	12	17	9	49	28	
Eggs per brood	-	2	2	2	1.96	2	2	2	2	2	1.94	2	1.99
V (0.85-0.98 mm)													
Female with egg	-	4	48	6	-	-	-	-	11	3	-	21	
Female without egg	-	-	9	3	-	2	-	-	-	-	-	25	
Eggs per brood	-	2	2	2	-	-	-	-	2	1.67	-	1.83	1.92
Total females with egg	37	78	76	68	65	76	68	79	64	28	20	47	
Total females without egg	22	18	24	32	35	24	32	21	36	72	74	53	
Total juvenile (Group-I)	41	4	-	-	-	-	-	-	-	-	16	-	
Mean egg/brood(all size gr)	1.80	1.76	1.87	2	1.96	2	2	2	2	1.89	1.97	1.91	1.93 (mean for all size group)
Actual field density(NO/l)	-	22.5	24.5	8.3	-	7.7	1.7	24.0	16.0	3.2	-	0.7	
Total specimens analysed	27	100	100	80	26	100	100	100	80	50	21	16	

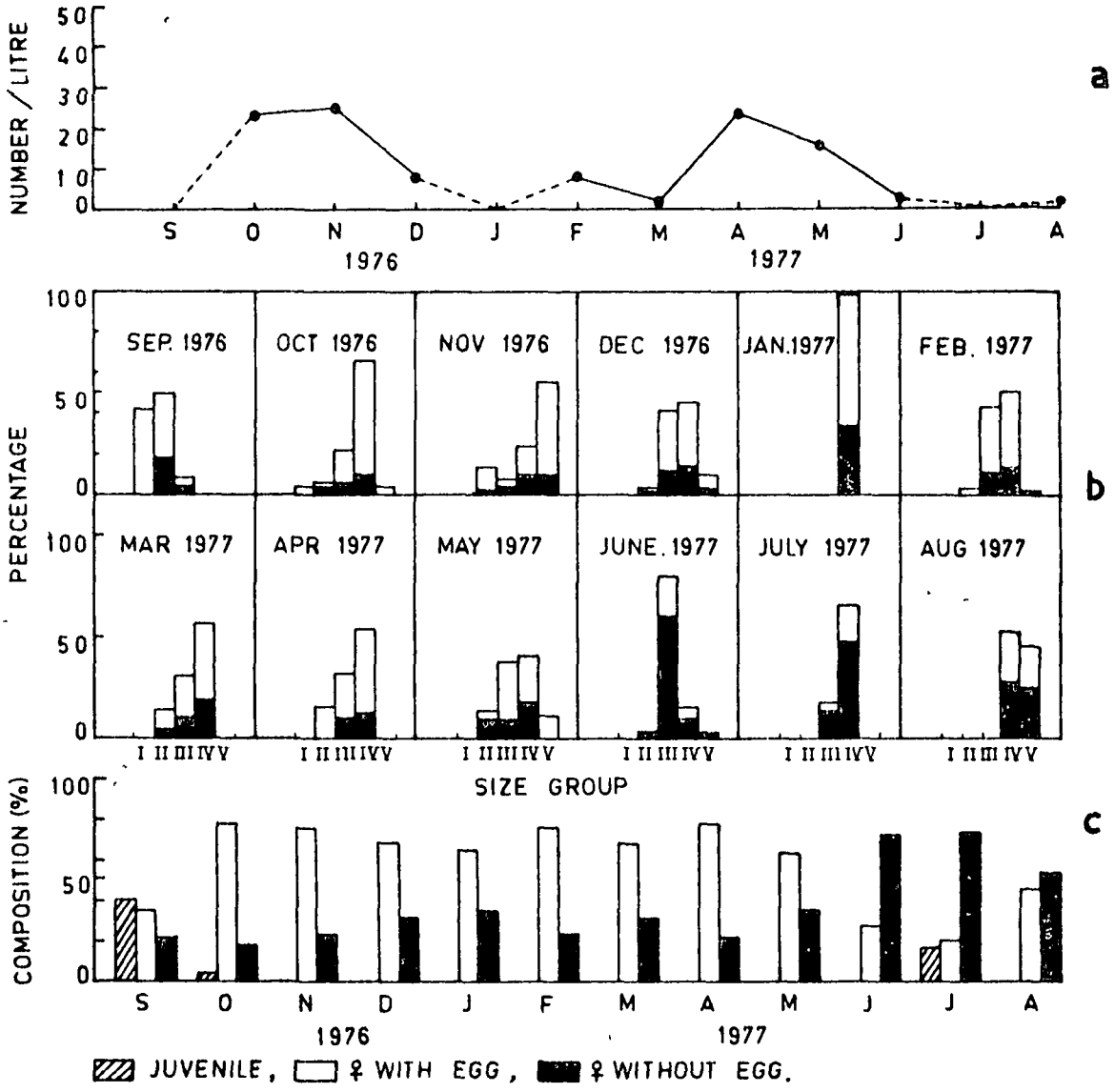
Values for juveniled, females with and without eggs are as percentages and the egg/brood given as numbers (Percentage figures given are rounded off to the nearest whole number)

Fig.47

Showing population structure of Acroperus harpae in Station-III (WIII) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.47


NUMBER / LITRE
50
40
30
20
10
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
100
50
0
SEP. 1976
OCT 1976
NOV 1976
DEC 1976
JAN.1977
FEB. 1977
MAR 1977
APR 1977
MAY 1977
JUNE. 1977
JULY 1977
AUG 1977
I II III IV V
b
SIZE GROUP
COMPOSITION (%)
c
JUVENILE, ♀ WITH EGG, ♀ WITHOUT EGG.

variations in the percentage contribution of different size groups has been depicted in Fig.47b. The annual ranges of contributions of different size groups were: Group-I (juvenile): 0 - 41%, Group-II: 0 - 51%, Group-III : 0 - 79%, Group-IV: 0 - 100% and Group-V: 0 - 57% .

Seasonal variations in the percentage composition of non-egg bearing females belonging to different size groups have been shown in Fig.47b while Fig.47c represents the percentage composition of total juvenile and females with and without egg. In Fig.47a actual density of A. harpae has been shown.

Egg production varied between different groups and the annual mean value ranged from 1.92 - 1.99 egg/brood in different size groups. Annual mean egg/brood for all size group was found to be 1.93.

In this station sexual females or males were not recorded throughout the study period.

Alonella excisa :

Details analysis of the population structure of Alonella excisa was carried out in WI and WIII of Ward Lake and Lady Hyderi Park pond. Length of this species ranged from a minimum of 0.22 mm to a maximum of 0.57 mm. For the present

purpose the length range was divided into 4 size groups. Following are the length ranges of different groups : Group-I (juvenile): 0.22 - 0.26 mm, Group-II: 0.26 - 0.38 mm, Group-III: 0.38 - 0.48 mm and Group-IV: 0.48 - 0.57 mm.

WI : Distribution and percentage composition of different size groups have been shown graphically in Fig.48b and the data gathered have been presented in Table-73. Group-I (juvenile) was recorded in May and August, 1977 forming a maximum of 8%. Ranges of percentage composition of Groups-II, III and IV were 0 - 58%, 17 - 79% and 0 - 33% respectively.

Total females with eggs formed from a minimum of 29% in April, 1977 to a maximum of 72% in December, 1976. Females without egg formed a maximum of 71% of the analysed specimens.

Egg/brood was always 2 in all adult size groups forming the annual mean value of 2 eggs/brood for all size groups.

No ephippial female or male were recorded throughout the study period.

WIII : Details of the analysis of Alonella excisa population at WIII of Ward Lake are presented in Table-74 and Fig.49. Juveniles (Group-I) was only seen during

Table-73 : Showing the details of population structure of Alonella excisa in Station-I (WI) of Ward Lake (September, 1976 to August, 1977).

Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Annual mean egg/brood/group
I (0.22-0.26 mm)	-	-	-	-	-	-	-	-	7	-	-	8	
II (0.26-0.38 mm)													
Females with egg	21	29	13	17	18	-	8	-	31	34	9	34	
Females without egg	11	18	12	8	33	-	5	-	15	24	39	16	
Eggs per brood	2	2	2	2	2	-	2	-	2	2	2	2	2.00
III (0.38-0.48 mm)													
Females with egg	43	12	46	34	8	63	50	21	26	32	28	25	
Females without egg	25	32	29	16	9	4	29	52	21	10	24	9	
Eggs per brood	2	2	2	2	2	2	2	2	2	2	2	2	2.00
IV (0.48-0.57 mm)													
Females with egg	-	9	-	21	30	31	4	8	-	-	-	8	
Females without egg	-	-	-	4	2	2	4	19	-	-	-	-	
Eggs per brood	-	2	-	2	2	2	2	2	-	-	-	2	2.00
Total females with egg	64	50	59	72	66	94	62	29	57	66	37	67	
Total females without egg	36	50	41	28	44	6	38	71	36	34	63	25	
Total juvenile (Group-I)	-	-	-	-	-	-	-	-	7	-	-	8	
Mean egg/brood(all size gr)	2	2	2	2	2	2	2	2	2	2	2	2	2.00(mean for all size gr.)
Actual field density(No./l)	17.3	-	12.3	14.3	0.8	3.0	0.7	-	2.3	-	-	3.3	
Total specimens analysed	100	34	100	100	50	100	50	26	80	12	15	100	

Values for juveniles, females with and without eggs are as percentages and the egg/brood given as No (Percentage figures given are rounded off to the nearest whole number).

Fig.48

Showing population structure of Alonella excisa in Station-I (WI) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig. 48

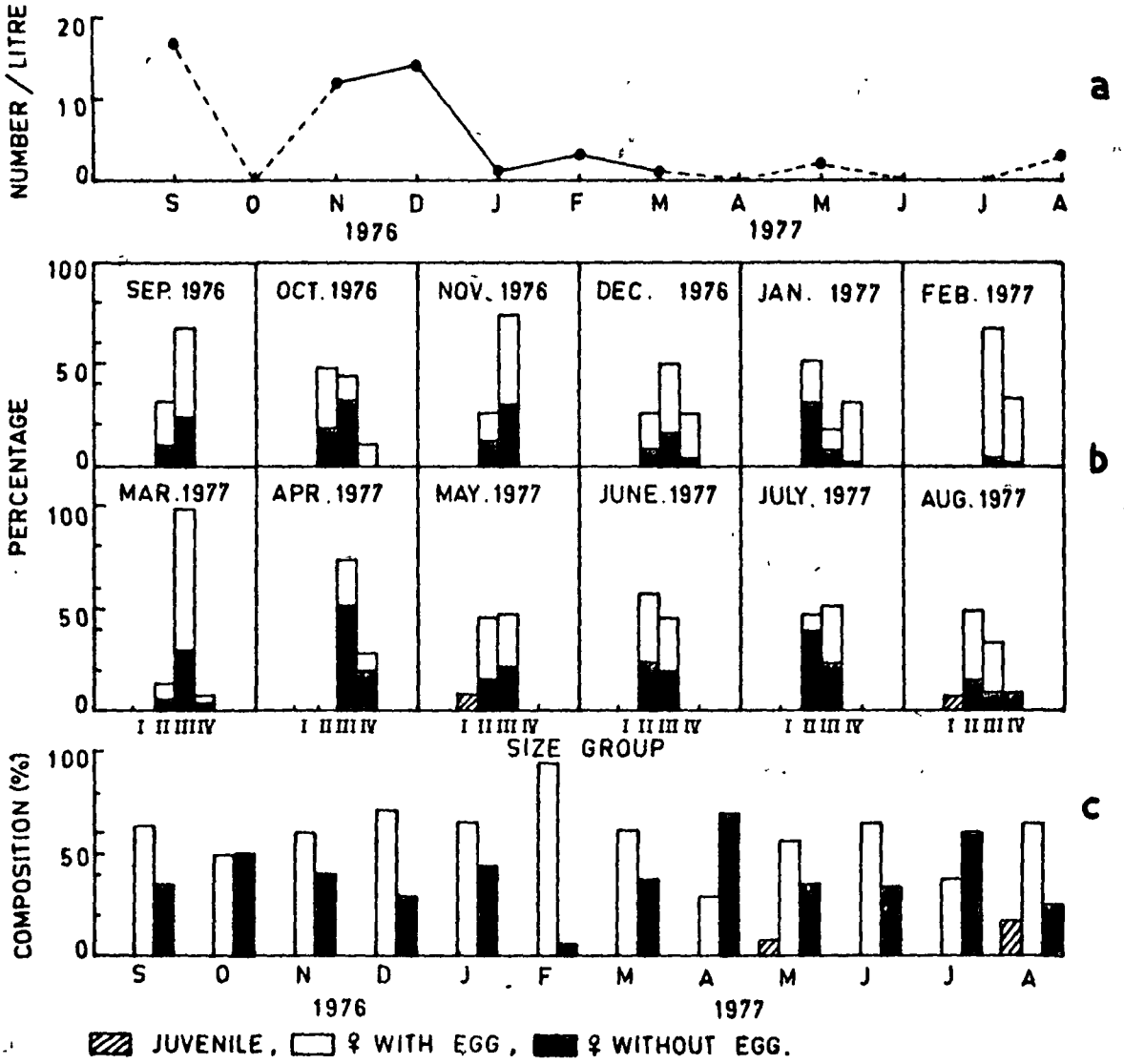

NUMBER / LITRE
20
10
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
100
50
0
SEP. 1976
OCT. 1976
NOV. 1976
DEC. 1976
JAN. 1977
FEB. 1977
MAR. 1977
APR. 1977
MAY. 1977
JUNE. 1977
JULY. 1977
AUG. 1977
I II III IV
b
SIZE GROUP
COMPOSITION (%)
c
JUVENILE, ♀ WITH EGG, ♀ WITHOUT EGG.

Table-74 : Showing the details of population structure of Alonella excisa in Station-III (WIII) of Ward Lake (September, 1976 to August, 1977).

Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Annual mean egg/brood/ group
I (0.22-0.26 mm)	-	-	-	-	-	-	-	-	-	-	11	-	
II (0.26-0.38 mm)													
Females with egg	12	11	8	5	-	-	-	53	31	-	46	5	
Females without egg	11	39	9	14	-	-	-	18	-	-	25	9	
Eggs per brood	2	2	2	2	-	-	-	2	2	-	2	2	2.00
III (0.38-0.48 mm)													
Females with egg	48	14	73	43	40	29	29	8	31	72	17	61	
Females without egg	25	29	10	38	34	16	30	21	4	28	1	24	
Eggs per brood	2	2	2	2	2	2	2	2	2	2	2	2	2.00
IV (0.48-0.57 mm)													
Females with egg	4	7	-	-	23	42	27	-	23	-	-	1	
Females without egg	-	-	-	-	3	13	14	-	11	-	-	-	
Eggs per brood	2	2	-	-	2	2	2	-	2	-	-	2	2.00
Total females with egg	64	32	81	48	63	71	66	61	85	72	63	67	
Total females without egg	36	68	19	52	37	29	44	39	15	28	26	33	
Total juvenile (Group-I)	-	-	-	-	-	-	-	-	-	-	11	-	
Mean egg/brood(all size gr)	2	2	2	2	2	2	2	2	2	2	2	2	2.00 (mean for all size group)
Actual field density(NO/l)	21.2	4.7	10	1.7	3.8	2	2.5	2.2	3	1	1	6.7	
Total specimens analysed	100	100	100	68	50	69	57	48	50	17	20	100	

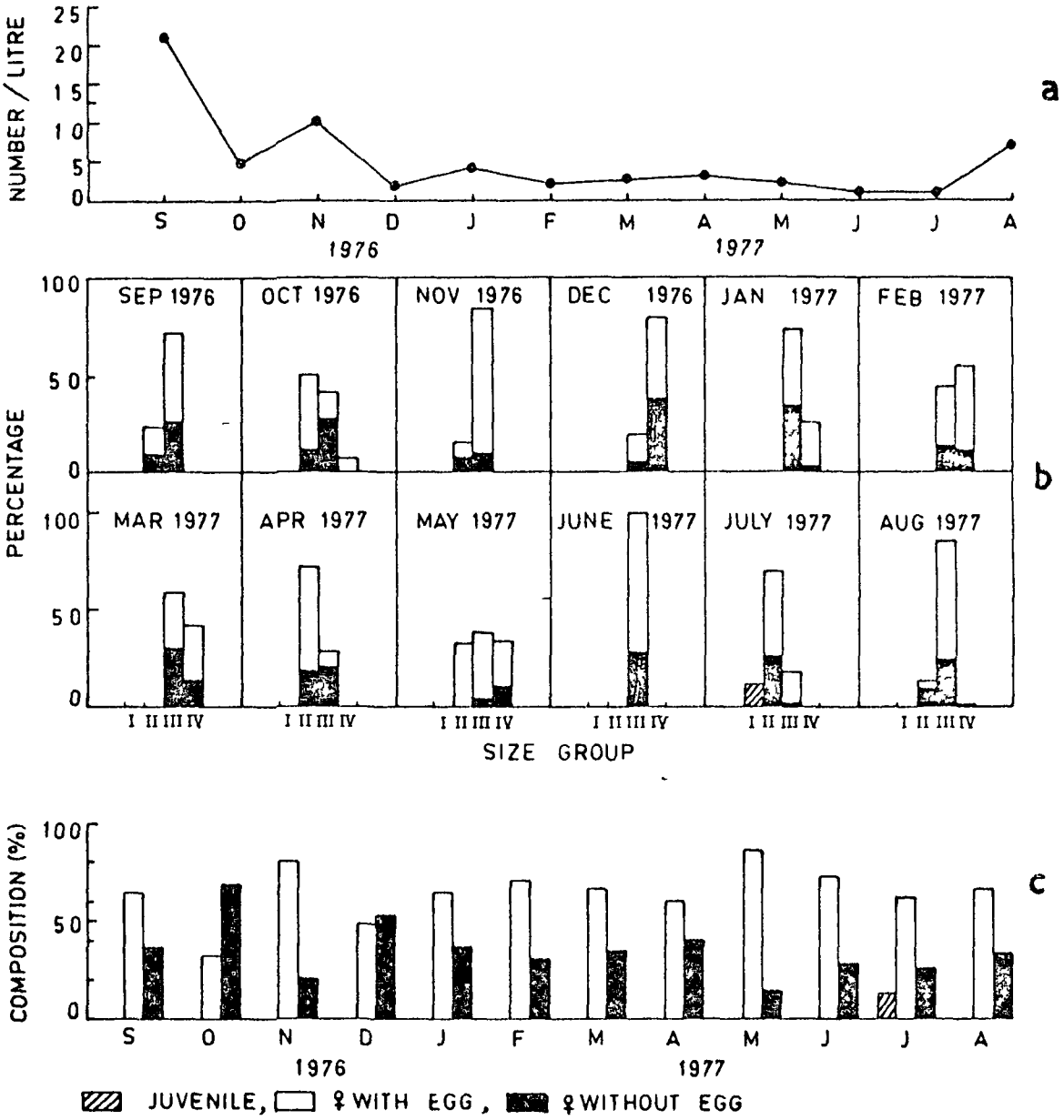
Values for juveniles, females with and without eggs are as percentages and the egg/brood given as numbers (Percentage figures given are rounded off to the nearest whole number).

Fig.49

Showing population structure of Alonella excisa in Station-III (WIII) of Ward Lake.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.49


NUMBER / LITRE
25
20
15
10
5
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
100
50
0
SEP 1976
OCT 1976
NOV 1976
DEC 1976
JAN 1977
FEB 1977
MAR 1977
APR 1977
MAY 1977
JUNE 1977
JULY 1977
AUG 1977
I II III IV
SIZE GROUP
b
COMPOSITION (%)
c
JUVENILE, ♀ WITH EGG, ♀ WITHOUT EGG

July, 1977 forming 11% . Group-II individuals were seen in 8 out of the 12 months samples forming a maximum of 71% both in April and July, 1977. Group-III was represented throughout the period and ranged between 18 - 100% of the specimens analysed during different seasons. Group-IV was somewhat sporadic in distribution forming 0-55% during different seasons.

Percentage fluctuations of females with and without eggs as well as juveniles have been depicted in Fig.49c. Total non-egg bearing females ranged from 19 - 68% of during different study months.

Egg/brood recorded for this species was always 2 and the studied samples did not contain any sexual female or male specimen.

Lady Hyderi Park pond :

Structure analysis of the population of Alonella excisa has been shown in Table-75. In this pond the population of A. excisa was confined to lower length range as Group-IV individuals were recorded only in February and June, 1977 forming a maximum of 10%. The analysed specimens belonged mostly to Groups-II and III almost throughout the season. Group-I (juvenile) occurred in 7 out of the 12 months study period and

Table-75 : Showing the details of population structure of Alonella excisa in Lady Hyderi Park pond (September, 1976 to August, 1977)

Size Group and categories	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Annual mean egg/brood/ group
I (0.22-0.26 mm)	-	-	14	-	17	-	-	5	7	10	28	5	
II (0.26-0.38 mm)													
Females with egg	15	-	9	32	31	-	18	37	24	39	40	11	
Females without egg	2	-	-	22	-	-	-	16	-	3	-	42	
Eggs per brood	2	-	2	-	2	-	2	2	2	2	2	2	2.00
III (0.38-0.48 mm)													
Females with egg	55	55	74	46	43	53	53	27	63	43	21	35	
Females without egg	28	45	3	-	9	37	29	15	6	2	11	7	
Eggs per brood	2	2	2	2	2	2	2	2	2	2	2	2	2.00
IV (0.48-0.57 mm)													
Females with egg	-	-	-	-	-	10	-	-	-	1	-	-	
Females without egg	-	-	-	-	-	-	-	-	-	2	-	-	
Eggs per brood	-	-	-	-	-	2	-	-	-	2	-	-	2.00
Total females with egg	70	55	83	78	74	63	71	64	87	83	61	46	
Total females without egg	30	45	3	22	9	37	29	31	6	7	11	49	
Total juvenile (Group-I)	-	-	14	-	17	b-	-	5	7	10	28	5	
Mean egg/brood(all size gr)	2	2	2	2	2	2	2	2	2	2	2	2	2.00 (mean for all size gr.
Actual field density(No./l)	0.5		4.3		4.7		0.8		6.5	21.7	6.7		
Total specimens analysed	10	16	100	24	100	10	20	100	100	100	47	50	

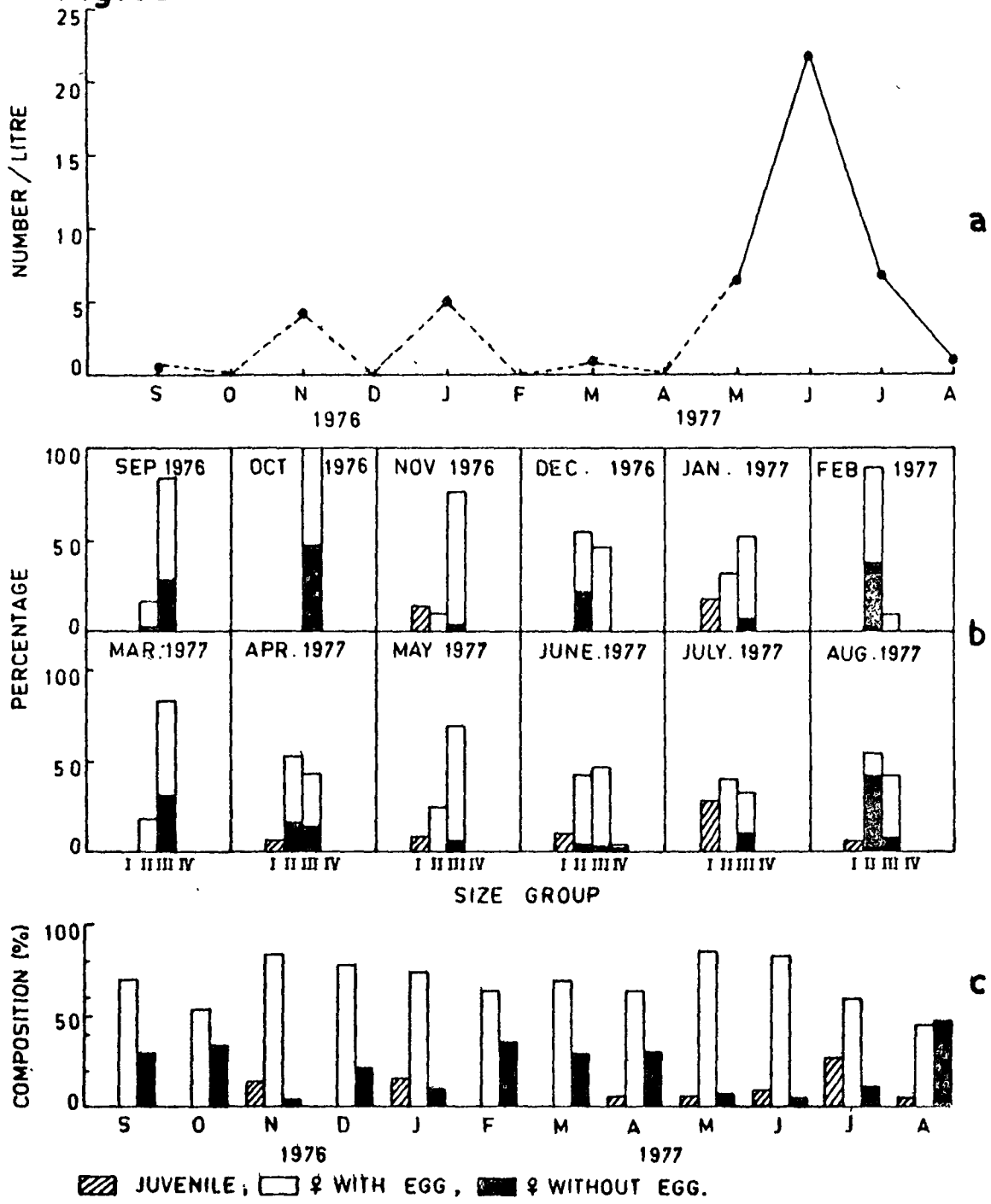
Values for juveniles, females with and without eggs are as percentages and the egg/brood given as numbers (Percentage figures given are rounded off to the nearest whole number).

Fig.50

Showing population structure of Alonella excisa in the Lady Hyderi Park Pond.

a. Seasonal variations in population density (No/l).
b. Seasonal variations in the percentage composition of different size groups.
c. Seasonal variations in the percentage composition of juveniles, egg-bearing and non egg-bearing females.

Fig.50


NUMBER / LITRE
25
20
15
10
5
0
S O N D J F M A M J J A
1976
1977
a
PERCENTAGE
100
50
0
SEP 1976
OCT 1976
NOV 1976
DEC. 1976
JAN. 1977
FEB 1977
MAR. 1977
APR. 1977
MAY 1977
JUNE. 1977
JULY. 1977
AUG. 1977
I II III IV
SIZE GROUP
b
COMPOSITION (%)
100
50
0
S O N D J F M A M J J A
1976
1977
JUVENILE ; ♀ WITH EGG , ♀ WITHOUT EGG.
c

and formed a maximum of 28% of the analysed animals (Fig.50b).

Females with and without eggs showed variations in different size groups during different seasons. Contributions of females with egg ranged between 55 - 87% while total non egg bearing females formed 3 - 45% . Juveniles (Group-I) ranged between 0 - 28% .

Number of eggs per brood was 2 in all size groups during different seasons. No ephippial mother or males were recorded in any of the studied months.

PART-II

D I S C U S S I O N

The seasonal variationsin the physicochemical properties at the four stations in Ward Lake, Fish Dale and Lady Hyderi Park ponds have been shown serially in Tables-33, 34, 35, 36, 45, and 48. These three impoundments vary in age, size and depth and have already been categorised along with other ecosystems encountered in Shillong area (Table-31). Thus it is apparent that though these systems were investigated intensively at weekly interval, the results obtained are well within the ranges of values obtained at two-month intervals for the other impoundments (Part-I). As such, these systems are characterized by moderately acidic pH, low ranges of conductivity, alkalinity and silicates and with moderately high phosphates and nitrates. However, in course of 18-month study the six sampling stations did show variations in their physicochemical properties. In this section a comparison between the different stations in terms of physicochemical and biological characteristics have been made and the data presented in Table-76 and 77.

It is well known that in fresh water environments temperature is one of the main variants influencing the boota (Reynoldson et al. 1965, Maccan 1961, 1963, Martin, 1972, Young, 1975, Daniel and Boyden, 1975). In the present studies surface water temperature in the four stations of Ward Lake, Fish Dale and Lady Hyderi park ponds showed close similarities in their seasonal trends as shown in Figs.4, 5, 6, 7, 16 and 19. Taking into account the temperature variations along with data

on humidity and rainfall (Table-1, Fig.1) four seasons could be defined though with slight overlapping (Part-I). These four seasons are spring (March - April), Summar-rainy (May-August), Autumn (September - November) and Winter (December- February).

Hydrogen ion concentration varied between 6 -7 in the four stations of Ward Lake and also in Fish Dale pond. But in Lady Hyderi Park pond pH value ranged between 5.58-6.51, showing a comparatively lower value. Biological importance of pH has been long established since this factor is related directly with photosynthetic activities of algae, the carbonates of calcium and magnesium are precipited from bicarbonates and the water becomes more alkaline (Sharma, 1978) and pH ranging between 6.5 - 8.2 is likely to favour this dissolution of bicarbonates and the liberation of free carbon dioxide (Jana and Sarkar, 1971, Jana, 1973). Further, it has also been pointed out that low values of pH was accompanied by increase in the zooplankton production (Sreenivasan, 1963), Moitra and Bhattacharya, 1965, Jana, 1973). Hence, pH value has been regarded as an index for the suitability of aquatic biotopes for pisciculture practices and the admissible range recommended for the said purpose is between 6.5 - 9.0 (Swingle, 1957, Michael, 1969, Mathew, 1975). By the same criterion, the Lady Hyderi Park pond has much less productive potential as evident also from its plankton content. One of the reasons for such low values may be the extremely turbid nature preventing algal growth as the water is being constantly

disturbed by the aquatic bird population kept under captivity in this system.

One of the important factors known to limit the production of plankton is the abundant biogenous salts in a lake medium. Electrolytic conductivity is a measure of the amount of biogenous substances present in the waters in ionic state (Brzek et al, 1975). Usually conductivity readings reach the highest in highly productive waters (Rodhe, 1951, Radwan et al ,1973). A significant corelation between phytoplankton biomass and conductivity was recorded by Brzek et al (1975) in the three polish lakes of different trophy. In the present study, conductivity values ranged between 30 - 100 umhos/cm in all the ponds and stations with the single exception of WIV where the range was between 78.93 - 122.43 umhos/cm (Table-36). These values showed the peak in the month of December, 1977 in WI while in WII the highest value was recorded in August, 1977 . In WIII also the same trend was noted while in WIV, Fish Dale and Lady Hyderi Park pond the peak values were recorded in March, 1977. Further, this increase was sudden which could be attributed to the washing in of electrolytes from the surrounding areas during the first rains. In addition to this, the sharp increase in conductivity value recorded during the month of March in the Fish Dale pond could also have been due to the fact that at the end of February, 1977 when the level of the pond was very low, water from a surrounding stream was let in. This is thought to be more likely a source of electrolytic

enrichment as this a cemented pond with very low bottom deposit.

One another important factor in any aquatic ecosystem is the amount of in situ dissolved oxygen present. Dissolved oxygen content is known to be influenced by a number of enrironmental factors (Ganapati, 1940) and according to the law of solubility high temperature should be the period of low oxygen content. Further, oxygen, pH and carbon dioxide are closely linked with respiration and photosynthesis, the ratio of which are primarily determined by temperature and illumination in small rock ponds (Anderson, 1971). Seasonal variations in the amount of dissolved oxygen at the four stations of Ward Lake and Fish Dale and Lady Hyderi Park ponds have been shown in Figs. 4, 5, 6, 7, 16 and 19. Condentration of oxygen ranged between 4.6 -10.7 mg/l in all the sampling stations except in Lady Hyderi Park pond. However, the highest value of 17.76 mg/l as recorded in Station-IV of Ward Lake might be due to the difference in the sampling timing at that instance. On the other hand, the lower limit of dissolved oxygen in Lady Hyderi Park pond (2.68 mg/l), apparently due to the low phytoplankton productivity, thought to be one of the reasons.

The seasonal trend in the fluctuations of the carbon dioxide content, though more or less similar in all the six sampling stations as shown in Figs. 4, 5, 6, 7, 16 and 19 and in Table-76; in Lady Hyderi Park pond carbon dioxide content

was higher in comparison to the other two impoundments. Diel pattern of carbon dioxide concentration has been shown to exhibit a direct correlation with the amount of phytoplankton (Armitage, 1962, Michael, 1969). As the amount of oxygen, carbon dioxide and pH values are closely linked with the respiration and photosysthesis (Daniel and Boyden, 1975), this factor is of adequate importance to understand the metabolism of aquatic ecosystems. It is seen that in all the present systems carbon dioxide was always recorded. However, as the estimation of this gas was confined only to morning samples, these values could reflect the carbon reserves yet to be utilised in photosynthesis during the latter part of the day. Nevertheless, a detailed diurnal study is required to understand the total dynamics of carbon dioxide system.

Total alkalinity was due to bicarbonates only except in the month of July, 1977 when 8.2 mg/l carbonate alkalinity was recorded in the Fish Dale pond. Again, in the same system sudden rise in alkalinity from 33.35 mg/l in July, 1977 to 52.60 mg/l in August, 1977 as also reflected in the pH rise from 5.9 to 7.0, may be attributed to the enhanced algal activity. This is in agreement with other earlier reports (Goldman and Wetzel, 1967, Sreenivasan, 1964, Vijayaraghavan, 1971). In the rest of the systems also higher values of alkalinity were observed from March, 1977 till September, 1977 with corresponding high phytoplankton productivity. Rainfall is also known to decrease the total alkalinity values

(Mukherjee and Bhattacharya, 1949) although the moderately higher values of alkalinity recorded during December till February was due to the evaporation of water and subsequent decrease in water level (Hazelwood and Parkar, 1961, Michael, 1969). Thus it has been shown that there were considerable differences in the total alkalinity values between the six different sampling stations, though the absolute range of alkalinity values was quite low here with 15.0 - 60.0 mg/l. Huet (1948) found that a total alkalinity range of 100.00-200.00 ppm to be the best range for supporting diversified aquatic life also also Philipose (1960) who mentioned that moderately high alkalinity (50- 100 ppm) to be good for the growth of fishes.

The seasonal fluctuations in the concentration of phosphate, nitrate and silicate have been summarised in Table-76 Phosphate ranged between 0.28 mg to 1.88 mg/l in WI of Ward Lake while in WII the range was 0.3- 1.12 mg/l and in WIII the value never exceeded 0.98 mg/l during the 18-month study. But in WIV the upper limit of phosphate concentration was 2.97 mg/l as recorded in May, 1977. On the other hand in the two ponds at Fish Dale and Lady Hyderi Park the maximum amounts were 1.43 and 1.21 mg/l respectively. Further, the peak values of phosphates in all the systems were recorded during the heavy monsoon period, obviously due to the fact that this nutrient was washed in from the surrounding areas through the temporary inlets developed during the rainy seasons. The importance of surrounding catchment areas in the nutrient economy of small

water bodies have already been shown by earlier workers (Swingle, 1957, Woodmansee, 1958, Heron, 1961, Michael, 1969). It has been further pointed out in Part-I that the phosphate values encountered in these water bodies are somewhat higher than the earlier values recorded from the tropical plains of India.

Concentration of nitrate varied considerably during the different seasons in the four station in Ward Lake, with WIV showing the maximum amount of this nutrient. In Lady Hyderi Park and Fish Dale ponds also fluctuations of this nutrient were of similar nature (Fig.16 and 19). It is observed that in all of these sampling sites the nitrate content was more during the winter months (December- February) followed by subsequent decline evidently due to the utilisation during the spring bloom of phytoplankton. Similar relationships were established by Lannergren (1975) and Reid and Squibb (1971). However, the nitrate levels recorded in the present ponds were quite high in comparison to other Indian situations as shown earlier.

One another nutrient considered for study under this section is the amount of silicate. It is well known that silica is an important nutrient for the growth of diatoms (Dickson, 1975). The amount of silicate in the present water bodies varied considerably and the highest concentration was recorded in Lady Hyderi Park pond. Among the four stations of Ward Lake, however, WIV showed the maximum content. It is interesting

Table-76 : Showing the annual ranges of physicochemical factors of the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976-February, 1978).

Factors	WI	WII	WIII	WIV	Fish Dale pond	Lady Hyderi Park pond
Water temperature (°C)	12.00-25.67	11.00-25.50	10.50-25.00	11.00-24.67	9.00-24.00	11.00-23.17
pH (units)	6.16- 6.84	6.30- 7.00	6.13- 6.70	6.01- 6.82	5.90- 7.18	5.58- 6.51
Conductivity (umhos/cm)	55.55-88.20	61.80-103.47	60.50-89.15	74.94-122.43	31.63-110.87	55.82-99.15
Dissolved oxygen (mg/l)	5.52-10.70	5.06-99.46	4.52- 9.89	4.60-17.76	5.24-10.11	2.68- 9.04
Carbon dioxide (mg/l)	2.40-10.25	2.20- 7.16	2.60-11.10	3.25-15.93	2.80- 9.05	5.60-21.80
Alkalinity (mg/l)	15.30-32.30	15.60-52.60	16.13-37.30	17.90-58.85	10.13-46.85	14.25-49.15
Phosphate (mg/l)	0.28- 1.02	0.21- 1.69	0.33- 0.97	0.13- 2.97	0.29- 1.43	0.33- 1.20
Nitrate (mg/l)	0.30- 1.58	0.17- 1.03	0.11- 1.27	0.30- 2.21	0.11- 1.50	0.10- 1.70
Silicate (mg/l)	1.41- 5.27	0.41- 3.52	1.76- 6.23	1.84-10.53	2.11- 7.24	3.51-12.73

to note that the silicate values were generally more during the winter months as a sequel to the lowering of water levels in these shallow sampling stations followed by its probable utilisation by the members of Bacillariophyceae. Depression in the silicate value during September/October also coincided with the autumnal bloom of bacillariophyceae.

In the four stations of Ward Lake total number of phytoplankton showed high density from November, 1976 to February, 1977 and as well as in October, 1977. In Station-I these higher densities were due to the contributions of Myxophyceae represented by high blooms of Microcystis forming more than 90% of the total plankton on several occasions and also partly due to the higher densities of Oscillatoria. In Station-II, on the other hand, except in the month of September, 1976 myxophyta formed around 55% of the total phytoplankton. However, the total numerical density of phytoplankton was generally high in this station. WIII had a lower phytoplankton density and the highest value was recorded in October, 1977 of which 85% was of Myxophyceae alone. During the rest of the period their density was less than 50% of the total. In WIV, maximum abundance of phytoplankton was recorded during December, 1976 and January, 1977. Unlike in other stations this was due to Bacillariophyceae which on several occasions formed more than 90% of the total. Chlorophyceae was fairly represented in this station, while Chrysophyceae and Dinophyceae showed only a patchy seasonal

distribution.

In the Fish Dale pond, the numerical abundance of phytoplankton was lower than in Ward Lake and the maximum density was recorded from May, 1977 till August, 1977 showing a summer bloom. Chlorophyhceae was the most dominant in this station.

In Lady Hyderi Park pond numerical density of phytoplankton was quite low in comparison to other sampling stations. In this pond Bacillariophyceae and Chlorophyceae dominated the total phytoplankton while the contributions of Myxophyceae was comparatively low. Dinophyceae and Chrysophyceae were much less in abundance and of patchy distribution during the different seasons. Thus the numerical density as well as the percentage composition of different phytoplankton taxa varied between the stations of Ward Lake as well as Fish Dale and Lady Hyderi Park ponds.

A comparative account of phytoplankton reveals that in Station-I of Ward Lake Myxophyceae was dominant throughout the annual cycle with Chlorophyceae in subdominant density, while Chrysophyceae, Dinophyceae and Bacillariophyceae formed moderate density. Station-II, on the other hand, showed dominance of Chrysophyceae as well as Dinophyceae except in late summer till early autumn when Myxophyceae dominated. In WIII, Bacillariophyceae was most abundant with moderate contributions by Myxophyceae. Extremely poor representation of both Binophyceae and Chrysophyceae was another marked feature of

this station. In WIV, the nature of fluctuations in phytoplankton was similar to that of WIII with highest density of Bacillariophyceae. In Fish Dale pond Chlorophyceae was dominant throughout the greater part of the season and was marked by poor numbers of Myxophyceae, Chrysophyceae and Dinophyceae. The other sampling station, Lady Hyderi Park pond was very low in its phytoplankton abundance and the bulk was almost equally shared by the member of Chlorophyceae and Bacillariophyceae while the other groups were sparse and insignificant contributors except for the Myxophyceae.

Permanent algal bollms of this nature formed of a single or several members of blue green algae are common in fish ponds of North-Eastern India and the temple ponds of peninsular India (Sharma, 1978). Ganapati (1940) ascribed this algal bloom to a number of factors namely high water temperature, water movements and excessive amount of phosphate. Role of water temperature has, however, been pointed out already by various workers (Fritsch, 1907, Smith, 1924, Pearsall, 1932, Chacko and Krishnamurthy, 1958, Ganapati, 1960, Bhowmik, 1968, Michael, 1969). The range of temperature most favourable for algal development has been reported to be 24° - $31^{\circ}C$ (Verma, 1964). However, George (1962) recorded algal blooms even at low temperature ($13.7^{\circ}C$) which corresponds to the present record of winter bollm. It has been pointed out earlier that the composition of phytoplankton with diatoms being dominant and

subdominance of blue green algae is typical of highly eutrophic conditions (Forsyth and McColl, 1975). Thus, the occurrence of a situation in Ward Lake, points towards its eutrophic nature. Growth of phytoplankton requires the assimilation of inorganic nutrients from the water in which they are growing (Harrison et al, 1977). Generally it is considered that these nutrients are withdrawn from the water in the proportions required for growth (Redfield et al, 1963). Further, studies have shown that the nutrient uptake ratio or cellular chemical composition can be altered by biological factors such as, cell size (Paasche, 1973b), age of the culture (Pugh, 1975), light (Collos and Lewing 1976, Devis, 1976), temperature (Jorgensen, 1968, Harrison, 1974), salinity (Pugh, 1975), source of nitrogen (Strickland et al, 1969) and as well as nutrient limitations (Harrison et al, 1977). Moreover, algae that respond to increased nutrient concentrations are usually known to be favoured by water temperature and light intensity (Mc Combie, 1960) as for instance, blue greens in the late summer and diatoms in winter and spring (Cairns, 1956). The same is also true for the present studies. One of the reasons for the decline of blue green populations may be due to decreasing light intensity and day length as pointed out by earlier workers (Gruendling, 1971, Moore, 1974, Casterlin and Reynolds, 1977). Further, unicellular algae are known to be favoured over filamentous species during the winter due to low light intensities (Sperling and Blum, 1974) which probably explains the winter dominance of diatoms as seen in the present

investigations.

Seasonal fluctuations in the abundance and percentage composition of zooplankton have been shown in Fig. 12b, 13b, 14b, 15b, 18b and 21b. In Station-I of Ward Lake high density of zooplankton was recorded in September, 1976 with the maximum abundance during December, 1976 and 1977, representing the autumn and winterswarms. In WII the autumn and winter pulses were recorded with the highest density in September, 1976. In WIII an additional spring maxima was also recorded. In WIV only the autumn maxima was well marked. In Fish Dale pond a winter maximum was recorded though summer-rainy season (May - August) had a moderately high value. While in Lady Hyderi Park pond both winter and spring maxima were well marked.

Protozoans were fairly represented in WI with their maximum contributions being 73.97% during May, 1977 (Summar-rainy). But in WII the maximum abundance was in January, 1977 (650 units/l) forming 92.72% of the total, while they were completely absent from December, 1977 till February, 1978. Again in WIII the spring bloom was recorded with the higher contribution of 95.64% of the total. In WIV, on the other hand, the same early summer maximum was recorded though in this station protozoan abundance was lower than in the other stations of Ward Lake. In Fish Dale pond maximum density was in December of both the years showing a winter maxima. In Hyderi Park pond, the spring bloom was recorded with comparatively lower mean density throughout the

rest of the season. In all these ponds the rise in density was due to the abundance of ciliates and generally winter blooms of protozoa are known for other Indian impoundments also (Michael, 1968). However, the density and period of occurrence of individual protozoan species was reported to vary during different seasons (Wesenberg- Lund, 1939, Welch, 1952, Davis, 1955). Pennak (1953) suggested the optimum temperature range for the growth of protozoans to be 16° to 25°C and probably this explains the protozoan pulses observed in April - May in most of the surveyed stations. Further, the amount of available food has been regarded as another factor controlling seasonal blooms in Protozoa (Noland, 1925, Bamforth, 1958, Michael, 1968), though no direct evidence is available from this study.

The rotifer population showed a bimodal fluctuation ranging between October till April representing autumn, winter and spring seasons. Such a pattern was observed also earlier from other Indian situations (Das and Srivastava, 1956, Vasisht and Dhir, 1970, Tandon and Singh, 1972, Vasisht and Sharma, 1975, Sharma, 1978). Even the higher density during the summer (May - August) in WII and WIII is comparable to the findings of George (1961, 1966).

Copepod populations were high in density during October and November, 1977 in WI, while in WII peak value was recorded during September, 1976. In WIII copepoda was represented more in their numerical density and their abundance was

comparatively high from April till October, 1977. In Station-IV of Ward Lake the highest density was seen in September, 1976 while in Fish Dale pond maximum was in September, 1977. In Lady Hyderi Park on the other hand, highest numerical abundance was shown in July, 1977. Thus in the present study for most of the stations only one marked seasonal peak was recorded for the Copepoda in contrast to the findings of Chacko and Krishnamurthy (1958), Vasisht (1968) and Seenayya (1973), although, such an unimodal pulse was also reported by Michael (1968). The peak of copepod populations may be indicative of their active period of reproduction as was suggested by Michael (1968), Mathew (1972) and Sharma (1978). Further the comparatively higher temperature during April till October is thought to be another factor favouring their reproductive activities as temperature has already been shown to have a direct relationship with copepod populations (Sharma, 1978).

Generally, ostracods were represented in olow densities in the different stations, although their appearence was marked by higher densities during September/October and also in December and January. They were absent totally from the open water station of WII of Ward Lake which reflects their truly weed inhabiting nature. The contrasting differences in the seasonal periodicity of ostracods between different sampling stations are thought to be due to their niche preference associated with food organisms. Further, as it has been pointed out that each plankton species has its own seasonal history

usually with the appearence of one to several seasonal peaks (Davis, 1955) and such apparent difference in the peak formation in the sampling likely to be due to such differences.

The Cladocera as a group showed a bimodal peak in their seasonal abundance, though the period of their maximum density varied from station to station. In WI maximum numbers were confined to September- October and December- February showing the autumn and winter maxima. In WII only autumn peak was recorded as was also in WIII in November, 1976. However, in both the stations there was an increasing trend in winter and spring which failed to reach swarms. In Station-IV, three peaks one each in spring, autumn and winter, were quite sharp though the spring maxima (March-April) was of comparatively lower density. In Fish Dale pond, no definite peaks were recorded and with only slight increase in Cladoceran numbers in July, 1977. On the other hand, in Lady Hyderi Park pond, the winter and spring pulses were well marked. It is thus found that in all stations Cladocera formed a substantial bulk of the total zooplankton communities as was also observed by many earlier workers (Chacko and Krishnamurthy, 1954, Seenayya, 1973), Ali, 1976, Sharma, 1978, Armitage and Smith, 1968). However, the summer-rainy season of May-August was mostly characterised by low cladoceran densities. That the rainfall can have adverse effects on zooplankton has already been pointed out (Michael, 1968, Mathew, 1972, Jana, 1973, Sharma, 1978). Further, that

Table-77 : Showing the ranges of percentage contributions of different families/groups of organisms in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond (September, 1976 to February, 1978).

Family/Group	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
Phytoplankton						
Myxophyceae	9.33-96.80	0.48-82.62	0.42-85.24	1.46-49.33	0.00-24.03	1.51-62.50
Chlorophyceae	0.58-20.90	1.35-36.53	0.96-59.04	0.54-80.41	5.85-98.34	1.56-74.71
Dinophyseae	0.00-49.37	0.00-82.28	0.11-43.14	0.00-00.24	0.00- 5.45	0.00- 4.93
Chrysophyceae	0.00-41.98	0.00-83.42	0.00-18.50	0.00- 2.03	0.00-14.50	0.00-22.15
Bacillariophyceae	0.22-73.13	0.00-15.19	4.12-98.44	14.69-98.00	0.66-88.50	13.36-81.95
Zooplankton						
Protozoa	1.14-85.62	0.00-92.72	0.58-55.54	0.33-95.64	11.04-95.33	2.46-48.04
Rotifera	3.56-53.17	0.63-86.59	0.00-97.03	0.00-58.55	0.00-84.76	3.28-73.40
Ostracoda	0.00- 6.44	-	0.00-11.00	0.21- 9.14	0.00- 1.32	0.00- 6.60
Copepoda	2.75-44.93	0.39-78.04	0.72-27.62	0.72-23.49	0.00-63.13	0.37-39.40
Cladocera	2.94-88.26	0.32-61.00	1.30-61.59	4.24-97.57	1.74-61.67	9.46-83.45
Associated organism						
Nematoda	0.00-00.54	0.00- 0.18	0.00- 0.98	0.00-18.97	0.00-20.00	0.00-12.27
Bryozoan sporoblast	0.00- 0.25	0.00- 0.17	0.00- 0.70	-	0.00- 0.26	0.00- 0.63
Inseceta	0.04- 5.70	0.00- 0.61	0.05-13.11	0.05- 8.67	0.00-14.29	0.12- 8.82

there could be differences in the seasonal cycles of Cladocera within stations of the same system as seen at present is also known (Pennak, 1946). Thus in the present study high densities of Cladocera were seen in all the three littoral stations while only lower numbers were recorded in the open water Station (WII) of Ward Lake. This may be due to intrinsic niche differences offering less or more food supply as it has been pointed out that enriched nearshore areas of lakes are expected to have a richer algal flora as compared to the limnetic zones (Cassie 1974, Munawar and Munawar, 1975).

Apart from truly zooplanktonic organisms, other invertebrate species were also occasionally recorded in the plankton. Of these, members belonging to Nematoda, Ephemeroptera and Chironomidae were particularly well represented in WIV and Lady Hyderi pond in different seasons. However, elaborate discussion on these associated organisms is outside the scope of the present thesis.

Lakes ranging from oligotrophic to eutrophic conditions have been classified on the basis of their plankton flora by many authors. Thus Hutchinson (1967) categorised 'eutrophic diatom associations' (Asterionella, Fragilaria, Synedra, Melosira and Stephanodiscus), 'eutrophic desmid associations' (Staurastrum and Cosmarium), ' eutrophic chlorococcal associations' (Pediastrum, Scenedesmus and Ankistrodesmus) and ' eutrophic myxophycean associations' (Aphanizomenon, Anabaena

and Oscilatoria). In the present studies with the exception of Stephanodiscus, and Aphanizomenon, all other genera occurred and bloomed at some time or other during the annual cycle in the different ecosystems (Table-78). Further, the presence of a more or less moderate Microcystis bloom in Ward Lake and its occasional appearence in Fish Dale pond further points towards their eutrophic nature (Kutkuhn 1956, Swayer 1966, Sreenivasan 1972, Mathew 1975). The presence of heterocystous blue green algae like Anabaena in the present systems may also point to eutrophic conditions since nitrogen fixation by blue greens only occur in very productive lakes (Howard, et al 1970). Ceratium is known to be another indicator algae (Nygaard 1949) present in Ward Lake, which once again stresses upon the eutrophic nature of Ward Lake. However, as pointed out by Casterlin and Reynolds (1977), the wide ecological tolerance of some algae such as the fresh-water species of the genus Asterionella (Huber-pestalozzi 1942) render them of little value as indicator organisms. In this context, it may be mentioned that Palmer (1969) reviewed the published reports of 165 authors and compiled a list of 60 genera and 80 species of algae most tolerant to pollution. He devised an algal pollution index (1-5 scale) for rating water samples of high or low organic pollution. Different index numbers varying between 0-5 have been assigned to different algal genera. In an given instance, when the totalled index numbers exceed 20, high organic pollution is indicated. Recently this indexing was followed by Casterlin and

Table-78 : Showing the occurrence of algal genera associated with pollution in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park Pond during September, 1976 to February, 1978.

Algal genera	Palmer's Pollution Index	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
		WI	WII	WIII	WIV		
Oscillatoria	5	+	-	+	+	+	+
Euglena	5	-	-	-	+	-	+
Scenedesmus	4	+	+	+	+	+	+
Navicula	3	+	+	+	+	+	+
Synedra	2	+	-	-	+	+	+
Ankistrodesmus	2	-	+	-	+	-	+
Melosira	1	+	+	+	+	+	-
Closterium	1	+	+	+	+	+	+
Anabaena	0	+	-	+	+	+	-
Pediastrum	0	+	+	+	-	+	-
Spirulina	0	+	+	+	+	+	-
Ulothrix	0	+	+	+	+	-	+
Cymbella	0	+	-	-	+	-	+
Fragillaria	0	+	+	+	+	+	-
Spirogyra	0	+	-	+	+	+	+
Cosmarium	0	+	+	+	+	+	+
Diatoma	0	+	-	-	+	-	+
Asterionella	0	+	+	+	+	-	-
Selanastrum	0	+	+	+	+	+	+

Table-79 : Showing a comparison of pollution level in the 4 Stations of Ward Lake, Fish Dale pond and Lady Hyderi Park pond using Palmer's Pollution Index.
(September, 1976 to February, 1978)

Month	Ward Lake				Fish Dale pond	Lady Hyderi Park pond
	WI	WII	WIII	WIV		
1976						
September	14	9	11	17	5	15
October	12	5	12	18	5	15
November	13	8	12	14	6	14
December	10	4	12	16	9	13
1977						
January	11	4	12	18	9	13
February	11	2	12	15	11	13
March	11	2	13	14	4	12
April	12	4	14	13	5	12
May	14	6	10	16	3	12
June	16	8	11	16	2	13
July	18	6	10	15	4	14
August	15	6	14	11	2	12
September	16	9	13	11	3	12
October	14	10	14	10	5	11
November	10	12	16	16	9	18
December	9	14	9	18	9	19
1978						
January	11	12	12	18	9	15
February	13	9	12	23	9	15
M E A N	12.78	6.72	12.17	15.50	6.06	13.17

Reynolds (1977) for Harveys Lake, Pennsylvania, USA in establishing its moderately polluted status. In the present studies out of the 60 genera listed (Palmer 1969), a total of 19 genera appeared in different sampling stations and the totalled index showing medium organic pollution (Table-79). Of these, Station-IV of Ward Lake showed the highest average index value of 15+5, while Stations- I and III and Lady Hyderi Park pond showed moderate pollution, the annual mean values being 12.78, 12.17 and 13.17 respectively. However, WII of Ward Lake and Fish Dale ponds had lower level of organic pollution with 6.72 and 6.06 . Thus Palmer's (1969) integration of all studies certainly gives a reasonable categorisation of such organisms as specific biological indicators (Casterlin and Reynolds 1977). On this basis, Ward Lake seemed to be moderately eutrophic, Lady Hyderi Park pond less so, while the cemented Fish Dale pond shows the least influence of organic pollution. It is also to be noted that among the four stations of Ward Lake, Station-II showed the least pollution, likely to be due to its location at deep open water surface in comparison to the other three littoral stations. The latter findings are in conformity with those of Cassie (1974) who showed that near-shore flora do have both pollution tolerant and benthic types of algae as these areas are usually regions of major nutrient input (Munawar and Nawwerk 1971).

Species composition of Cladecera in different stations of Ward Lake, Fish Dale and Lady Hyderi Park ponds considerably varied among these systems (Table-51 and Figs. 23, 24, 25, 26, 27 and 28). The total number of species recorded during the present studies was 19 of which Ward Lake harboured 18 species seven in Fish Dale pond and nine in Lady Hyderi Park pond. Besides, among the four stations of Ward Lake, 11 species were recorded in WI, 7 in WII, 10 in WIII while a total of 14 species were recorded in WIV (Table-51). Thus, WIV seemed to offer the most conducive environment for different cladoceran species while WII, the open water station, had the least species diversity. Again, Ward Lake as a whole had a greater species composition in comparison to the other two impoundments. It is likely that Ward Lake being much larger in dimension and having existed longer than the other two systems, probably provides a relatively stable environment for the growth and development of several species, in terms of number of ecological niches as well as diversity of food sources. A similar size-dependant species diversity was reported by Pennak (1957) while studying the mountain lakes of Colorado. On the other hand, the small impoundment at Fish Dale being completely cemented, obviously provided a less suitable habitat and resulting in a low species diversity. The Hyderi Park pond with its inshore vegetation is thought to have favoured chydorid species (Smirnov 1963) and hence showed greater species diversity. It is interesting to note that in all these impoundments, members

of Chydoridae dominated the sladoceran fauna with the exception of WII of Ward Lake which is an open water station and had a low number of chydorid species. This was also true for the cemented pond at the Fish Dale. The low number of chydorid species in these stations were likely to be due to the absence of littoral vegetations as most of the chydorids are well known to be weed inhabiting forms (Smirnov 1963). However, a few species of truly littoral chydorids did appear occasionally in Station-II of Ward Lake and in the cemented nursery pond at Fish Dale. Thus, in WII infrequent appearence of Biapertura affinis, Alonella excisa as well as Chydorus sphaericus is thought to be accidental, probably drifted away by wind action from littoral to the open water. Further, the numerical densities of these species never reached high numbers indicating of their temporary intrusion. Such an explanation, however, does not suffice to explain the appearence of C. sphaericus, as the exact habitat of this species has been disputed by many workers. Anderson (1971) noted C.sphaericus in open water zones though in low densities and categorised this species as limnetic without differentiating it as littoral or planktonic. Thus, while this species did occur in WII of Ward Lake, their true habitat preference needs more confirmatory studies. In Fish Dale pond Chydorus sphaericus was represented more in the collections, though this pond was also devoid of any vegetation being of complete cemented construction. This pond was very shallow in comparison to Station-II of Ward Lake

with a completely flat bottom with practically no littoral zone. Thus, based on the present studies, this species can only be called as a heleoplanktonic form as suggested by Hutchinson (1967) as its precise niche preference is yet to be assessed as pointed out earlier. The other three chydorid species, Acroperus harpae, Pleuroxus similis and Alonella excisa which occurred in Fish Dale pond never formed substantial populations and quite likely were brought in by the inflow of the surrounding watershed drained into this pond during the draught period when the water level was low. The other sampling stations of Ward Lake and the Lady Hyderi Park pond were located in the littoral zones with marginal weeds, which likely to have served as good shelter as well as feeding zones for the chydorid species and thus explains their dominance (Smirnov 1961, 1963).

For the purposes of comparison, the Similarity Index of cladoceran fauna had been calculated for the different stations of Ward Lake, Fish Dale and Lady Hyderi Park ponds using Sørensen's index (QS) (Table-80). Thus it can be seen that among the stations of Ward Lake maximum similarity was between Station-I and III suggesting the homogeneity of these habitats while the differing degrees of similarity between the rest of the stations probably reflect localised differences. Further, when comparisons were made between different stations of Ward Lake with Fish Dale pond and Lady Hyderi Park pond,

Table-80 : Showing Sørensen's similarity index (QS)of Cladocera fauna for the different Stations of Ward Lake, Fish Dale and Lady Hyderi Park ponds.

Station	WI	WII	WIII	WIV	Ward Lake	Fish Dale pond	Lady Hyderi Park pond
WI	-						
WII	0.66	-					
WIII	0.86	0.59	-				
WIV	0.62	0.48	0:75	-			
Fish Dale pond	0.67	0:43	0.71	0.67	0:42	-	
Lady Hyderi Park pond	0:70	0:50	0.74	0:59	0.52	0:88	

WIII of Ward Lake showed a higher index implying closer similarity in their faunal composition. Comparison of the total Cladocera fauna of Ward Lake with those of Fish Dale and Lady Hyderi ponds revealed lower value of QS suggesting gross differences in the faunal composition of these three impoundments. On the other hand, Fish Dale and Lady Hyderi Park ponds were highly similar in their cladoceran fauna as also evidenced by higher index value.

The present investigations have shown that the seasonal distribution of different cladoceran species varied in different sampling stations. Thus, among the family Sididae only two species, Sida crystallina and Diaphanosoma excisum were recorded from Ward Lake. S. crystallina appeared only during the last month of the entire study period (February 1978) in the weed beds of WIV. This species is always observed to be a strictly weed-inhabiting form as also indicated by Smirnov (1963). Diaphanosoma excisus on the other hand, occurred only in the open water station of Ward Lake and always in less numbers, while in other Indian water this species has been reported to form dense populations (Michael 1969). Temperature and food are thought to influence their populations density.

The only macrothricid cladoceran encountered in the present study was Ilyocryptus spinifer from Station-III of Ward Lake whose appearence in the plankton sample seemed to be

fortuitous as this species is a well known benthic form (Fryer 1974).

Among the dephnids, Simocephalus exspinosus was present throughout the study period in Station-IV of Ward Lake except in December, 1977, while in other stations its distribution was patchy. It was of interest to note that this species was mostly confined to weed beds of Rotala rotundifolia and Ammania sp. Further, it was totally absent from the open water station of WII and occurred only on two occasions at the Fish Dale pond. Besides, when Station WIV in Ward Lake was manually deweeded at the end of November, 1977 the species again disappeared during the following month (December, 1977). All these observations confirm the dependency of this daphnid species on the weed beds. The other Simocephalid Simocephalus serrulatus was recorded in good numbers from WIV of Ward Lake in January and February, 1977 when the former species S. exspinosus was in low density. It is not known whether inter specific competition was in play giving a competitive advantage to one of them, though no specific analysis was done to augment this contention. Scapholeberis kingi, the epineustic species appeared in all stations, although generally absent during winter and early rainy months. Thus, their occurrence in the warmer periods of the annual cycle probably suggesting their preference for warmer seasons as already suggested by Sharma (1978). In the open deep water station of Ward Lake, their

occurrence was confined only to September and October of 1976, while their abundance was more in shallow water zones as seen in most collections. It is probable that these organisms preferred the less disturbed marginal zones and are wind drifted to littoral regions due to their adaption of clinging to the surface film of water (Fryer 1956).

In the present study, two species od Daphnia are recorded. Daphnia lumholtzi appeared only in the deep water station of Ward Lake during the last month of the present investigations. As a result no population analysis nor seasonal trends could be worked out for this species. However, its appearence in this station indicates its truly planktonic nature. The other Daphnia sp. which sparsely occurred in the Hyderi Park pond is of taxonomic significance in the Indian context since it differed markedly from the two known species, Daphnia carinata and Daphnia lumholtzi. The detailed systematic position of this species is discussed elsewhere (Michael, personal communication). Their brief appearence without developing a substantial population is thought to be due to its accidental seeding into this pond through different species of aquatic birds brought from time to time as a means of developing the surrounding park area for recreational purposes. It is, however, well known that birds play a significant role in the dispersion of different cladoceran species (Proctor 1964, Anderson 1971).

The other daphnid species Ceriodaphnia cornuta made its only appearence in June - July of 1977 in Station-I of Ward Lake. The population densities of this species wherever encountered never reached high numbers although microaggregation in Ceriodaphnia is well known and is attributed to their reproductive activities (Brandt and Fernando 1971).

The moinid, Moina micrura which is a planktonic species reported also from other Indian impoundments (Michael 1962, Murugan 1975) was recorded in October, 1977 in the WIV of Ward Lake. The distribution of this species was confined to the warmer months and to low densities suggesting that temperature probably acts as a limiting factor, since this species usually occurs in high densities in other impoundments of tropical Indian plains (Michael 1969, 1971, Murugan 1975, Sharma 1978). Further, factors like predation pressure by fishes on Cladocera (Brooks and Dodson 1965) and even high phosphate content are known to have some limiting effect on this species (Asch and Kingsbury 1972). In this context it is of interest to note that the phosphate levels of this station was somewhat higher.

Family Bosminidae was represented by the single species, Bosmina longirostris which appeared in all the six sampling stations. B. longirostris is known to be a widespread species (Brandlova et al 1972, Anderson 1974) and has been associated

with the eutrophic nature of aquatic ecosystems (Edmondson et al 1956), while Zago (1976) considers it as an indicator of eutrophication. As discussed earlier all the three impoundments in the present study were eutrophic in nature, though within differing degrees (Table-79) and this might be one of the reasons for the almost continuous distribution of B.longirostris in all systems during the different seasons. Again, it is opined that the comparatively low ranges of water temperature in these impoundments are likely to have favoured better growth, persistence and fecundity of B. longirostris as also reported by Bhajan and Hynes (1972), who found that temperature above 21°C while enhances the growth of this species, yet unable to sustain it for a longer period. Further, Bosmina longirostris is known to have competitive advantage in acidic pH medium (Janicki and De Costa 1977) which may be another reasons for its ubiquitous occurrence in all the present systems which have low hydrogen ion concentration.

Among Chydoridae, Chydorus sphaericus has been found to show maximum incidence among all species of Cladocera, occurring throughout the seasons. As pointed out earlier this species appears to be widely distributed in the aquatic systems of Shillong (Part-I) suggestive of their higher level of tolerence as also pointed out earlier by Anderson (1971) and Patalas (1974). The other chydorid species namely, Biapertura

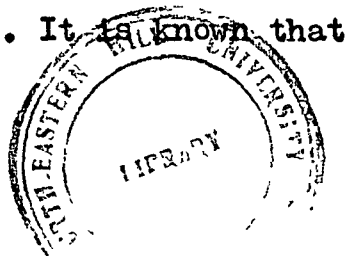
affinis, Camptocercus australis, Acroperus harpae, Pleuroxus similis and Alonella excisa were mainly confined to weed beds, which serve both as shelter and feeding territory and reflect their well known preference to littoral regions of lakes and ponds (Smirnov 1963). Among these species, Biapertura affinis and Alonella excisa showed relative dominance both in terms of numerical densities and seasonal distribution which can only be attributed to their successful adaptations to these habitats as discussion is restricted for wat of adequate information on the ecology of littoral chydoridae in general (Lynch 1980). Two additional chydorid species, Alonella nana and Alona sp. also appeared in WIV of Ward Lake though in small numbers and their occurrence could only be explained in terms of their niche selectivity to the weed beds.

In the present study, Simocephalus exspinosus and S. serrulatus appeared together in WIV, though one of them dominated in numbers as seen from Tables-52 and 54. This phenomenon is in agreement with the observations of Sago (1976). Normally among the Cladocera more than one species of the same genus is not known to occur as reported by Pennak (1957) which is also true for the rest of the other genera in the present studies.

The numerical density of different cladoceran species varied from station to station. Some species belonging to

certain genera did not form substantial populations and as such have not been discussed as no definite seasonal pattern could be established from their insignificant numbers. Thus the present discussion is restricted to the numerical abundance of eight species only of which two belonged to family Daphnidae, one of Bosminidae and five in Chydoridae.

Simocephalus exspinosus showed considerable fluctuations in its numerical densities (Fig.30). In WI during the month of February 1977 and 1978 abrupt rise in densities was witnessed. In WII this species was totally absent while WIII showed only a moderate increase in population density in November of both years, indicative of an autumn pulse in contrast to the late winter maxima in WI . In WIV, on the other hand, a distinct autumn rise was noted (September 1976) while the population passed through the winter with subdued densities showing a slight increase in early spring of March, 1977. However, in the following September, no such autumn swarm was recorded and the population dwindled to negligible numbers, ultimately becoming totally absent during December, 1977. In Fish Dale and Lady Hyderi Park ponds the numbers of this species were very low. From the above account, it appears that S. exspinosus showed the higher numerical density during September to March (i.e, autumn, winter and spring), though not confined to any one of the seasons. It is known that



generally each planktonic species has its own natural history usually with the appearence of one to several peaks (Davis 1955). It may be added that the sudden disappearence of S. exspinosus from WIV is thought to be due to human interference as this part of Ward Lake was completely deweeded during the month of November, 1977, thereby destroying the natural habitat of this species and such effects are also noted byCorni and Strainer (1976). The failure to develop adequate population of this species in the other stations of the present study can be attributed to food (Smyly 1967, Kersting and Leeuw 1976) in addition to absence of suitable substrate in the form of weeds asaalready mentioned.

Fluctuations in the population density of Scapholeberis kingi in different sampling stations have been shown in Fig.29. Though this species is unique in being epineustic (Fryer 1956) and apparently having least competition with other crustacean filtrators, their density was not very high (35 units/l). In WI this species showed its maximum density at the commencement of the autumn season in September, 1977 and 1978. Again, it appeared in moderate density throughout spring till the beginning of winter. The same pattern was seen in WIII while in WIV and Lady Hyderi Park pond their density was poor. This species was well represented in Fish Dale pnnd where in addition to the autumnal maxima slight increase was noted in December showing an early winter pulse. Thus this species

seems to be more in density throughout the autumnal period in all sampling stations (Table-53).

Seasonal fluctuations in the numerical densities of the bosminid, Bosmina longirostris have been depicted in Fig.31. In WI this species showed autumn and winter peaks while in WII only the autumn maxima was well marked. The same was true for WIII while in WIV the winter swarm was distinct after which the population dwindled to negligible numbers. In Lady Hyderi Park pond, again the winter maxima were recorded in 1976 and 1977. However, in the former year, the winter maxima showed two adjacent pulses while in the latter, the higher values were recorded even from the end of November (late autumn) through the winter after which their numbers declined. In Fish Dale pond the trend was different showing higher values during June - July of 1977, although, during February of both 1977 and 1978 also a slight increase was noted. Barring the Fish Dale pond with no definite seasonal pattern, the higher densities in late autumn and early winter in other stations are suggestive of a low temperature preference of this species. Nevertheless, when the temperature reaches still lower levels during January and February (late winter) these organisms probably fail to survive. If the above interpretations are assumed to be correct, the optimum range of temperature for this species could seem to fall between the range of 15° - 20°C. Such a temperature preference was also reported by

Bhajan and Hynes (1972) for B.longirostris to favour better growth, persistance and fecundity. However, Patalas (1956) and Smyly (1957) recorded a spring maxima for B.longirostris, while the winter maxima of the present investigations find a paralled to that of Rylov (1935) for this species.

Chydorus sphaericus was the most dominant in terms of numerical abundance among the chydorid species recorded in different sampling stations (Fig.32). In WI, inspite of this species occurring throughout the study period, September till November recorded higher densities though the peak was in February, 1977, implying both autumn and winter maxima. The same trend was noted in WIII with winter increase continuing through early spring after which the population reaching low densities. More or less the same trend was observed in WIV with the autumn peak much pronounced than that of late winter/spring. In Fish Dale pond the same pattern was seen while in Lady Hyderi Park pond, the peak was reached in November, 1976 (late autumn) followed by a spring maxima with much lower density. Thus C. sphaericus has been found to show distinct autumn pulse with a comparatively low second maxima during the late winter/spring. These findings are in agreement with that of Bernardi and Canali (1975). In the present study, it has been noted that woen when C. sphaericus appeared occasionally in the open water station of Ward Lake, it failed to form substantial

populations, though many workers reported this species in higher densities in the pelagic zooplankton (Reed 1964, Cummins et al 1969, Patalas 1969).

Maximum numerical density of Biapertura affinis was seen in WI of Ward Lake (Fig.33). Numerically this species never formed high density in any of the sampling stations and their seasonal distribution was sporadic. Despite no definite pattern in their seasonal fluctuations, it was seen that their populations showed moderate increase during July till October representing the summer-rainy and autumn seasons. However, their weed association has been evidenced by their extremely poor representation in WII and Fish Dale ponds which were devoid of vegetation.

Seasonal fluctuation pattern of Alonella excisa has been shown in Fig.36 which indicates its dominance in terms of numerical densities during autumn and early winter in WI. In WIII, though their numbers were low, still higher densities were seen during early autumn of 1976 and 1977. In WIV this species exhibited maximum density in September, 1976 and declined subsequently though continued through winter and finally disappeared in February, 1977. In the rest of the period in 1977 no animal was recorded, though in January and February of 1978 were present in very few numbers. In Lady Hyderi Park pond A. excisa had a patchy distribution showing

maximum abundance during June, 1977 which continued till September, 1977 when the density became very low showing a summar maxima in this pond. Thus from this study it can be concluded that though the favourable period of growth of A. excisa is early autumn till middle of winter, a summer maxima is also evident.

The other two species of chydorid, Camptocercus australis and Acroperus harpae appeared in the littoral stations of Ward Lake and Lady Hyderi Park pond. C. australis showed high densities during the winter months in WI, while in WIII, highest value was recorded in November, 1977, with fairly moderate density during winter months also. In WIV, however, C. australis did not show any distinct peak and appeared from September till November of 1976 with low densities. Thus from Fbg. 34 it is apparent thattthis littoral species succeeded well during winter months though late autumn is also likely to have provided favourable conditions. In Acroperus harpae the period of maximum density concided with two distinct seasons namely autumn and spring and it survived well through early summer months both in WI and WIII. On the other hand, in Lady Hyderi Park pond, the population being of very low density no definite pattern could be described (Fig.33).

In order to understand each of the cladoceran species in detail, several parameters were measured based on length frequency analysis from field samples. The length frequencies ultimately indicated different size groups. Of these, except the juveniles (Group-I) , the rest of them were further categorised into famales with and without eggs. Additional information on sex ratio , fecundity and gamogenesis have also been gathered. Due to the lack of adequate literature on size groups of Cladocera elsewhere , for the purpose of comparison the present discussion is mainly confined to the species studied herein in the investigated systems.

Analysis of the population structure of the daphnid species, Simocephalus exspinosus revealed certain distinctive characteristics (Table-62,Fig.37). Group-I which represented juveniles ranged between 0.55 to 0.85 mm beyond which size primiparous individuals were recorded, while from the laboratory studies on the same species (Part-III) it has been shown that the four preadult instars ranged from 0.563 to 1.128 mm in length. It thus show a distinctly larger size at initial maturity in laboratory cultures. Further, during September and October, 1976 as well as in July, 1977 when the population density in the field was particularly high, higher incidence of juveniles (Group-I) occurred in the population as was also reported by George and Edward(1971) for Daphnia hyalina.During the peak

density in September, 1976 only few mature females were seen with empty brood pouch (2%) while the juveniles formed a mean density of 41%. Conversely, when the abundance was very low (2.5 units/l), mature females with empty brood pouch formed 53% of the total count, indicative of reduced reproductive activities ultimately resulting in the decline of the population. In this species, appearence of ephippial mothers were confined to late autumn to early spring with an exception of late winter (February 1977). However, no male was seen during the entire study period. While the absence of males in Cladocera is known in both laboratory cultures (Banta 1914) as well as in field populations (Edmondson 1955, Michal 1962), production of sexual eggs may be due to decline in the food level (Slobodkin 1954), temperature and photoperiod (Stross 1965, 1966) Shan and Frey 1968, Shan 1969, 1970). However, the exact stimulus for production of sexual eggs has yet not been clearly defined for natural populations (Hebert 1974). Further, despite any distinct pattern in the seasonal distribution of different size classes, the annual mean brood size of different size groups revealed Group-V as the most productive (length 1.75 - 2.02 mm). From the laboratory studies on S.exspinosus (Part-III), it is evident that higher number of eggs were produced in the sizes ranging between 1.649- 2.25 mm (7th to 12th instars) though the highest value was recorded at the 10th instar. Thus, the size at which maximum egg/brood

recorded was somewhat similar in both field and laboratory situations. Nevertheless, in the natural populations the mean brood size of Simacephalus exspinosus was found to be 7.16 in contrast to 21.16 obtained from the present laboratory studies which needs to be explained. It is likely that while laboratory rearing of individual specimens was optimal with total absence of any form of intra or interspecific competetion, the field populations had to face the adversities of nature as many biotic and abiotic factors like food (Ingle et al 1937, Brooks 1946, Ryther 1954, Green 1956, Vijverberg 1976), food and crowding (Pratt 1943), oxygen concentration (Fox et al 1951, Green 1966), light (Edlen 1943) as well as the age of mother (Anderson and Jenkins 1942) are known to influence clutch size in Cladocera. The smaller maximum size attained by individuals of field population is also thought to be another character related to food availability. Even the smaller size of this species at maturity referred to earlier could be attributed to any of these factors of which supply of food seems to be a prime factor (Ward and Hebert 1972, Vijverberg 1976), though size regulation through predation pressure cannot be altogether ruled out (Lynch 1980).

Data on the population analysis of the bosminid, Bosmina longirostris have been furnished in Tables-63, 64 and 65. In Station-I of Ward Lake, the maximum incidence of

juveniles (Group I) occurred at the period of high population densities. In this station individuals belonging to Group II to IV made major percentage contribution during the annual cycle, while Group V (0.5 to 0.59 mm) was recorded only during low density periods. The egg/brood in WI varied between 1.96 to 2/brood in different size groups, while the mean annual egg/brood for all sizes was 1.81. In WII, contributions of juveniles varied between 1 to 4% with their occurrence independent of the population density, while the larger animals (Group V) were represented more during the low density periods. In this station the annual mean fecundity was comparatively high than that of WI (1.97/brood). Hence too the population was formed mainly of the members of Groups II to IV (0.23 to 0.50 mm). In Fish Dale pond, on the other hand, occurence of large sized forms were once again restricted to low density periods, though not strictly. The annual mean egg/brood was higher than that of WI of Ward Lake, and fluctuated between 1.92 to 1.98 eggs/brood in different size classes. Age structure of Bosmina longirostris has been studied by Janicki and DeCosta (1977) who emphasized the importance of such studies also in calculating the production/biomass ratio. Further, they pointed out that the incidence of older females in the collections during low population density indicaive of reduced reproductive activities as was also seen in our

present study. Even the appearence of high percentage of non egg-bearing females in all size groups can be attributed to the effect of food as lower levels of food concentration is known to turn the parthenogenetic females into non-reproductive forms (Slobodkin 1954). Thus in the three stations the mean egg number per brood were 1.81, 1.96 and 1.97 for B.longirostris. These findings on egg/brood are in close agreement to those of Bhajan and Hynes (1972). Again, out of the three populations of Bosmina, the one at Station-II of Ward Lake showed a higher egg production rate implying a more favourable niche in the limnetic zone in contrast to WI located close to the shore with a lower mean number of 1.81.

Detailed analysis of the different populations of the chydorid, Chydorus sphaericus and the results obtained are shown in Tables-66, 67, 68 and 69 while data on their length group analysis during different seasons graphically shown in Figs.41, 42, 43 and 44. In WI of Ward Lake the appearence of the members of Group I during September and October, 1976 as well as February and August, 1977 coincided with the relatively high population density with the exception of March, 1977 (Table-66). Even the relative abundance of size Groups-II to IV coincided with their numerical densities. Again when a comparison of the occurrence of animals with and without eggs was made it was seen that incidence of ovigerous

mothers were correlated with higher density of the population while the lower value of 1.98 eggs/brood recorded for Group-III (0.27 to 0.31 mm) in January, 1977 coincided with lower density in the field population. Unlike in B. longirostris the larger animals of the present species (0.37 to 0.41 mm), were recorded during higher field density (September and October 1976) probably suggestive of optimal environmental conditions, although their occurrence in February finds a parallel to the appearence of large forms as overwintering populations (Keen 1976). In WIII of Ward Lake, more or less a similar picture was obtained for C. sphaericus though during the highest field density of 45 animals/l, not even a single member of Group I was present among the 100 animals analysed. However, barring this exception, generally juveniles did appear during high population densities as was also seen in WI. The apparently reduced rate of egg production was recorded twice during the annual cycle at this station, one coinciding with lower field density while the other when the field population was moderately higher (12 animals/l). Members of Group-VI (0.42 to 0.56 mm) was recorded in this station both during lower and higher population densities as that of WI. Again, with the exception of April, 1977 when numbers/litre were particularly low, mature females with eggs formed about 80% of the total population in the 12 months study comparable to that of Station-WI. In Statioh-IV of Ward Lake as well as Lady Hyderi Park pond, though no

definite seasonal trend in the frequency occurrence of size groups could be obtained, synchrony of juveniles and older females with high population densities were seen. Thus, the high occurrence of gravid mothers during high density period in this station was in conformity with the findings in other stations. However, occasionally individuals with just 1 egg/brood were also noted.

Thus in all the four sampling stations, populations of Chydorus sphaericus mostly consisted of animals ranging in length between 0.21 to 0.41 mm representing Group-II to Group-V during the present studies. It may, therefore, be concluded that in C. sphaericus high population density generally coincides with greater incidence of gravid females. Similarly, incidence of juvenile is generally linked with higher population density evidently coinciding with a higher rate of reproduction. However, the acceptional appearence of larger individuals during lower population densities may be attributed to the declinging trend of the population. The occasional reduced egg number of 1/brood as against the normal of 2/brood may be due to insufficient food availability as it is well known that fecundity of most cladoceran species is related to their nutritional status (Brooks 1946, Green 1956, Hebert and Ward 1972, Vijverberg 1976).

Though Pleuroxis similis occurred in most of the

collection sites, the only population which lent itself for detailed analysis was that of Station-III of Ward Lake (Table-70, Fig.45). Even then except for January and February, 1977, size group analysis of this species was based on less than 40 animals. Incidence of nongravid females was more in this species and even in the peak density period more than 28% of the total was formed by females with empty brood pouch. The other difference was that the juveniles were recorded when the total population density was insignificant. Further, the mean egg/brood was always 2 in this species irrespective of the differences in size groups. This is suggestive of a relatively stable clutch size in this species even when the population density was insignificant though as pointed out earlier, different biotic and abiotic factors are known to influence fecundity in Cladocera (McArther and Baillie 1929, Brooks 1946, Green 1956, 1966, Vijverberg 1976). In this species, maximum contribution was from the large sized Groups of III to V ranging between 0.58 to 0.90 mm. Again, appearence of more numbers of older individuals (Group-V) during low density periods as seen in Chydorus sphaericus was not the case with Pleuroxus similis. Length group analysis on Acroperus harpae was made from the populations obtained both in WI and WIII of Ward Lake (Table-71, Fig.46). The WI population resembled Chydorus sphaericus in having high numbers of juveniles during high population density suggesting active recruitment

to the population build up. The record of seven empippial females among the 100 animals counted in March, 1977 is of significance as no male was seen at any time of the population analysis. Such ephippial incidence without males in cladoceran populations have been reported by earlier investigators (Apstein 1907, Brook and Rzoska 1954, Byars 1960, Michael 1962). In this connection it may be said that though Brehm (1953) held the view that gamogenetic generation will not be found normally in the absence of males. Edmondson (1955) showed in Daphnia middendorffiana that ephippial eggs can still be produced , though not fertilised. It has also been pointed out recently that sex determination in Cladocera is apparently environmental (Hebert and Ward 1972). Further, in the present study these ephippial mothers of A. harpae occurred during the time of high percentage of females with empty brood pouch (72% of the total population), showing thereby a relatively unfavourable environment. It is now well known that atleast under laboratory conditions production of resting eggs are influenced by several factors such as food, temperature, photoperiod and crowding of mothers (Banta and Brown 1929, Pennak 1953, Edmondson 1955, Davison 1969, Shan and Frey 1968, Shan 1969, 1970) which are also likely to operate under field conditions.

In WIII, on the other hand, out of the three months in which juveniles of A. harpae were recorded, two occasions

coincided with insignificant field total density of this species. As such, incidence of more number of juveniles, though indicative of active reproduction, does not necessarily suggest a corresponding higher population density as factors like predatory pressure among many others are already known to regulate cladoceran communities (Dodson and Brooks 1965, Green 1969, Dodson 1974, Lynch 1980). Furthermore, both in WI and WIII more number of larger females of this species were recorded during periods of relatively high numerical abundance as was also the situation in Chydorus sphaericus in most stations. Fecundity of the above mentioned populations of Acroperus harpae varied between 1.93 to 2 eggs/brood though in majority of the months studied less than 2 eggs/brood was seen, thought to be directly related with fluctuations in nutritional levels in the habitat (Hebert 1974, Redfield, 1980).

In Alonella excisa, the general pattern of population structure was similar to that of other chydorids. The abundance of juvenile instars in this species did not follow any set pattern in the three populations of WI and WIII of Ward Lake and Lady Hyderi Park pond as also seen in Acroperus harpae. Percentage contribution of non ovigerous females in this species were generally more during seasons of low population density which is similar to the findings on other chydorid species discussed above. Though this species appeared

in varying densities with their number at times being negligible, exhibited a remarkably constant egg number in all size groups. When compared with the present laboratory findings on Alonella excisa (Part-III), the initial length of the juveniles in the field as found to be much smaller (0.22 - 0.26 mm) to that of laboratory individuals (0.303 -0.376 mm). Again, the maximum size recorded in the laboratory was 0.612 mm in contrast to 0.57 mm recorded from the field samples. Such differences are suggestive of a smaller size at maturity in nature brought about, among several other factors mostly by differences in food and temperature (McArthur and Baillie 1929, Vijverberg 1976). It is of interest to note that Green (1966) had already suggested that in warmer water, greater number of smaller eggs are produced to ensure greater rate of population growth, as small sized eggs are known to result in smaller sized embryos (Steele and Steele 1975). Further, relatively lower maximum length attained by the field animals might have been also the result of availability of food as both quality and quantity of food is known to effect growth in Cladocera (Vijverberg 1976).

Recently Lynch (1980), while reviewing the evolution of life history patterns of Cladocera in general opined that small sized cladoceran species, though remain vulnerable to invertebrate predation, produce larger offsprings which

mature at an early stage thereby reducing juvenile mortality. However, though this might explain the smaller size of Alonella excisa at maturity under field conditions, no such predation data is available from the present study to substantiate the above opinion. Further, as detailed in Part-III, in the laboratory culture some individuals of Alonella excisa were seen to pass through few non-reproductive instars, under the same feeding regimes as the rest of the culture which showed active reproduction and growth. This phenomenon may also explain the presence of females with empty brood pouch even when the field population is otherwise active and growing. Such occurrence of non ovigerous adult females in the present species as also seen in the other chydorids discussed above might be true for chydorids in general which are thought to have a similar life cycle pattern as viewed by Shan (1969).

In a very recent review, an analysis of data from seventy different workers had been made by Lynch (1980) who summarised the life history strategies in various cladoceran species. Based on both field and laboratory information gathered on all the present species, a comparison has been made with the Summary Table of Lynch (1980). It is apparent that Simocephalus exspinosus in the present study has a smaller maximum size with a larger brood size as compared to other reports. This smaller initial size and as well as smaller clutch

Table-80a : Comparison of the life history parameters of different cladeceran species.

Species	Habit	*Min. size (mm)	*Max. size (mm)	Mean Egg/ brood	*Max. clutch size	Most productive size/ size range	Source
Simocephalus exspinosus	Littoral	-	3.50	-	25.00	-	Lynch (1980)
		0.56	2.40	21.16	38.40	2.07	Present lab. study
		0.55	2.02	7.16	18.00	1.75-2.02	Present field study
Bosmina longirostris	Planktonic	0.23	0.52	-	15.00	-	Lynch (1980)
		0.18	0.59	1.98	2.00	-	Present field study
Alonella excisa	Littoral	0.30	0.61	-	2.00	-	Present lab. study
		0.22	0.57	2.00	2.00	-	Present field study
Acroperus harpae	Littoral	-	1.00	-	-	-	Lynch (1980)
		0.30	0.98	-	2.00	-	Present field study
Pleuroxus similis	Littoral	0.40	0.90	-	2.00	-	Present field study
P.aduncus	Littoral	0.36	0.66	-	-	-	Lynch (1980)
Chydorus sphaericus	Littoral	0.22	0.60	-	2.00	-	Lynch (1980)
		0.19	0.56	-	2.00	-	Present field study

*Min. - Minimum; * Max. - Maximum

size in S. exspinosus seen in the present study reveals the descripancies even for the same species from region to region. These are thought to be due to differences in the geographical localities with differing food, temperature and other regimes. Such differences have already been pointed out and discussed in Bosmina longirostris. These findings at-least partially answer the generalised question raised by Frey (1967) whether widespread eurytopic species are in reality a collection of smaller geographic populations with different ecologies and physiologies. The mean brood size of B. longirostris as computed in the present lake and ponds while closely similar to the findings of Bhajan and Hynes (1972), the maximum brood size of eggs is far below the upper limit of 15 eggs reported for this species in the above review (Table-80a). On the other hand most of the comparative data provided for the present chydorid species in the same Table suggest the apparent similarity of chydorid life histories even in different geographic locations.

Thus from the above discussions it may be concluded that the daphnid Simocephalus exspinosus had more or less a similar growth pattern both under field and laboratory conditions, though variations in brood and body size existed. On the other hand, all the species of chydorids, exhibited some degree of overall similarity in their population

structure though with the following differences. Both Acroperus harpae and C. sphaericus showed minor variations in relation to egg numbers, while Pleuroxus similis and Alonella excisa had a constant number of 2 eggs/brood even when their field density was poor. Thus in terms of reproductive potential there seems to exist two categories among the present chydorid assemblage, one showing slight variations in egg number (Chydorus sphaericus and Acroperus harpae) while the other with constant egg number apparently not influenced by changes in the environmental conditions. Pleuroxus similis and Alonella excisa fall into this latter group. However, it may be added that though the observed variations in mean egg numbers of the former group range only in negligible fractions, it may still be of significance in view of the constancy of 2 eggs/brood known for most of the smaller chydorid species.

PART-II

SUMMARY

Detailed investigations on the hydrobiological conditions and cladoceran fauna were carried out on three selected habitats for a period of 18 months at weekly intervals. This study was aimed at gaining insight into the biology of different cladoceran species under natural conditions. These study impoundments situated at an altitude of 1600 m, within the Shillong city, were Ward Lake, the largest and deepest among the Shillong systems, Fish Dale pond and Lady Hyderi park pond. These impoundments showed variation in size, shape, depth and vegetation. Further, while Ward Lake is for recreational purpose and stocked with common carps, Fish Dale pond is a nursery pond and Lady Hyderi park pond is used for maintaining aquatic birds within a children's park. A total of six sampling stations were established, four of them in Ward Lake while the other two smaller ponds each treated as a single sampling station.

Studies on the morphometry and associated vegetation showed differences among these ponds. The ranges of values obtained on the physicochemical properties in these systems were similar to those of other impoundments of Shillong surveyed at two monthly intervals. Thus these three impoundments were also characterised by low values of pH, conductivity, alkalinity as well as silicates. On the other hand moderately higher values of phosphate and nitrate were recorded. However, differences in the physicochemical properties were noted between the different sampling stations.

Seasonal variation in temperature followed the same trend in all stations while pH values ranged between 6 and 7 in five out of the six stations. In Lady Hyderi park pond the pH value was relatively lower. Except for station IV of Ward Lake with slightly higher values, conductivity readings ranged between 30-100 umhos/cm. The sharp increase in conductivity values on certain occasions have been discussed. In Lady Hyderi park pond a higher carbon dioxide value was recorded coinciding with lower densities of algae. Only bicarbonate alkalinity was recorded in all stations with the exception of a single instance. These values were lower in comparison to other aquatic systems of India. Phosphates and nitrates were moderately higher in their concentration while the amount of silicate was low in all stations.

Higher phytoplankton densities were recorded during October, November and February in all four stations of Ward Lake, while lowest density was seen in Lady Hyderi park pond. The major phytoplankton groups recorded were Myxophyceae, Chlorophyceae, Dinophyceae, Chrysophyceae and Bacillariophyceae. Variations in the seasonal abundance of different groups were noted in different sampling stations, and thus Myxophyceae and Chlorophyceae dominated in stations I, II and III of Ward Lake, while in station IV Bacillariophyceae and Chlorophyceae were more. In Lady Hyderi park pond also the same was the case. Besides, in Fish Dale pond Chlorophyceae formed the bulk.

Maximum abundance of zooplankton was seen in station IV of Ward Lake while the least was in Fish Dale pond. Differences were noticed in the seasonal fluctuations of zooplanktonic groups and causes discussed.

Based on the phytoplankton community structure the degree of pollution was assessed. Thus two out of the three impoundments fall under moderate level of organic pollution while the third under low pollution. Also, differences were noted in the degree of pollution even between the stations of the same system.

A total of 19 cladoceran species was recorded during the present study. In Ward Lake alone a total of 18 species were seen, while in Fish Dale and Lady Hyderi park ponds, the numbers were 7 and 9 respectively. The chydorid cladoceran were mostly associated with the littoral vegetation. In terms of diversity, more species were recorded in the largest system as compared to others.

In addition to their presence in the littoral zone, Chydorus sphaericus was also seen in the limnetic stations. The occasional appearence of other chydorids in ponds completely devoid of vegetation, however, seemed to be due to migration aided by wind action as well as through diverted inflow of water. Though higher similarity index values were recorded for the different stations irrespective of systems, gross differences in the total species number of Cladocera existed between the three impoundments.

Seasonal distribution of cladoceran species showed variations among different stations. While the two Sididae species were patchy in distribution, the only dominant daphnid species, Simocephalus exspinosus was found mostly associated with a particular weed throughout the seasons. Scapholeberis Kingi , the epineustic species appeared in all of the three systems. The two species of Daphnia , Ceriodaphnia cornuta as well as Moina micrura had restricted occurrence during the annual cycle. Bosmina longirostris appeared in most stations during the greater part of the seasons. Among the chydorids, Chydorus sphaericus had a continuous distribution throughout the study period while other chydorids exhibited seasonality in their occurrence.

Numerical density of different species showed variations during the 18 months study in different stations. Though a certain degree of similarity existed in the seasonal abundance in different stations, a number of dissimilarities were also noted and discussed.

Dominance of chydorid Cladocera was well marked in littoral stations and seemed to be causally related to the vegetation. On the other hand, species belonging to Daphnidae, Moinidae and Bosminidae were well represented in the limnetic regions in conformity with the planktonic habit of a majority of them. Further, nonoccurrence of more than one species of the same genus was usually noted and when more than one species appeared, one dominated

numerically.

Results on the size group analysis of one daphnid species, one bosminid and four chydorid species have been presented. The daphnid species, Simocephalus exspinosus exhibited some similarity to the same species cultured under laboratory conditions. The field specimens, however, showed lower number of eggs/brood and had a smaller maximum size. Size groups did not exhibit any seasonal pattern though larger forms appeared in the populations during low density periods while the juveniles were generally more during high field density. Non egg bearing as well as ephippial mothers were also recorded, though no males were seen. Both in the bosminid and the chydorid species, the same trend was noted. In addition, incidence of more number of females with empty brood pouch was recorded during low population density periods. Further, in two out of the four chydorid species, slight variations in mean fecundity value were recorded while in the other two, a constant number of 2 eggs/brood were seen. These findings have been compared with recently published reports and the salient differences discussed.

PART-III

LABORATORY LIFE CYCLE STUDIES OF DIFFERENT CLADOCERAN SPECIES

PART-III

INTRODUCTION

The planktonic crustacean filter feeders play a major role in the secondary productivity of freshwater ecosystems. Most of these animals are primary consumers, directly utilising the primary production and hence decide to a large extent the nature of energy flow in ecosystems (Weglenska 1971) since they influence the primary links in food chain. Further, among these Crustacea, the group Cladocera is well known to form the food of fishes for both adult and fry (Alikunhi 1952, Welch 1952, Pennak 1953, Vaas and Van-Oven 1959, Michael 1962, Navaneethakrishnan and Michael 1971, Vijayaraghavan 1970). Thus proper understanding of the basic life parameters of Cladocera are of primary importance to obtain an insight into their biology under natural conditions. These realisations have prompted many workers to make a comparative study of laboratory and field life histories of Cladocera (Green 1956, Korinek 1970, Bhajan and Hynes 1972, Bottrell 1975, 1975a, Vijverberg 1976). In India too, studies in this direction were started in the early sixties (Michael 1962) followed by a few studies in subsequent years (Parabrahmam et al 1967, Vijayaraghavan 1970). However, in recent years a number of studies were conducted on the life history patterns of cladoceran species from the tropical plains of India, confined mostly to the lower latitudes (Navaneethakrishnan and Michael 1971, Murugan and Sivaramakrishnan 1973, 1976, Murugan 1975, 1975a. Unfortunately, no attempt has been made so far to study the life cycles of Cladocera at the relatively higher latitude where subtropical conditions are obtained, particularly so in the altitudinal hill

regions of North-Eastern India. Further, under Indian conditions, among the members of different families of Cladocera barring the daphnids and moinids, the life cycle patterns are not worked out in other families, especially in the largest group of chydorid Cladocera. Even, on a worldwide basis the life history studies on chydorids are just being worked out as reviewed by Shan (1969), who studied the detailed life history of *Pleuroxus denticulatus* and suggested a probable general pattern in the life history of chydorids. In addition, our knowledge on the life history of the males of Cladocera in general are still meagre, as compared to that of the parthenogenetic females, noteworthy works being those of McArther and Baillie (1929) and Lei and Clifford (1974) on the male life cycles.

Taking into account the foregoing facts, an attempt has been made here to study the life cycle details of few selected cladoceran species representative of the families, Daphnidae, Moinidae, and Chydoridae under the present subtropical climatic conditions (*vide infra*, Part-I). Thus laboratory life cycle studies were conducted on the male and female of *Daphnia lumholtzi*, females of *Simocephalus exspinosus*, *Moina micrura* and *Alonella excisa* and the results discussed.

PART-III

MATERIAL AND METHODS

Three of the four species for the present study had been collected from the plankton of Ward Lake. The species Moina micrura was collected from a small pond at New Colony locality of Shillong (Fig.2, System-III). A plankton net fabricated out of No.25 xxx bolting silk was used for this purpose. On return to the laboratory, the samples were transferred to a glass trough of 3 l capacity. Cladoceran species were picked out with the help of a wide-mouthed glass pippette and the particular species to be studied were sorted out. The gravid females of each species were isolated and placed in petri-dishes of 2.5 cm diameter with filtered pond water as the culture medium. Subsequently the freshly hatched first instar neonatae were collected from these dishes and each of them was reared separately in similar sized dishes. Usually the events during the entire life cycle were traced in 30 to 50 animals for each species and the mean of the data were computed.However, only 15 to 20 males could be reared for Daphnia lumholtzi.Pond water, after removal of net plankton was used as the culture medium. Water was changed every day. A soft brush was used for cleaning the rearing dishes. A cloth net mounted on a wire frame served as a cover for the dishes in order to avoid scum formation due to the dust particles falling on the water surface. All the measurements of the different life cycle parameters were obtained using a compound microscope. The life cycles of species studied were Simocephalus exspinosus and Daphnia lumholtzi belonging to family Daphnidae; Moina micrura of family Moinidae and Alonella excisa under family Chydoridae.

The length measurements of both the parthenogenetic females and males of Daphnia lumholtzi were made as shown in Fig.5[illegible] . The anterior and posterior spines were not included. This measurement from the base of the posterior (Caudal) spine to the base of the head spine (helmet) corresponds to the 'total length' of Anderson (1932), the 'length' of Edmondson (1955) and the body length of Lei and Clifford (1974). For Simocephalus exspinosus, Moina micrura and Alonella excisa length measurements were made from the tip of head to the base of the carapace for each species as shown separately in Fig. . Length was measured using an ocular micrometer under a compound microscope. All the illustrations were made using a Camera lucida.

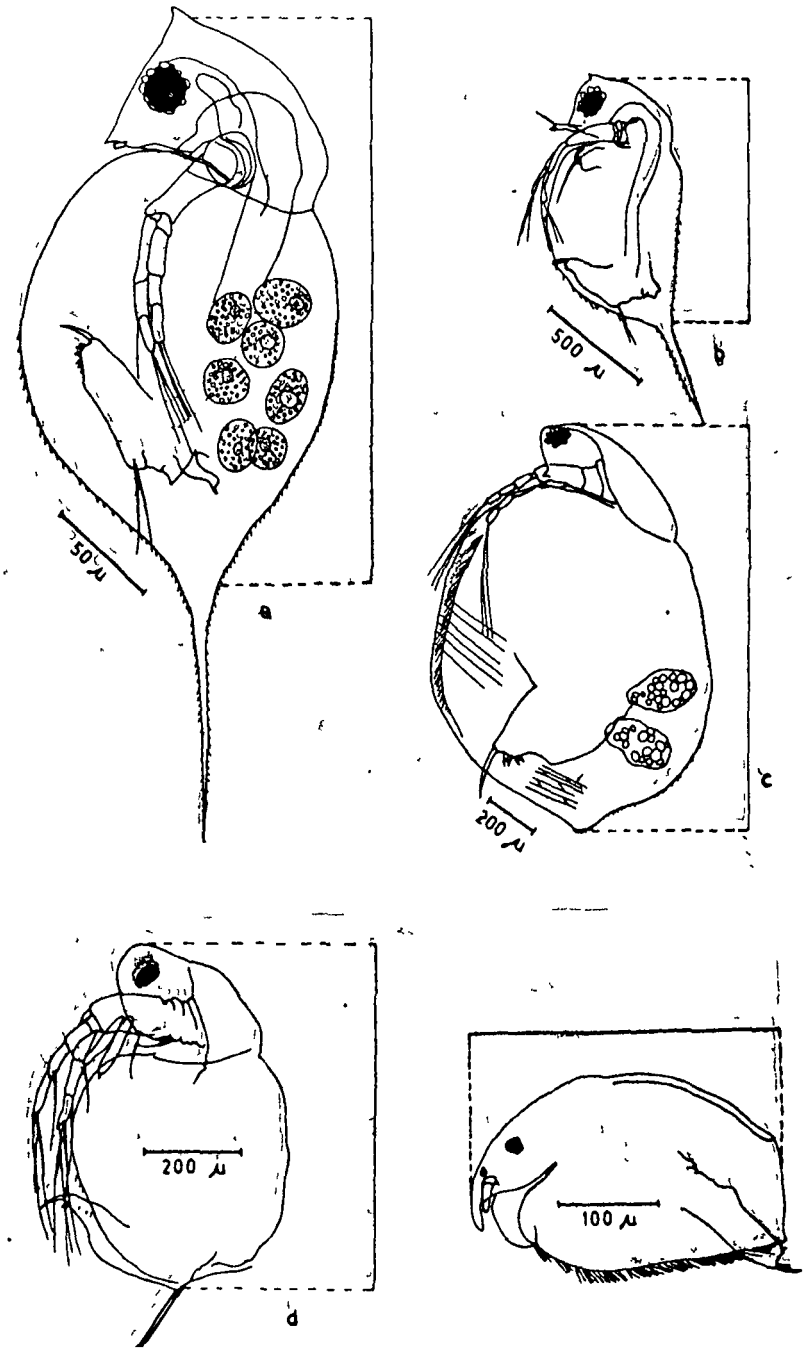
Rate of egg production in the species investigated was calculated by plotting the cumulative frequency of eggs against the number of adult instars. The slope of the regression line (a value) gives a measure of the rate of egg production (Navaneethakrishnan and Michael 1971). Thus the equation of the straight line fitted is $Y = ax + b$, where x denotes the number of adult instars and y denotes the cumulative number of eggs, while 'a' and 'b' are constants and 'a' gives a direct measure of the rate of egg production (Navaneethakrishnan and Michael 1971).

Fig.51

Showing length measurements of :

a. Daphnia lumholtzi (female)
b. Daphnia lumholtzi (male)
c. Simocephalus exspinosus
d. Moina micrura
e. Alonella excisa

Fig. 51



PART-III

RESULTS

LIFE CYCLE

Daphnia lumholtzi (female)
Daphina lumholtzi (male)
Simocephalus exspinosus
Moina micrura
Alonella excisa

Life cycle of Daphnia lumholtzi Sars:

Parthenogenetic female : The various life cycle parameters of the parthenogenetic female of Daphnia lumholtzi have been furnished in Table-80. It will be seen that the freshly born neonata measured 0.637 mm in length which matured after 4 moults. The primiparous female measured 1.350 mm long and reached the maximum length of 1.954 mm in the 14th instar and failed to show any further size increment in the 15th instar after which death occurred. The length at different instars is shown in Fig.52. Thus, under laboratory conditions the total life span recorded was 775.13 hours (32.30 days) at 22°to 26°C. Animals became mature at the age of about 144 hours or at the 6th day. There was considerable variations in the duration of instars with the adult instars distinctly longer than the preadult instars. Variations in the duration of the 4 preadult instars ranged between 30.49 to 38.79 hours while the adult instars varied between 42.58 to 66.46 hours. However, 14th or the penultimate instar was the longest with 66.46 hours duration. The total number of eggs produced during a life time of 32.30 days was 51.09. Highest number of eggs per brood was recorded at the 8th or the 4th adult instar (7.29/brood), while the lowest value was 1.75 eggs per brood in 15th instar (11th adult instar). In Fig.53 fecundity and duration of different instars have been plotted against the age of the females

Table-81 :Showing the different life cycle parameters of female Daphnia lumholtzi studied under laboratory conditions.

Instar	Mean length (mm)	Eggs/brood (No.)	Cumulative No. of eggs	Duration of instar (Hr.)	Cumulative duration of instar (Hr.)
1	0.637	-	-	30.49	30.49
2	0.770	-	-	36.00	66.49
3	0.911	-	-	38.06	104.55
4	1.094	-	-	38.71	143.26
5	1.350	4.44	4.44	42.58	185.84
6	1.549	4.48	8.92	49.66	235.50
7	1.638	6.68	15.66	52.89	288.39
8	1.735	7.29	22.89	57.50	345.89
9	1.768	5.42	28.31	55.15	401.06
10	1.816	4.90	33.21	58.72	459.76
11	1.857	5.38	38.54	61.64	521.40
12	1.895	4.63	43.27	61.46	582.86
13	1.922	3.79	47.01	61.20	644.06
14	1.954	2.33	49.34	66.46	710.52
15	1.954	1.75	51.09	64.81	775.13

Table-82: Showing the different life cycle parameters of male Daphnia lumholtzi studied under laboratory conditions.

Instar	Mean length (mm)	Duration of instar (Hr.)	Cumulative duration of instar (Hr.)
1	0.582	34.29	34.29
2	0.728	43.02	77.31
3	0.786	52.80	130.11
4	0.900	37.71	167.82
5	0.972	37.71	205.53
6	1.072	54.86	260.53
7	1.115	49.71	310.10
8	1.272	51.43	361.53
9	1.327	60.00	421.53
10	1.384	54.86	476.39
11	1.406	65.14	541.53
12	1.451	66.60	608.39

Fig.52

Showing changes in the length of the parthenogenetic female of Daphnia lumholtzi during different instars.

Fig.52

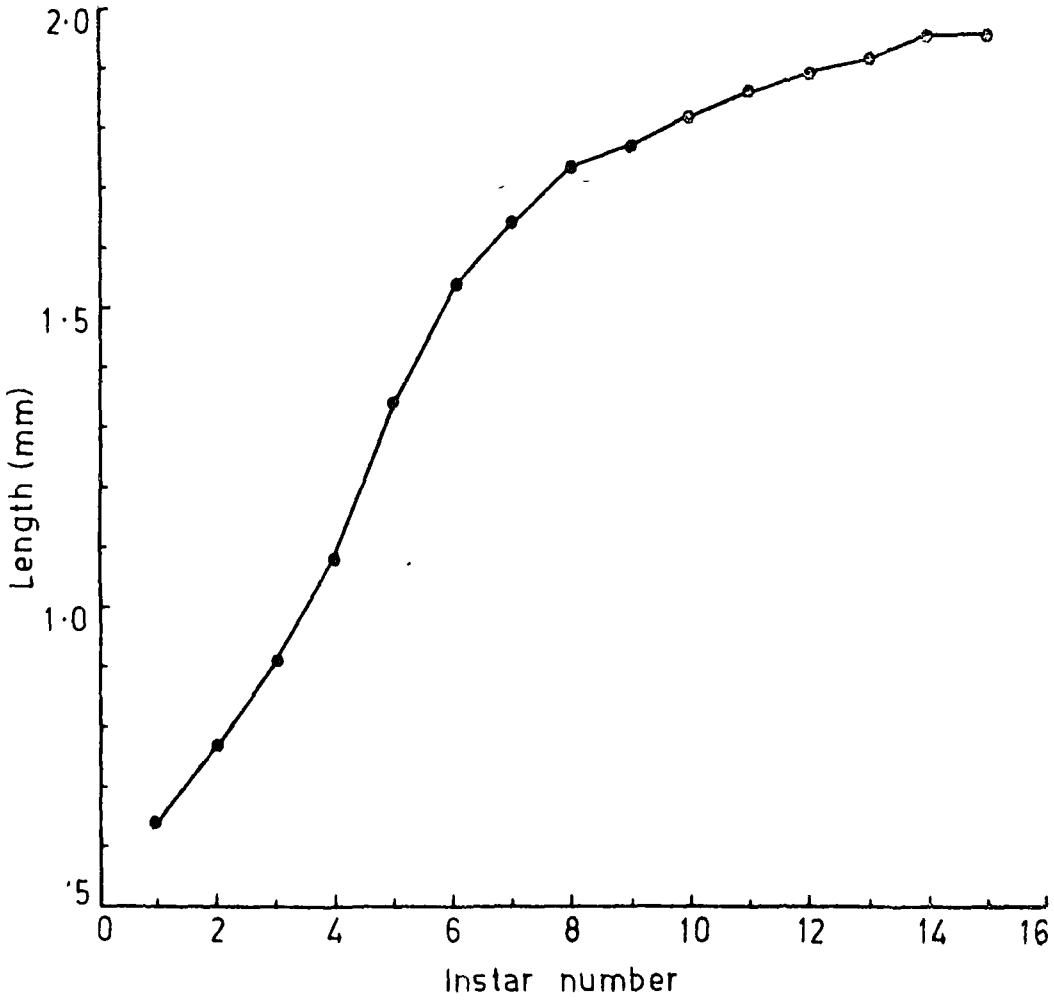


Fig.53

Showing number of egg/brood , age and number and duration of instar in the parthenogenetic female of Daphnia lumholtzi.

Fig.53

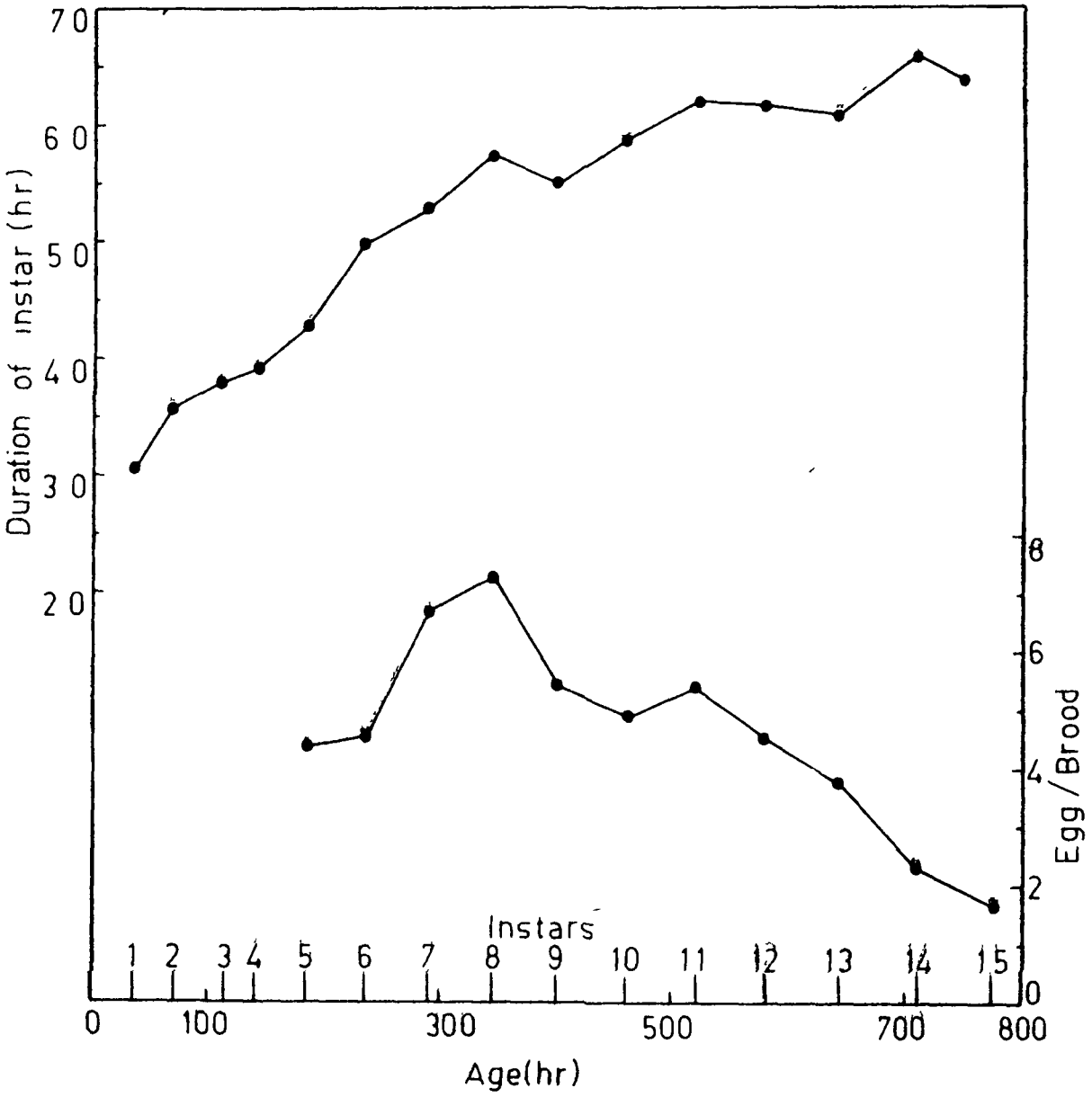

Duration of instar (hr)
70
60
50
40
30
20
Egg / Brood
8
6
4
2
0
Instars
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0
100
300
500
700
800
Age(hr)

Fig.54

Rate of egg production of Daphnia lumholtzi.

Fig.54

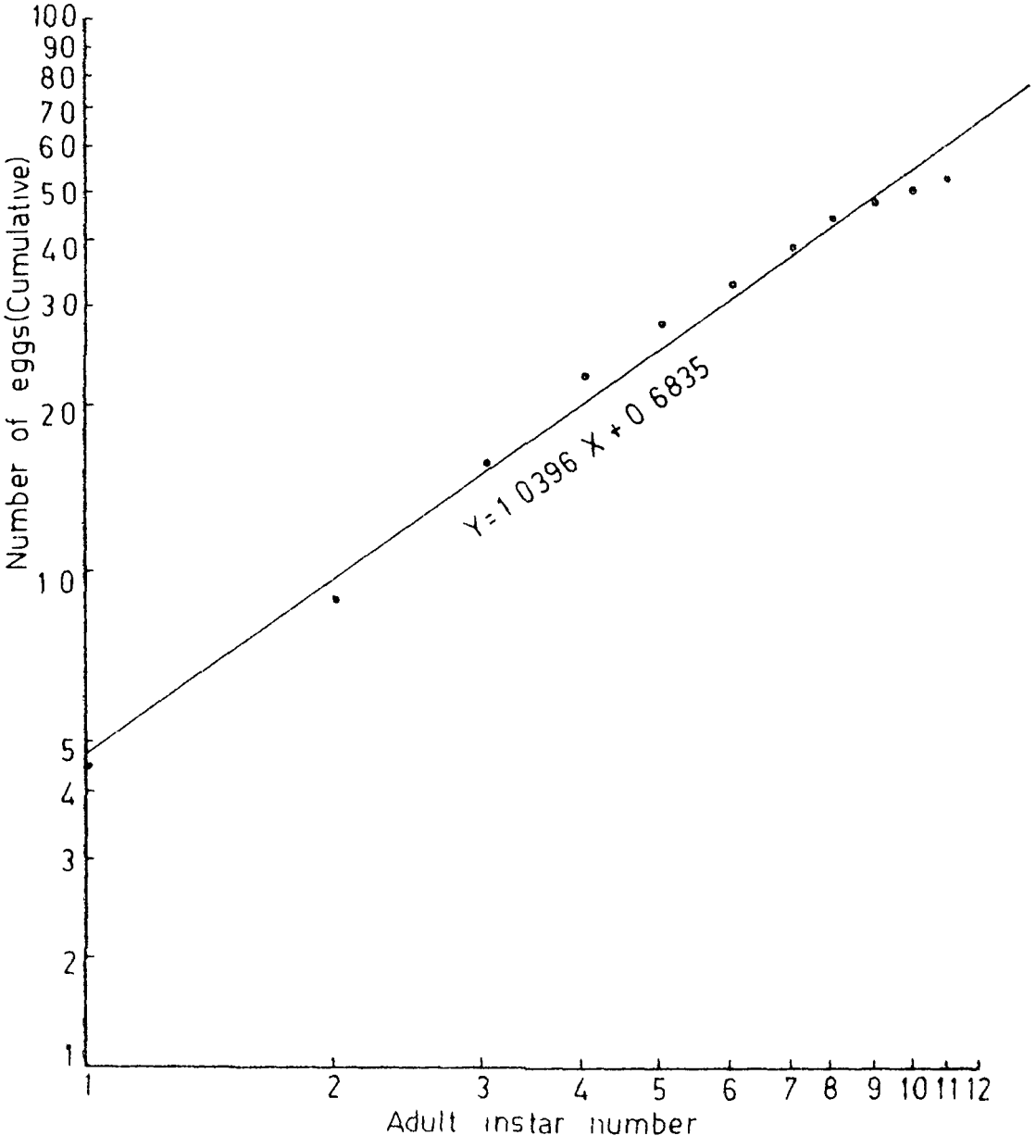

Number of eggs(Cumulative)
100
90
80
70
60
50
40
30
20
10
5
4
3
2
1
Y=1 0396 X + 0 6835
1
2
3
4
5
6
7
8
9
10
11
12
Adult instar number

Fig.55

Showing changes in the length of the male Daphnia lumholtzi during different instar.

Fig.55

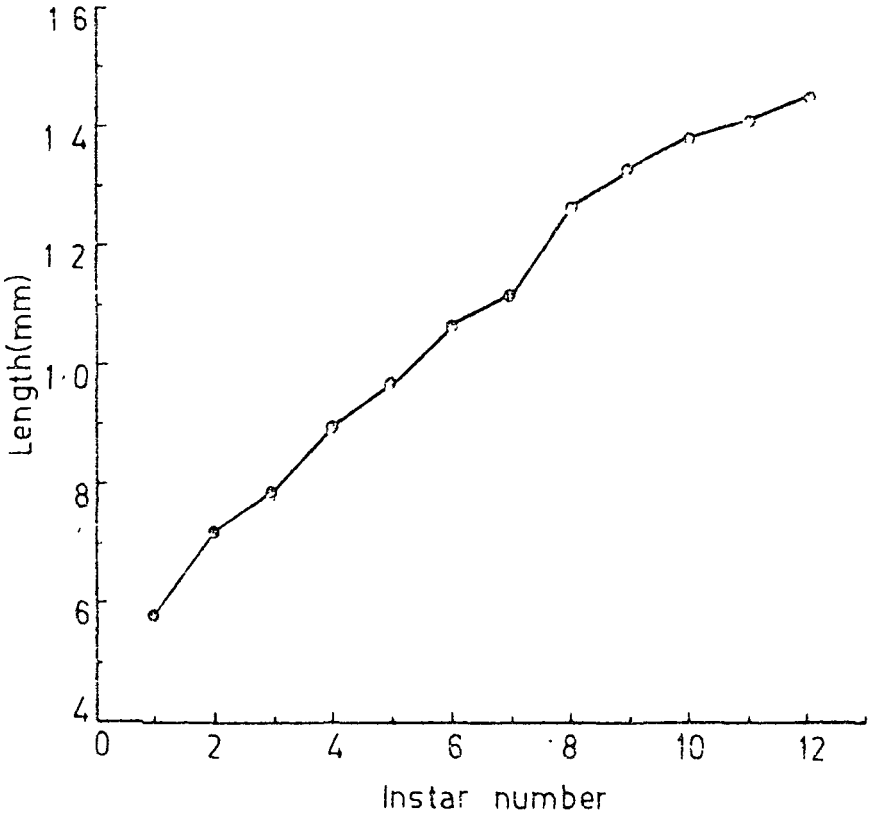
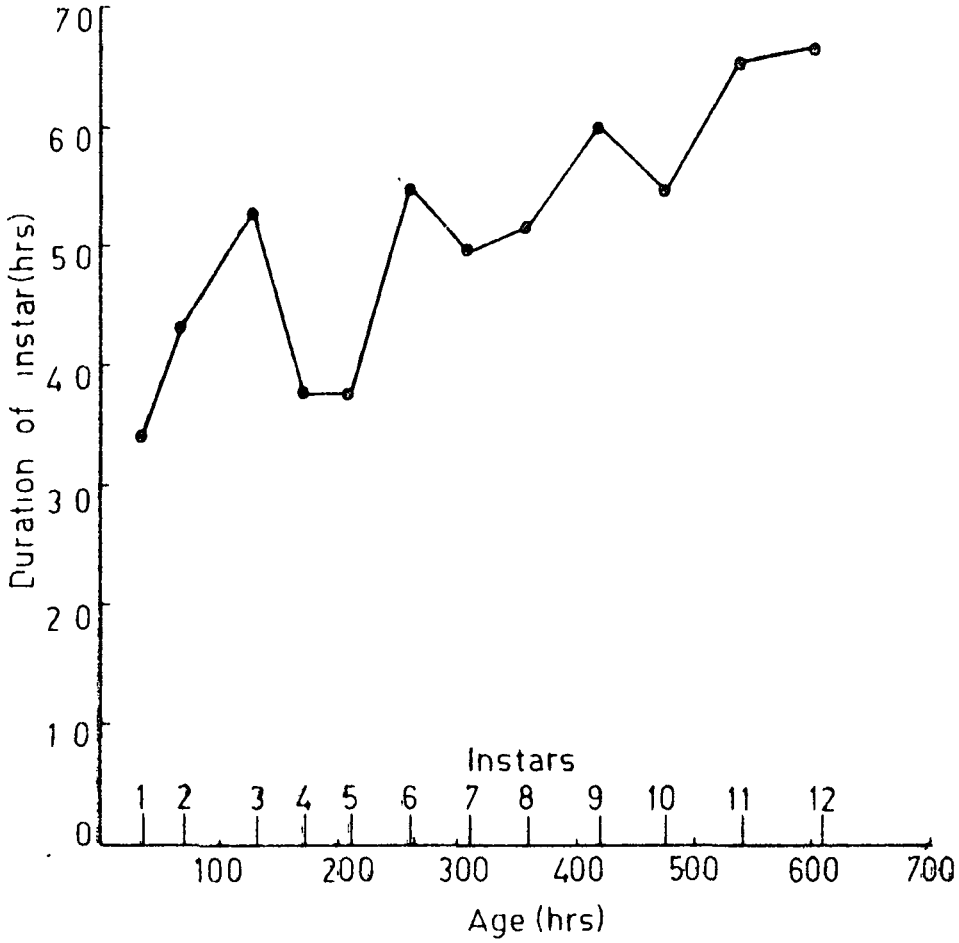


Fig.56

Duration of instars in the male of Daphnia lumholtzi.

Fig.56


70
60
50
40
30
20
10
0
Duration of instar(hrs)
Instars
1 2 3 4 5 6 7 8 9 10 11 12
100 200 300 400 500 600 700
Age (hrs)

under study. The cumulative frequency of eggs in different adult instars had been plotted in Fig.54 and the angle of slope (a value) of the fitted curve was found to be , a = 1.0396. Among the 30 females reared, only one of them produced 5 ephippia following the parthenogenetic cycle.

Male : The total life-span, number of instars and their duration of the males of Daphnia lumholtzi have been given in Table-81 and Figs. 55 and 56. The individual male underwent a total of 12 instars in its life cycle and survived 608.29 hours (25.35 days) at a laboratory temperature range of 22° to 26°C. Length of the 1st instar juvenile was 0.582 mm while the maximum length recorded was 1.451 mm at the 12th instar. Unlike in the parthenogenetic female, the last male instar showed increment in length. The durations of different instars were highly variable and ranged between 34.29 to 66.60 hours, though the last 2 instars (11th and 12th) were distinctly longer than the others.

Life cycle of Simocephalus exspinosus (Koch) :

The life cycle of the parthenogenetic female of Simocephalus exspinosus included 16 instars of which 4 were preadult while the remaining 12 were adult instars. In Table-82 the different life cycle parameters recorded at a temperature range of 18° to 26°C are represented. Under laboratory

conditions the mean total life-span of this animal was found to be 946.64 hours (40.61 days) of which the 4 immature instars shared a total of 151.92 hours (6.33 days) and the remaining was spent during the adult instars (Fig.57). The freshly hatched neonata measured 0.563 mm which gradully increased to reach the maximum length of 2.40 mm at the 15th instar. The last instar did not show any further increment in length. The first adult instar (5th instar), at which the animals became primiparous measured 1.312 mm. The duration of different instars and the number of eggs per brood have been depicted in Fig.58 against the age of the animal. The total number of parthenogenetic eggs produced during the life-span of 40.61 days was 253.88. Instar 10 or the 6th adult instar had the highest number of eggs while the penultimate instar also showed another rise in egg numbers. Thus the eggs per female ranged from a minimum of 5.92 to a maximum of 38.04 and showed a distinct bimodality. Duration of different instars ranged between 35.04 to 78.72 hours. Of these, adult instars ranged betwen 60.00 to 78.72 hours while the 4 preadult instars showed a duration limit ranging between 35.04 to 56.16 hours with the highest duration at 10th instar (6th adult instar) while the lowest was that of 2nd instar with 35.04 hours. The rate of egg production was found to have an $\underline{a}$ value of 1.5883 with the equation of the fitted curve being $Y = 1.5883\ X + 0.7878$ (Fig.59).

Fig.57

Showing changes in the length of Simocephalus exspinosus during different instars.

Fig. 57

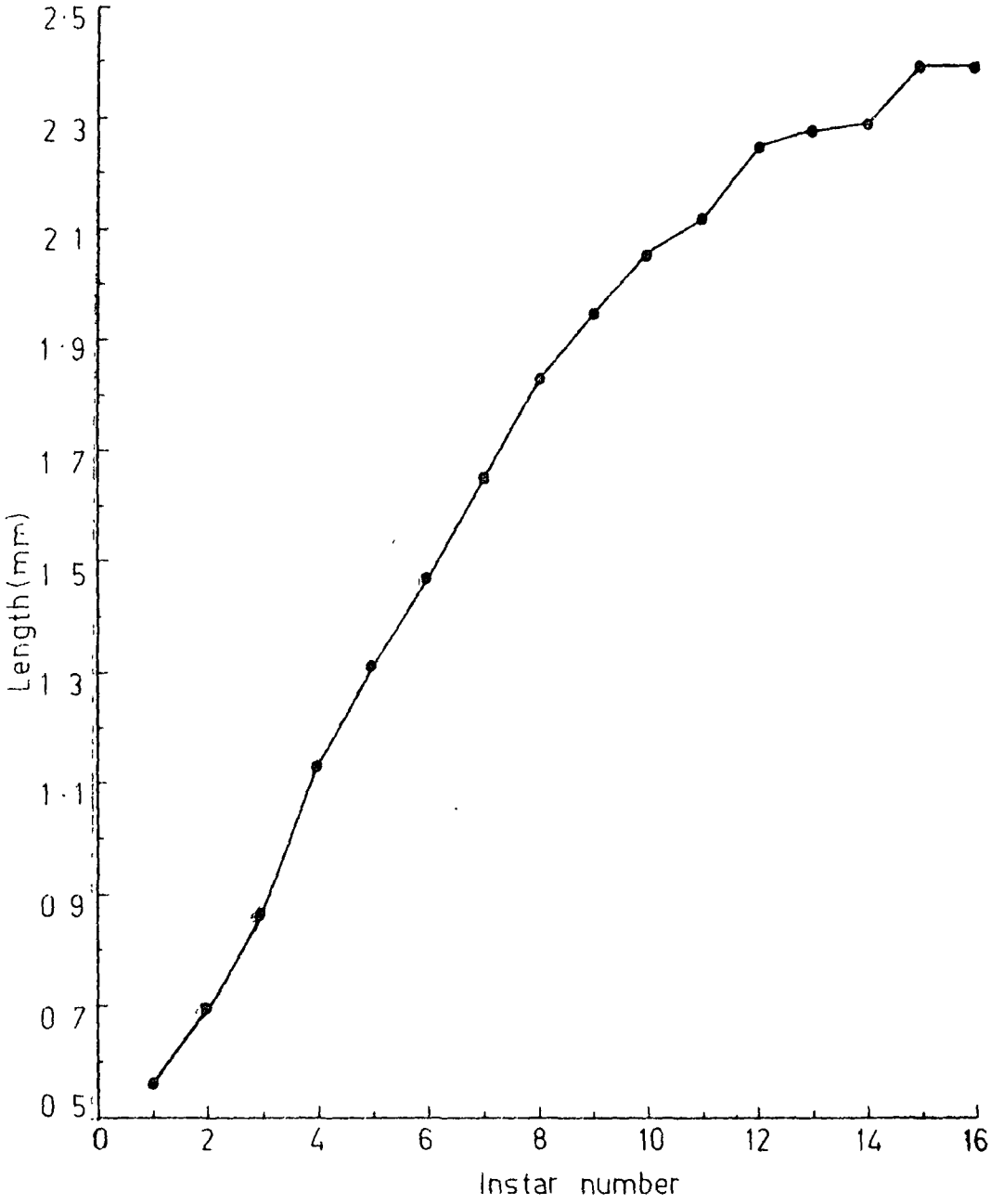

2·5
2 3
2 1
1·9
1 7
1 5
1 3
1·1
0 9
0 7
0 5
Length (mm)
0
2
4
6
8
10
12
14
16
Instar number

Fig.58

Showing number of egg/brood, age and number and duration of instar in Simocephalus exspinosus.

Fig.5.8

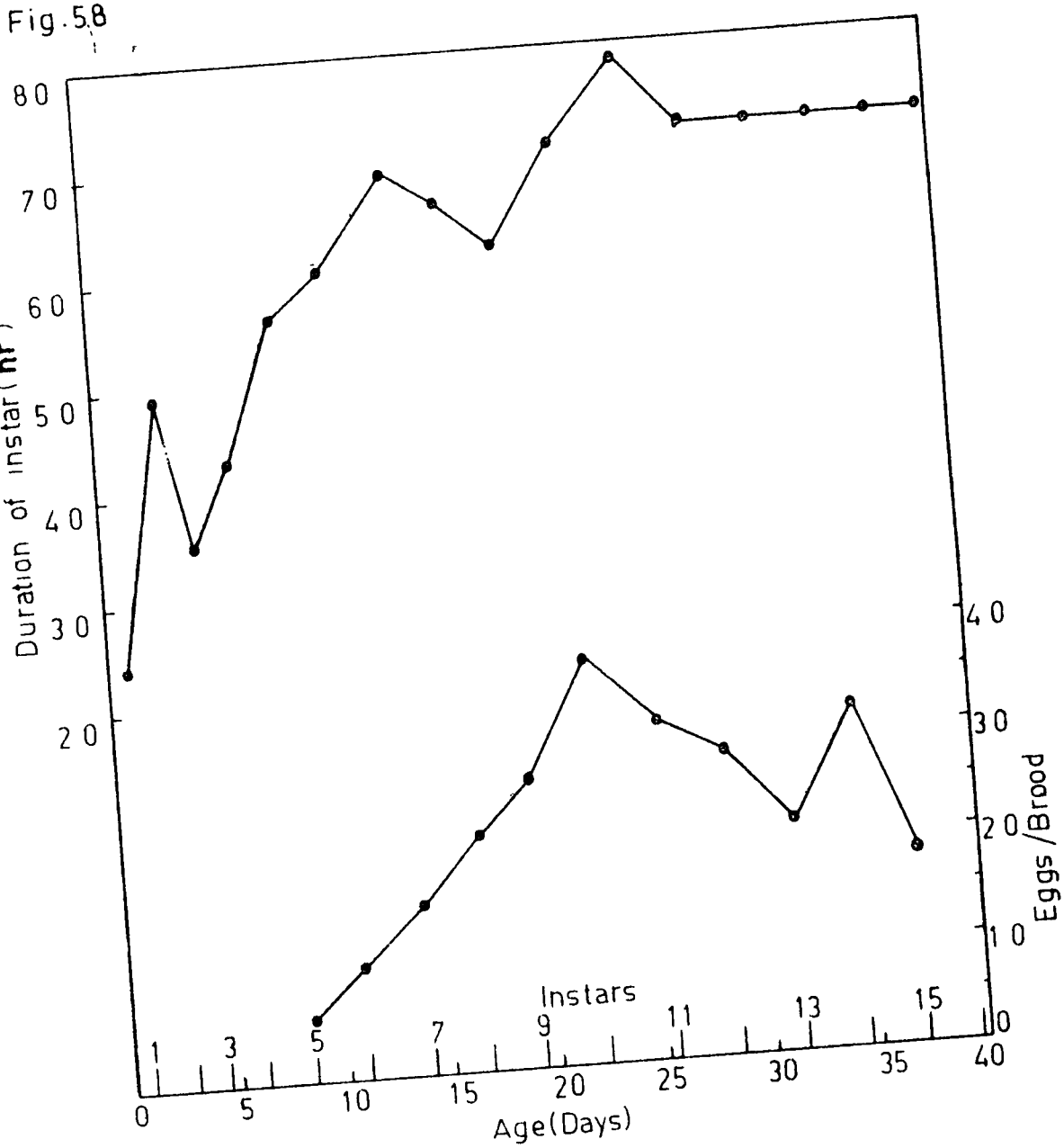
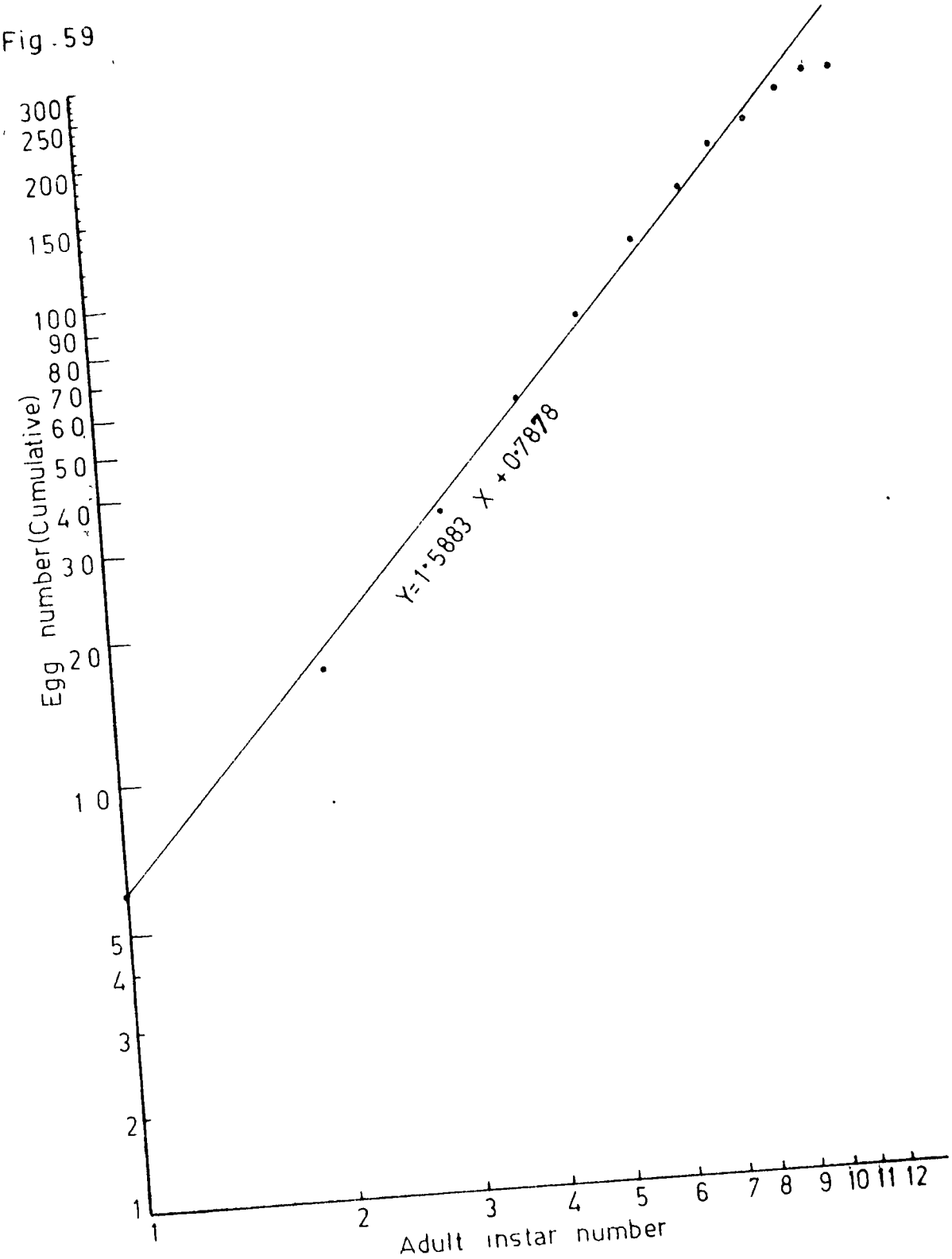

Duration of instar (hr)
80
70
60
50
40
30
20
Eggs /Brood
40
30
20
10
0
Instars
1
3
5
7
9
11
13
15
0
5
10
15
20
25
30
35
40
Age(Days)

Fig.59

Rate of egg production of Simocephalus exspinosus.

Fig. 59


Egg number (Cumulative)
300
250
200
150
100
90
80
70
60
50
40
30
20
10
5
4
3
2
1
Y=1·5883 X +0·7878
1
2
3
4
5
6
7
8
9
10
11
12
Adult instar number

Life cycle of Moina micrura Kurz :

Results on the laboratory studies of the life cycle of the parthenogenetic female of Moina micrura, conducted at a temperature range of 18°to 26°C have been shown in Table-83. The average total life span recorded for this species was 728.64 hours (30.36 days) as shown in Fig.61. The life cycle included 14 instars of which 2 were preadult and 12 adult instars. The 1st instar neonata was 0.563 mm in length which gradually increased to reach a maximum of 1.066 mm in the 13th instar. Instar number 14 or the last instar did not exhibit any perceptible increment in length. Fig.60 shows the length variations during different instars. The duration of different instars varied considerably as shown in Fig.61. The 1st instar lasted for only 27.84 hours while the 1st adult primiparous instar (3rd instar) was of 36.00 hours duration. Highest duration was that of 2nd adult instar (4th instar) with 64.34 hours. During the remaining instars the duration ranged between 51.84 to 60.00 hours. Rate of egg production was lowest during the last two instars. The 1st adult instar (3rd instar) contained 3.40 eggs per brood while the 6th, 7th and 8th instars (4th, 5th and 6th adult instars) were the most productive with a mean egg number of 6.48, 6.76 and 6.32 respectively. Then onwards the egg number declined to reach the lowest value of 3 on the 11th adult instar (13th instar) which remained unaltered even during the next instar. The cumulative frequency

Table-83 : Showing the different life cycle parameters of *Simocephalus exspinosus* studied under laboratory conditions.

Instar	Mean length (mm)	Eggs/brood (No.)	Cumulative No. of eggs	Duration of instar (Hr.)	Cumulative duration of instar (Hr.)
1	0.563	-	-	24.00	24.00
2	0.686	-	-	49.68	73.68
3	0.874	-	-	35.04	108.72
4	1.128	-	-	43.20	151.92
5	1.312	5.92	5.92	56.16	208.08
6	1.468	10.68	16.60	60.00	268.08
7	1.649	18.36	34.96	69.12	337.20
8	1.830	22.00	56.96	66.24	403.44
9	1.948	27.20	84.16	61.44	464.88
10	2.069	38.04	122.20	71.04	535.92
11	2.117	31.60	153.80	78.72	614.64
12	2.250	28.58	182.38	72.00	686.67
13	2.275	28.58	182.38	72.00	758.64
14	2.290	32.00	235.88	72.00	830.64
15	2.400	18.00	253.88	72.00	902.64
16	2.400	-	253.88	72.00	974.64

Table-84 : Showing the different life cycle parameters of *Moina micrura* studied under laboratory conditions.

Instar	Mean length (mm)	Eggs/brood (No.)	Cumulative No. of eggs	Duration of instar (Hr.)	Cumulative duration of instar (Hr.)
1	0.463	-	-	27.84	27.84
2	0.588	-	-	29.76	57.60
3	0.688	3.40	3.40	36.00	93.60
4	0.766	3.92	7.32	64.32	157.92
5	0.828	4.87	12.19	51.84	209.76
6	0.885	6.48	18.67	54.24	264.76
7	0.936	6.76	25.43	57.12	321.12
8	0.981	6.32	31.75	54.72	375.84
9	1.012	5.53	37.28	58.56	434.40
10	1.301	4.93	42.21	57.60	492.00
11	1.048	4.00	46.21	58.56	550.56
12	1.054	3.33	49.54	59.52	610.08
13	1.066	3.00	52.54	58.56	668.64
14	1.066	3.00	55.54	60.00	728.64

Fig.60

Showing changes in the length of Moina micrura during different instars.

Fig.60

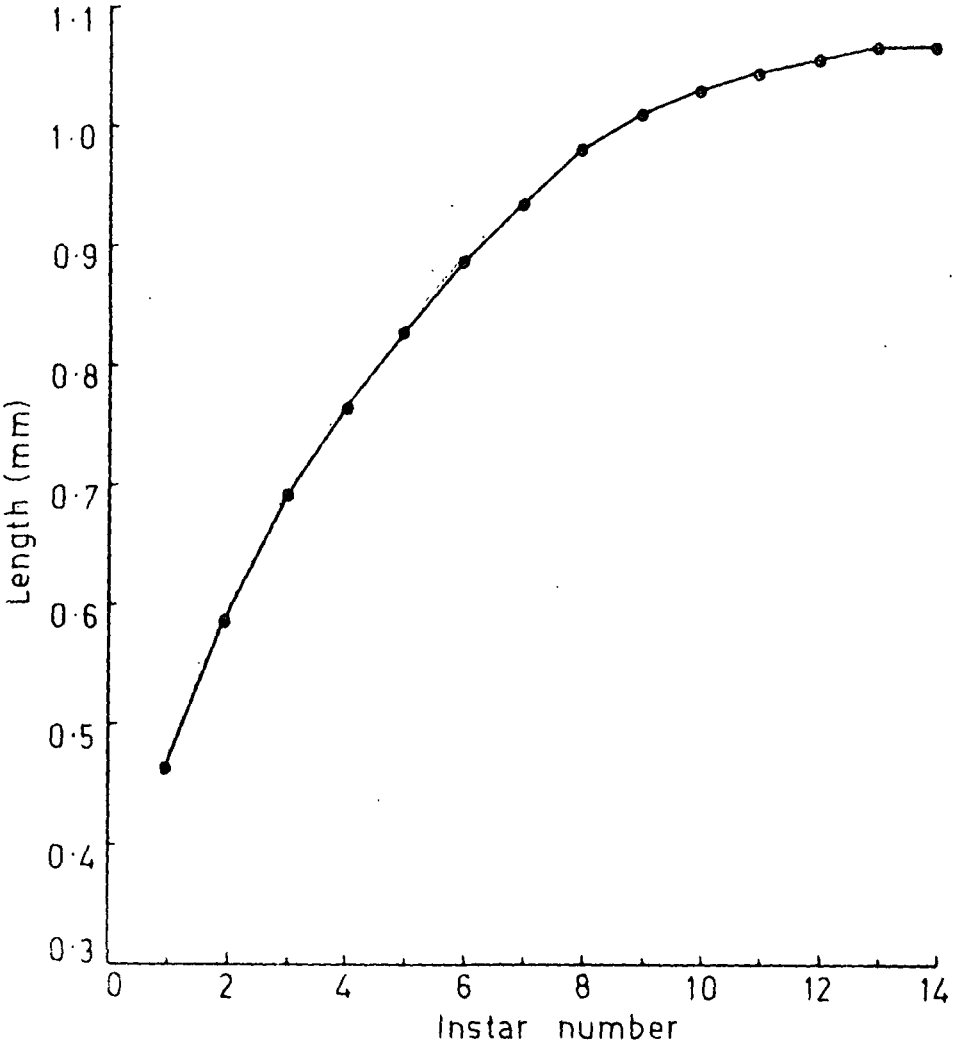


Fig.61

Showing number of egg/brood, age and number and duration of instar in Moina micrura.

Fig. 61

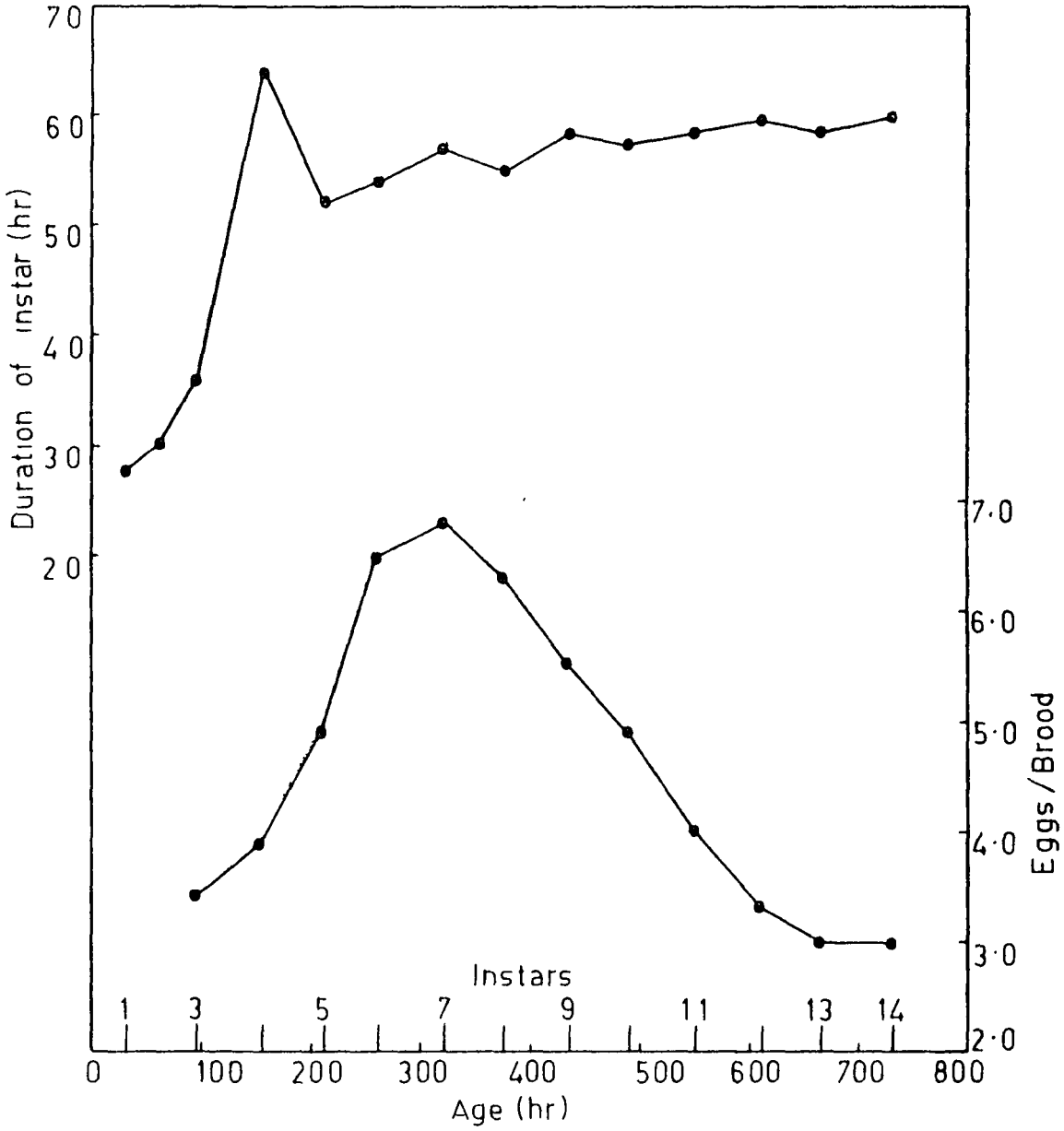
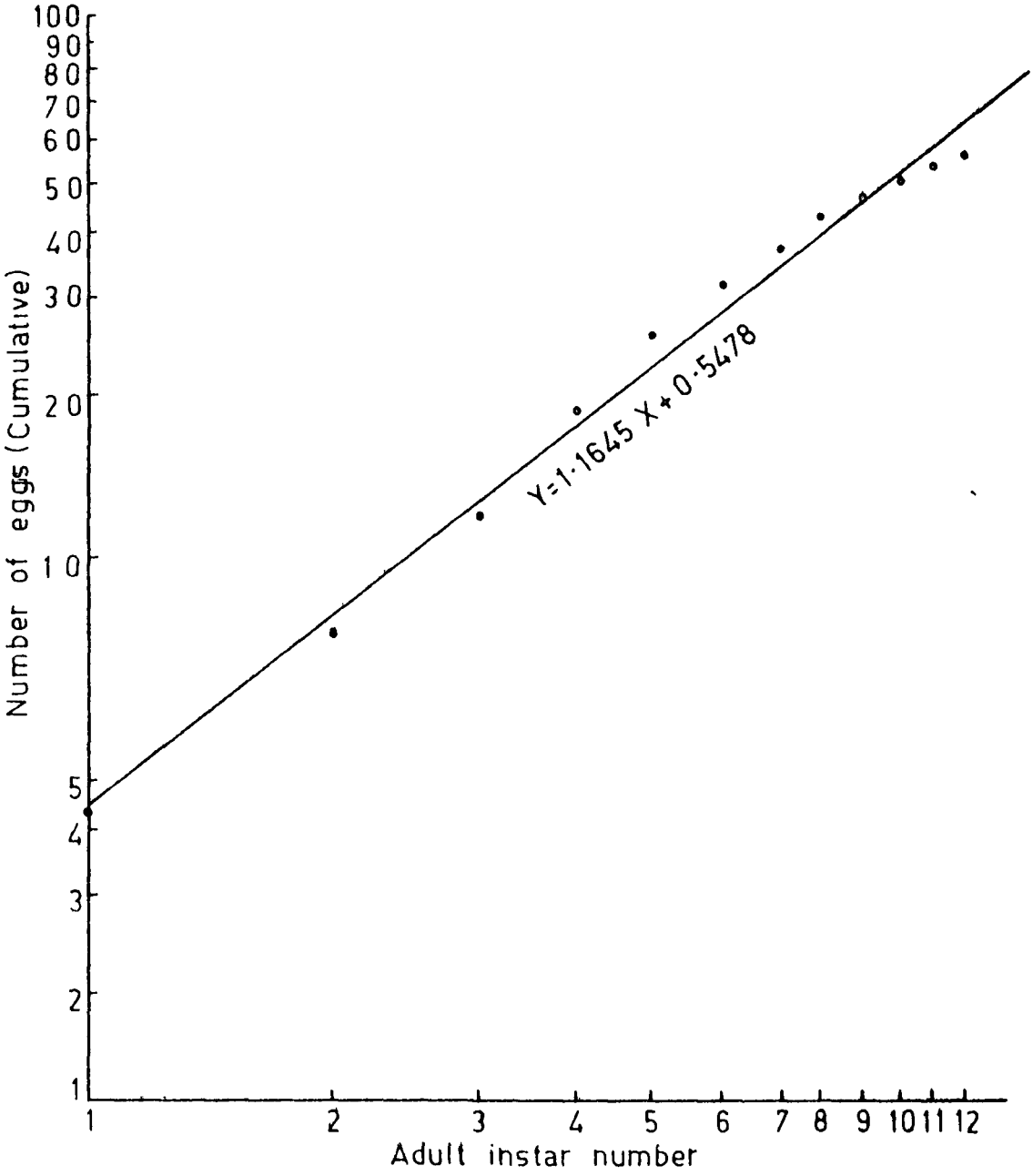

Duration of instar (hr)
70
60
50
40
30
20
Eggs / Brood
7·0
6·0
5·0
4·0
3·0
2·0
Instars
1
3
5
7
9
11
13
14
0
100
200
300
400
500
600
700
800
Age (hr)

Fig.62

Rate of egg production of *Moina micrura*.

Fig.62


100
90
80
70
60
50
40
30
20
10
5
4
3
2
1
Number of eggs (Cumulative)
Y=1·1645 X+0·5478
1
2
3
4
5
6
7
8
9
10
11
12
Adult instar number

of egg number for this species has been plotted against the number of adult instars in Fig.62. The angle of the slope of the straight line (a value) was found to be a = 1.1645, while the equation of the fitted curve was Y = 1.1645 X + 0.5478.

Life cycle of Alonella excisa (Fischer) :

The studies conducted on the life cycle of the parthenogenetic female of Alonella excisa exhibited an average total life-span of 1801.01 hours (75.04 days) under laboratory conditions. This experiment was conducted at a room temperature range of 18° to 25°C. The average mean length, instar duration and eggs per brood have been shown in Table-84. This species had a total of 28 instars in its total life-span of which the first 2 were preadult and the remaining 26 were adult instars. Increment in the length of A. excisa during different instars has been shown in Fig.63. The freshly born neonata measured 0.303 mm which grew steadily to reach the maximum length of 0.612 mm at the 26th instar. Since then the animals did not show any perceptible increase in length till the 28th instar after which they died. The first adult or primiparous instar was of 0.424 mm in length. The egg production per female was constant at 2 upto the 15 instar (13th adult instar). Out of the 26 adult instars the last 2 were non-productive, while the mean number of eggs / female was less than 2 eggs during

Table-85 : Showing the different life cycle parameters of *Alonella excisa* studied under laboratory conditions.

Instar	Mean longth (mm)	Eggs/brood (No.)	Cumulative No. of eggs	Duration of instar (Hr.)	Cumulative duration of instar (Hr.).
1	0.303	-	-	34.40	34.40
2	0.376	-	-	38.07	72.47
3	0.424	2.00	2.00	67.86	140.33
4	0.449	2.00	4.00	62.90	103.23
5	0.474	2.00	6.00	54.62	257.85
6	0.486	2.00	8.00	62.90	320.75
7	0.490	2.00	10.00	62.07	382.82
8.	0.497	2.00	12.00	51.31	434.13
9	0.529	2.00	14.00	51.31	485.44
10	0.542	2.00	16.00	57.93	543.37
11	0.551	2.00	18.00	61.24	604.61
12	0.559	2.00	20.00	67.86	672.47
13	0.562	2.00	22.00	61.24	733.71
14	0.566	2.00	24.00	61.71	795.42
15	0.568	2.00	26.00	62.76	858.18
16	0.571	1.98	27.98	63.69	921.87
17	0.575	1.80	29.78	64.62	986.49
18	0.580	1.94	31.72	67.64	1054.13
19	0.585	1.60	33.32	65.14	1119.27
20	0.590	1.88	35.20	62.86	1182.13
21	0.594	2.00	37.20	70.59	1257.72
22	0.598	2.00	39.20	70.00	1322.72
23	0.604	2.00	41.20	82.29	1405.01
24	0.605	1.94	43.14	72.00	1477.01
25	0.608	2.00	45.14	72.00	1549.01
26	0.612	1.82	46.96	84.00	1633.01
27	0.612	-	46.96	88.00	1721.01
28	0.612	-	46.96	72.00	1801.01

Fig.63

Showing changes in the length of *Alonella excisa* during different instars.

Fig. 63

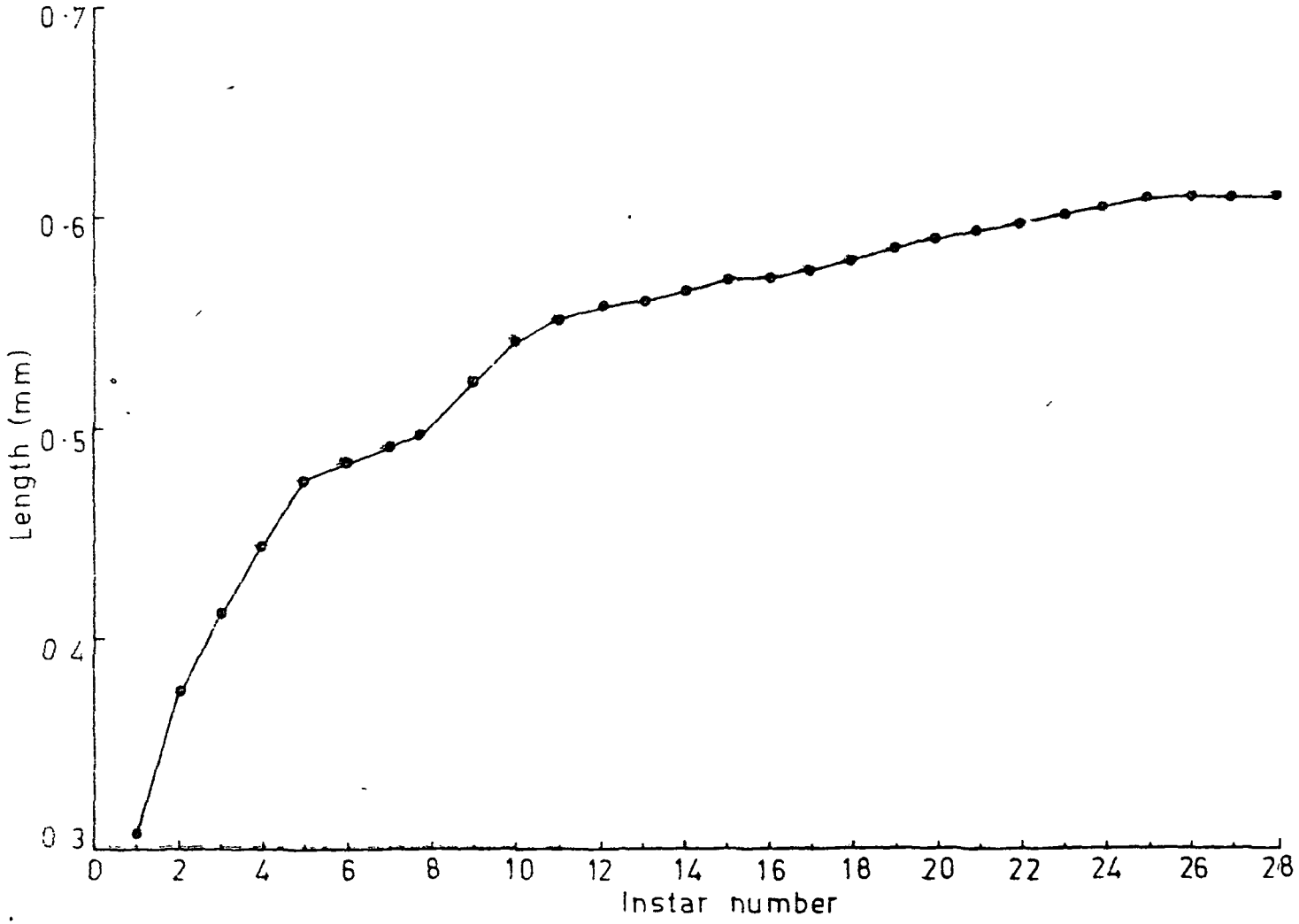

0·7
0·6
0·5
0 4
0 3
Length (mm)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Instar number

Fig.64

Showing number of egg/brood, age and number and duration of instar in Alonella excisa.

Fig. 64

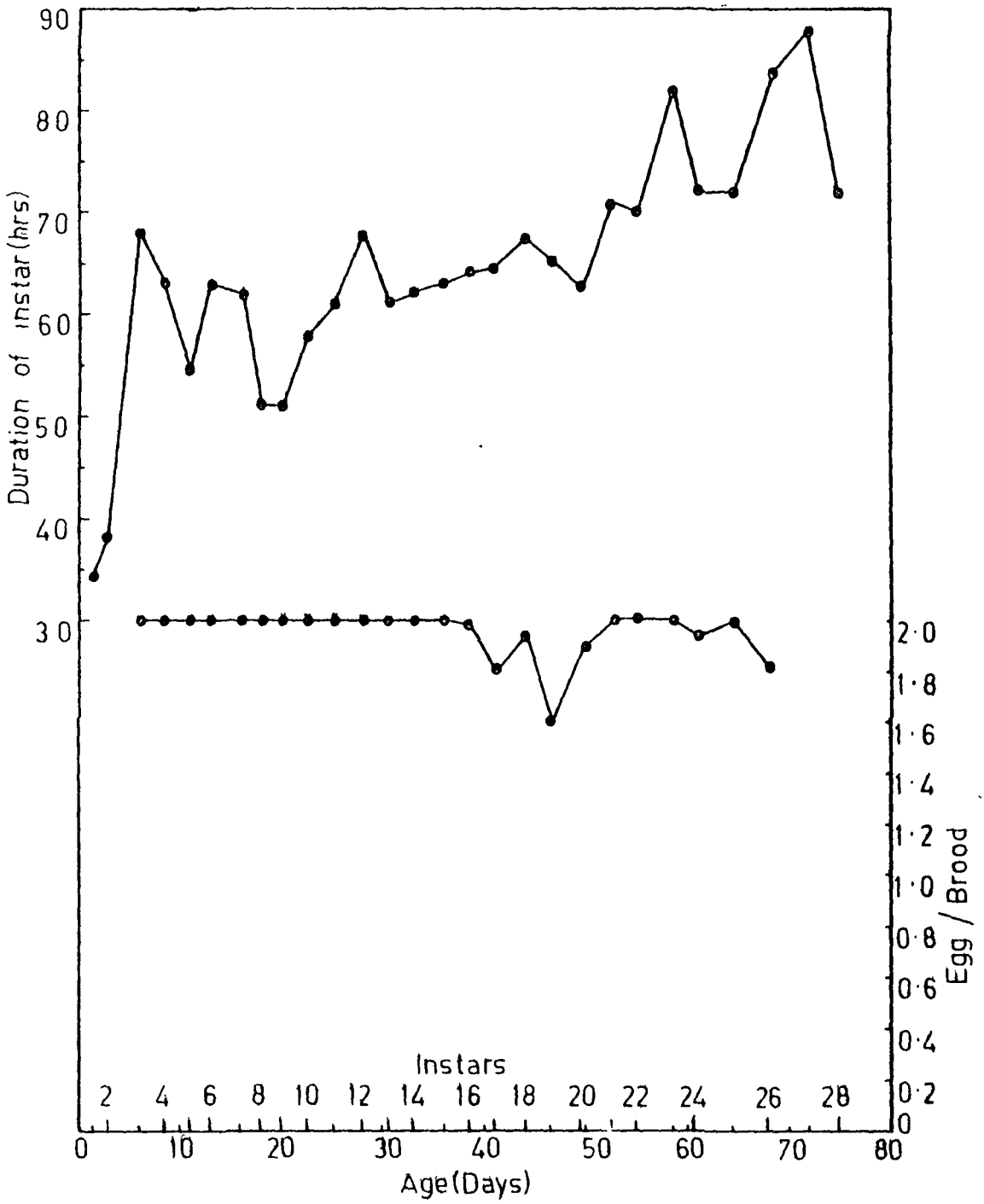
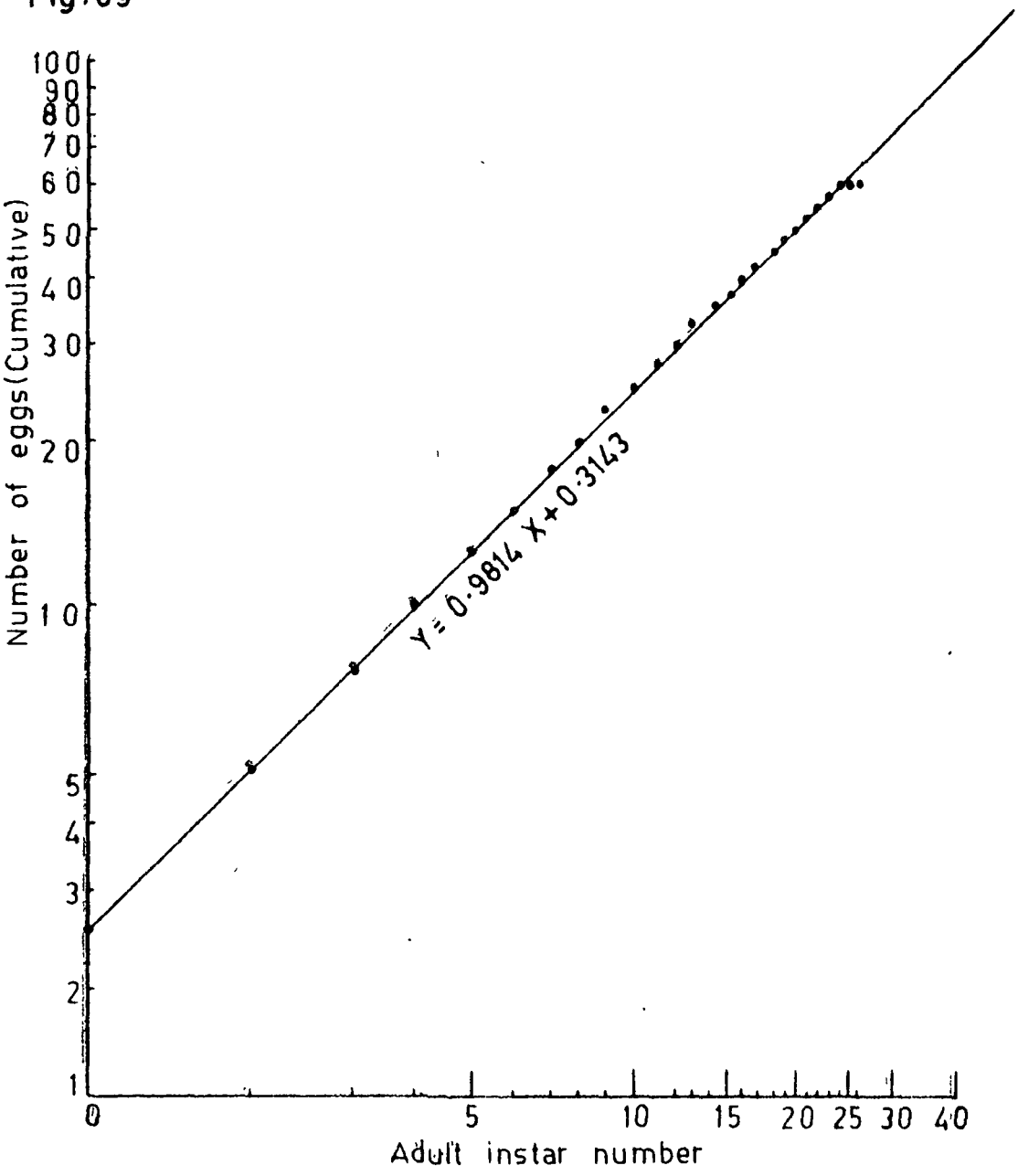

Duration of instar (hrs)
90
80
70
60
50
40
30
2·0
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0
Egg / Brood
Instars
2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 10 20 30 40 50 60 70 80
Age (Days)

Fig.65

Rate of egg production of *Alonella excisa*.

Fig. 65


Number of eggs(Cumulative)
100
90
80
70
60
50
40
30
20
10
5
4
3
2
1
Y= 0·9814 X+0·3143
0
5
10
15
20
25
30
40
Adult instar number

instars 16 to 20 (14th to 18th adult instars). Thus, apart from the last two instars when no egg was produced the mean egg production varied between 1.60 to 2 per brood. Fluctuations in egg production and duration of instars have been shown against the age of the animals in Fig.64. As in other species, this chydorid species showed less duration for the preadult stages. The first adult instar was distinctly longer than the preadult instars with an average duration of 67.86 hours. Highest duration of time was noted in the penultimate instar (27th instar) with a mean duration of 88.0 hours. Thus the variations in instar duration was 34.40 to 38.07 hours in the preadult stages while in the adult instars the durations ranged between 51.31 to 88.00 hours. The rate of egg production for this chydorid species was $\underline{a} = 0.9814$ and equation of the fitted line between cumulative frequency of egg production and the number of adult instars was $Y = 0.9814\ X + 0.3143$ (Fig.65).

PART-III

D I S C U S S I O N

Results on the laboratory studies conducted on the life cycles of the parthenogenetic females of Daphnia lumholtzi, Simocephalua exspinosus, Moina micrura and Alonella excisa was well as on the male of Daphnia lumholtzi are compiled and presented in Tables-80, 81, 82, 83 and 84.

In Cladocera it is well known that growth is stepwise and a discontinuous process, as increase in length occurs only immediately after moulting when the integument is still soft (Vijverberg 1976). This increase in size occurs very rapidly and takes less than a minute as was also observed in all the present species during their development (Edlen 1937, Green 1956). In the present studies the growth curves of all species showed a more or less similar pattern as was also observed in other species by earlier Indian workers (Murugan, Sivaramakrishnan 1973, Murugan 1975, 1975a). Further, in the females of all the four species studied here, length ceased to increase further after attaining a maximum size even though the animals continued to survive for one or few more instars. This phenomenon has already been recorded in other cladoceran species (Ingle et al 1937, Banta et al 1939, Murugan and Sivaramakrishnan 1973, 1976; Murugan 1975, 1975a). However, Richman (1958) reported a complete cessation or even negative growth in the older instars of Cladocera. But in the males of Daphnia lumholtzi growth continued till the last instar,

though the increment during this instar (12th instar) was much lower as compared to others (Table-81, Fig.55). Such similar continuous growth was also recorded in the females of Daphnia carinata (Navaneethakrishnan and Michael 1971) and in Ceriodaphnia cornuta (Michael 1962). Interestingly enough, the latter species, Ceriodaphnia cornuta when studied at a lower latitude ($9^{o}56'N$) (Murugan 1975a), showed complete absence of length increment after the 17th instar though the animals continued to live for another three more instars. Thus although the majority of the workers are of the opinion that growth in Cladocera is a continuous process throughout life (Vijverberg 1976), the present results along with the reports from other workers cited above go contrary and point to thenneed of further elucidation of this phenomenon.

From the present results it is apparent that maximum increase in terms of absolute length varied in different species of Cladocera. In the female of Daphnia lumholtzi (Table-80), maximum increase was observed between the adolescent and primiparous instars (4th and 5th instars). This is similar to the observations of Lei and Clifford (1974) on Daphnia schødleri and Navaneethkrishnan and Michael (1971) on the tropical species of Daphnia corinata . But in Simocephalus exspinosus (Table-82) this does not seem to be true as in this species the maximum growth was noted between the preadolescent and adolescent instars (3rd and 4th instars). For the two

other species, Moina micrura and Alonella excisa, maximum increment in length was recorded between the first and second juvenile instars which are also the preadolescent and adolescent instars in these species (Tables-83 and 84). These findings on the two latter species are in aggrement with the earlier findings on Moina micrura (Murugan 1975), Scapholeberis kingi (Murugan and Sivaramkrishnan 1976) and Simocephalus acutirostratus (Murugan and Sivaramakrishnan 1973). In the male of Daphnia lumholtzi, however, highest absolute growth in length was observed between the 7th and 8th instars (Table-81). Nevertheless, increase in length was also higher between the first and the second instars. In most cases, increment in length is generally said to be higher between the adolescent and primiparous instar as also seen from the present findings on Daphnia lumholtzi and other earlier reports (loc.cit). Although, Hutchinson (1967a) pointed out that the growth at any given instar is dependant upon and positively corelated to the amount of food supplied.

In Figs. 52, 55, 57, 60 and 63 the increment in growth at each instar for the females of Daphnia lumholtzi, Simocephalus exspinosus, Moina micrura and Alonella excisa as well as for the males of D. lumholtzi have been shown. It is seen that while the trend of the growth curves is almost linear during the juvenile instars, they slowly bend towards the X-axis indicative of relative retardation in length

increment during the juvenile instars was more apparent in Daphnia lumholtzi, Moina micrura and Alonella excisa . Such growth curves were observed in many other cladoceran species too (Anderson 1932, Richman 1958, Hrbackova-Esslova 1962, Smirnov 1964, Navaneethakrishnan and Michael 1971, Lei and Clifford 1974, Murugan 1975, 1975a, Murugan and Sivaramakrishnan 1976). Recently, Weglenska (1971) pointed out that increase in the body length of Cladocera is almost three times slower in the adult instars than those of the juveniles. On the other hand, in Simocephalus exspinosus the retardation in length increment was more gradual unlike in the other allied species, Simocephalus acutirostratus from India (Murugan and Sivaramakrishnan 1973).

In the present investigations, the number of preadult and adult instars varied for different species. In the females of Daphnia lumholtzi, the preadult instars numbered between four and five, although more than 80% of the females studied became primiparous only at the fifth instar. The other daphnid, Simoceppalus exspinosus passed through four juvenile instars before becoming primiparous. A comparison with reference to the number of preadult instars in different daphnids has been made in Table-85. It will be seen that the number of preadult instars as reported by different authors varied even for the same species. However, it is to be noted that culture media used for the study of different species varied from person to

Table-86 : Showing the number of preadult instars in different daphnid species.

Species	No. of preadult instars	Temp. °C	Culture medium	No. of observations	Source
Daphnia longispina	4	25	BMS	338	Banta (1939)
D. longispina	4	25	BMS	151	Ingle et al (1937)
D. magna	5	18-23	BMS	19	Anderson (1932)
D. magna	5-8	18-23	OBM	81	Anderson (1932)
D. magna	4-6	25	BMS	158	Anderson & Jenkins (1942)
D. magna	4-5	22	SSC	96	Green (1956)
D. obtusa	3-4	22	SSC	24	Green (1956)
D. obtusa	4	10, 20, 28	S/C	82	Hrbackova-Esslova (1962)
D. atkinsoni	5-6	22	SSC	18	Green (1956)
D. ambigua	*3-4	22	SSC	15	Green (1956)
D. curvirostris	*4-5	22	SSC	23	Green (1956)
D. Curvirostris	*4-5	10, 20, 28	S/C	93	Hrbacknva-Esslova (1962)
D. thomosoni	4-6 (5*)	22	SSC	19	Green (1956)
D. pulex	4-5	22	SSC	10	Green (1956)
D. pulex	*4-5	10, 20, 28	S/C	129	Hrbackova-Esslova (1962)
D. pulex	*4-5	15-22	BMS	80	Anderson et al (1937)
D. middendorffiana	5-7	10	FWC	9	Ferrari (1970)
D. hyalina	4-7	18-22	FWC	66	Hrbackova (1971)
D. hyalina	4	22	SSC	2	Green (1956)
D. carinata	5	29-31	FPW	30	Navaneethakrishnan & Michael (1971)
D. schødleri	4-7 (♀)	5, 20, 25	BMS	52	Lei & Clifford (1974)
D. schødleri	3-4 (♂)	5, 20, 25	BMS	24	Lei & Clifford (1974)
Simocephalus acutirostratus	4	28-30	FPW	15	Murugan & Sivaramakrishnan (1973)
Simocephalus exspinosus	4	17-24	FPW	25	Present study
Daphnia lumholtzi	*4-5	22-26	FPW	30	Present study

* Indicates a value which occurred in more than 80% of the total number observations.
(BMS : Banta's Manure soil madium, OBM : Oatmeal modification of Banta's medium, SSC : Standard suspension of Chlorella vulguris, S/C : Scenedesmus obliquus or Chlorella vulguris, FWC : Filtered Lake water added Chlorella, FPW : Filtered Pond water).

person as also the rearing temperatures. Both food and temperatures are known to be important factors influencing the number of preadult instars as it has been clearly demonstrated by many earlier workers (Green 1956, Edmondson 1960, Korinek 1970, Lee and Clifford 1974, Vijverberg 1976). Thus while no generalisation can be made on the number of the preadult instars, the only inference that can be drawn is that for most of the daphnid species the preadult instar numbers seem to vary between four to six, though not without exceptions (Table-85). Simocephalus exspinosus had four preadult instars and did not exhibit any variation under the present experimental conditions. Such a constancy in the number of preadult instars was also recorded in Simocephalus acutirostratus (Murugan and Sivaramakrishnan 1973) and Simocephalus vetulus (Bottrell 1975). Number of preadult instars in Moina micrura and Alonella excisa were always two. This record on M. micrura is similar to the earlier findings on this species (Murugan 1975). Shan (1969), while dealing with the life cycle of Pleuroxus denticulatus, pointed out a probable general pattern of life cycles in chydorid Cladocera. The present findings on the chydorid, Alonella excisa is in confirmity with that of the mentioned study, since both Alonella excisa and Pleuroxus denticulatus had a total number of two preadult instars. The present report on the life cycle of Alonella excisa is the first detailed study on Indian Chydoridae and hence of significance.

The number of adult instars in the females of Daphnia lumholtzi was 11 while Simocephalus exspinosus had 12 adult instars, and in Moina micrura and Alonella excisa, the numbers were 12 and 26 respectively. In Table-86 comparison of life cycle characteristics of different Indian cladoceran species has been made with those of the present findings. It may be noted that for all the species including the present ones, the culture medium used was filtered pond water. It can be seen from Table-86 that considerable similarity exists between the number of preadult instars while the number of adult instars varied from species to species. These variations may be attributed to food (Michael 1962, Hutchinson 1967, Lei and Clifford 1974, Murugan 1975), temperature (McArther and Baillie 1929, Green 1956, Bhajan and Hynes 1972, Vijverberg 1976), concentration of oxygen (Green 1956) and even hereditary factors (Hebert 1974).

It is of interest to note that the maximum length of Moina micrura in the present study was 1.066 mm recorded during the 14th instar while the same species had a maximum length of 1.008 mm as observed by Murugan (1975) at the 13th instar. However, the first juvenile instar in both cases was almost of the same size (0.465 and 0.463 mm) although the first primiparous instar (3rd instar) of the present individuals was much longer in size (0.688 mm) as compared to 0.602 mm

recorded in the earlier cited work. This difference in findings between the present study in having a total of 14 instars in contrast to 13 recorded in the earlier work can be attributed to nay of the environmental factors although trophic factors are better known to influence the growth and maximum size of Cladocera (Axelson 1961, Tonolli 1961, Wiktor 1961, Weglenska 1964, 1971). Barring these differences, the present results on Moina micrura is in almost close aggrement with those of the earlier observations of Murugan (1975).

The total life span recorded for Daphnia Lumholtzi female was 32.30 days, for Simocephalus exspinosus a total 40.61 days, in Moina micrura, 30.36 days while the chydorid, Alonella excisa lived for a total of 75.04 days. These data on the life span of the present species are relatively longer when compared with those of earlier Indian works (Table-86). It will be seen from the table that while works were conducted at a higher temperature range of 28°to 31°C, the present studies were done at 18° to 26°C. Thus the relatively longer life span of the species recorded in this studies are indications of a slower rate of growth, probably brought about due to differences in temperature regimes referred to above. Such slow rates of growth in Cladocera due to temperature differences have already been reported (Anderson et al 1937, McArther and Baillie 1929, 1929a, Edmondson 1960, Hall 1964, Weglenska 1971, Bottrell 1974, Vijverberg 1976). As pointed out earlier, one

Table-87 : Comparison of the life history parameters of different species of Cladocera worked out under Indian conditions (Culture medium in all cases was filtered pond water).

Species	Exptl. temp. °C	No.of preadult instars	No. of adult instars	Total life span (days)	Total span of preadult states (days)	No.of observations	Source
Ceriodaphnia cornuta	28-31	1-2	9	12	1.58-1.66	-	Michael (1962)
Daphnia carinata	29-31	5	8	24	4.50	30	Navaneethakrishnan and Michael (1971)
Ceriodaphnia cornuta	28-30	2	18	21.21	2.0	20	Murugan (1975a)
Simocephalus acutirostratus	28-30	4	18	44.0	4.0	15	Murugan and Sivaramakrishnan (1973)
Scapholeberis kingi	28-30	2	17	20.56	2.0	20	Murugan and Sivaramakrishnan (1976)
Moina micrura	28-30	2	11	13.0	2.0	30	Murugan (1975)
Daphnia lumholtzi	22-26	*4-5	11	32.3	5.97-7.47	50	Present study
Simocephalus exspinosus	17-24	4	12	30.36	2.40	50	Present study
Moina micrura	18-26	2	12	30.36	2.40	50	Present study
Alonella excisa	18-25	2	26	75.04	3.02	50	Present study

* Indicates a value which occurred in more than 80% of the observations.

another important factor known to effect the biology of Cladocera is food (Green 1956, Weglenska 1971, Vijverberg 1976). Even the quality and quantity of food has been shown to influence the growth of Cladocera as seen from the works of Weglenska (1971) who demonstrated that the effect of the quantity of food is better perceived at lower concentrations while increase in concentration shortens the duration of their attaining maximal size. Thus in the present study, in addition to temperature effect, the quality and quantity of food also could have played a role in the control of life span duration, although no direct evidence is afforded.

Among the four species studied at present, it was seen that the duration of instar varied considerably (Figs. 53, 58, 61 and 64). In all the four species, durations of preadult instars were always shorter than those of the adult instars. Further, the first adult instar was distinctive by being longer than the preadult instars in all the species. Once again, all adult instars were of longer duration than any of the preadult instars. A closely similar condition was reported in Daphnia carinata (Navaneethakrishnan and Michael 1971) and Simocephalus acutirostrauts (Murugan and Sivaramakrishnan 1973). In this context it is of interest to note that some temperate species of Daphnia, though reared in much lower ranges of temperature, the first adult instars lasted longer than the succeeding adult instars (Anderson et al 1937,

Ingle et al 1937, Anderson and Jenkins 1942). Yet in certain species like Ceriodaphnia cornuta, Scapholeberis kingi and the moinid, Moina micrura, the preadult and adult instars were reported to be of equal duration (Murugan 1975, 1975a, Murugan and Sivaramakrishnan 1976). While attempting to explain these different patterns of preadult and adult instar durations, Murugan (1975) differentiated two categories of daphnids ♀ (i) one with uniform duration of preadult and adult instars and the other (ii) with distinctly longer adult instars. Based on this, the two daphnids under the present study Daphnia lumholtzi and Simocephalus exspinosus will fall under the second category. It may, however, be added that the present findings on instar durations of the moinid, Moina micrura are not similar to the earlier report on the same species by Murugan (1975) who observed an uniform duration of all the instars.

The total number of eggs produced during the life span of the two daphnids, Daphnia lumholtzi and Simocephalus exspinosus were 51.09 and 253.88 eggs respectively. In Moina micrura total egg number was 55.04 while the chydorid, Alonella excisa produced 46.96 eggs in its entire life time. In Table-87 fecundity of these four species have been compared with those of other species reported by earlier Indian workers. It is seen that the mean number of eggs per adult instar were 4.65, 21.16, 4.63 and 1.81 for Daphnia lumholtzi , Simocephalus

exspinosus, Moina micrura and Alonella excisa respectively. Thus S.exspinosus appear to be the most productive (21.16) while the chydorid Alonella excisa produced the smallest brood size (1.81). It can further be seen that most daphnida certainly had a larger brood size than those of chydorids or the moinid. Thus while the fecundity in the non-chydorid Cladocera appears to be variable, the apparent constancy of the bored size in the majority of the chydorid Cladocera needs further resolution. Moreover, as pointed out in the context of growth, fecundity in Cladocera is also much dependant on the quantity and quality of food (Hrbackova-Esslova 1962, Hall et al 1970, Arnold 1971, Weglenska 1971) as well on temperature, Fox et al 1951, McArther and Baillie 1929, Green 1966, Navaneethakrishnan and Michael 1971, Murugan and Sivaramakrishnan 1973). In addition, even the relative size of the mother and the brood chamber could result in differences in egg numbers as already been demonstrated by Lei and Clifford (1974) who found that in Daphnia schodleri, mothers with smaller initial size tend to become mature at a later instar and also produce lesser number of eggs.

In Figs. 53 and 58 the eggs produced per brood have been plotted against the number of instars of Daphnia lumholtzi and Simocephalus exspinosus. It is apparent from figures that both these species showed two distinct maxima ir

the number of eggs produced indicative of a bimodal nature. In D. lumholtzi the first maxima was at the 4th adult instar which declined subsequently only to rise again on the 11th instar followed by a further steady decline in egg production. On the other hand, in S.exspinosus the two maxima were at the 6th and 10th adult instars. In both these species the last instars were devoid of eggs. The bimodal nature of egg production was also reported in other daphnids like Daphnia pulex (Anderson et al 1937), Daphnia magna (Ingle et al 1937), Simocephalus acutirostratus (Murugan and Sivaramakrishnan 1973) and Scapholeberis kingi (Murugan and Sivaramakrishnan 1976). These above findings are, however, in contrast to the observations made on Daphnia carinata (Navaneethakrishnan and Michael 1971) where only a single mode was noted.

Moina micrura and Alonella excisa exhibited a different pattern in egg production (Figs.61 and 64). M. micrura showed a single mode with the maximum number of eggs at the 7th instar which gradually decreased to reach the lowest value at the last instar (14th instar), though Murugan (1975) found the same moinid species showing a slight indication of bimodality. On the other hand, Alonella excisa showed a very different egg production curve (Fig.64). In this species, while the mean egg number was constant at two per brood till the 14th instar (12th adult instar), the remaining instars showed considerable fluctuations. Again, the last two instars

were non-egg bearing in this species. It is well known that chydorids from field populations are often found to have empty brood pouches. This phenomenon was also noted in the present laboratory culture of Alonella excisa which was responsible for the depressions in the mean egg production values. It was even observed that several mothers underwent moulting without producing eggs for one or more instars and again resumed normal production of two eggs per brood. These non productive instars were usually noted only after the mothers have completed their 15th moults or after 35.76 days in a total life span of 75.04 days. It has been observed that both Daphnia lumholtzi and Alonella excisa did not produce any egg during the last instars. The same was the case in Ceriodaphnia cornuta, Scapholeberis kingi and Simocephalus acutirostratus as reported by earlier workers. This shows that probably senescence of the older females is somewhat related to the reduction or even complete absence of egg production as was also pointed out earlier (Slobodkin 1954). Thus the foregoing discussions point out the difficulties to generalise the nature of egg production in Cladocera since fecundity in Cladocera is known to be influenced by a number of factors like food (Marshall and Orr 1952, Comita and Anderson 1959, Edmondson et al 1962, Edmondson 1962, Hall 1964), temperature (McArther and Baillie 1929, Anderson et al 1937, Navaneethakrishnan and Michael 1971, Lei and Clifford 1974), oxygen concentration (Green 1956), photoperiod (Shan 1969, 1974), and culture medium (Green 1956,

Vijverberg 1976).

Figs. 54, 59, 62 and 65 show the rate of egg production in the different species as calculated by plotting the cumulative frequency of eggs against the number of adult instars. In Table-88 a comparison of the rates of egg production in the present species has been made with those of the other species reported from India. Of the two daphnid species in the present study, Simocephalus exspinosus showed a higher rate of egg production (a = 1.5883) while Daphnia lumholtzi had 1.0396 as the a value, which reflects a comparatively lower rate of egg production. Moina micrura, on the other hand, showed a slightly higher a value of 1.1645 while Alonella excisa had the lowest production rate of a = 0.9814 (Table-88). Thus it is apparent that Simocephalus exspinosus of the present investigations was the second highest productive cladoceran in terms of fecundity, while Daphnia carinata (Navaneethakrishnan and Michael 1971) is the most productive among the Indian cladocerans so far studied. Moina micrura in the present study was found to be comparatively more productive than the report given for the same species from the plains of India (Murugan 1975). Daphnia lumholtzi on the other hand appears to be the least productive (a =1.0396) among all the daphnids so far reported from India. The chydorid species, Alonella excisa has, however, a much lower rate

Table-88 : Showing the comparison of fecundity in different cladoceran species worked out under Indian conditions (Culture medium in all cases was filtered pond water)

Species	No.of adult instar	Total No. of eggs	Total No. of broods	Mean eggs per adult instar	Rate of egg production (a value)	No.of observations	Source
Daphnia carinata	8	142.4	8	17.8	1.7695	30	Navaneethakrishnan and Michael (1971)
Ceriodaphnia cornuta	9	42.0	9	4.7	1.1959	-	Michael (1962)
Ceriodaphnia Cornuta	18	123.6	17	4.6	1.0767	20	Murugan (1975)
Simocephalus acutirostratus	18	248.0	16	13.7	1.1389	15	Murugan and Sivaramakrishnan (1973)
Scapholeberis kingi	17	239.0	16	14.8	1.3326	20	Murugan and Sivaramakrishnan (1976)
Moina micrura	11	61.18	11	5.6	1.0368	30	Murugan (1975)
Daphnia lumholtzi	11	51.09	11	4.65	1.0396	50	Present study
Simocephalus exspinosus	12	253.88	11	21.16	1.5883	25	Present study
Moina micrura	12	30.36	12	4.63	1.1645	50	Present study
Alonella excisa	26	46.96	24	1.81	0.9814	50	Present study

($\underline{a}$ = 0.9814) which in turn is reflective of the lower number of eggs produced by chydorids in general. Thus the higher rate of egg production in Simocephalus exspinosus is of significance in building up a higher secondary productivity which is already reflected in its greater abundance in the field. On the other hand Daphnia lumholtzi and Moina micrura were found to be of limited density as also seen from field collections (Vide infra, Part-II).

The life cycle of the males of Daphnia lumholtzi showed certain degree of similarity with that of females in the general pattern of growth, although it had only 12 instars with a total life span of 25.35 days (Table-81, Fig.55). Maximal growth in the male was seen between the 7th and 8th instars unlike the female in which the maximum growth was recorded between the 4th and 5th instars. Nevertheless, increase in length was also considerably higher between the first and the 2nd instars. A review of literature indicates that there are only two earlier reports of comparable nature on the life history of male daphnids. The first detailed study was on the male of Daphnia magna (McArther and Baillie 1929) which dealt with a comparative study of the total life span of male and female individuals of this species at different temperature ranges. The second work is a recent one by Lei and Clifford (1974) who dealt with the detailed biology of

the males and females of Daphnia schødleri. Results obtained from the growth pattern of the present males show general conformity with that of males of Daphnia schødleri (loc. cit.), although differences do exist in other parameters. Thus in the present study a total of 12 instars were recorded for Daphnia lumholtzi at a temperature range of 22° - 26°C, while in Daphnia schødleri the number of total instars were 18 or more at 25°C. Further, the maximum length increment observed between the 7th and 8th instars in the present species does not find a parallel with that of D. schødleri where the maximal growth was confined only to the earlier instars. In this context it may be suggested that only detailed studies on the males of more number of species will help sorting out such discrepancies. In conclution, it may be added that the present findings on the life cycle of the male of Daphnia lumholtzi is of significance being the first detailed Indian study on the males of daphnids.

PART-III

SUMMARY

Results on the laboratory life cycle studies of the parthenogenetic females of the daphnids, Daphnia lumholtzi and Simocephalus exspinosus , the moinid, Moina micrura and the chydorid, Alonella excisa have been presented and discussed. Also results on the studies of the male Daphnia lumholtzi have been documented. The present report on the males of Daphnia and on the life cycle of chydorid, Alonella excisa are the first detailed accounts from India on the male daphnids and as well on Indian chydorids. Data on the present investigations on the cladoceran life cycles have been compared with other earlier findings.

Growth curves of all species mentioned above were somewhat similar and comparable to those of other Indian studies. Females of these species showed a continuous increase in size upto a certain instar after which no perceptible increment was noted. In the male of Daphnia lumholtzi on the other hand, increment in length continued till the last instar though at a slower rate during the later instars. Such continuous growth is in conformity with other Indian reports. Maximum relative increase in size was between the preadolescent and the adolescent instars except in Daphnia lumholtzi where maximum relative increment was between adolescent and the primiparous instars. The male of Daphnia lumholtzi showed maximum increment between the 7th and 8th instars.

Number of preadult instars showed variations between the different species. In Daphnia lumholtzi number of preadult

instars varied between 4 to 5, while in Simocephalus exspinosus the preadult instars were always 4 in number. Both in the moinid and the chydorid species preadult instars were 2. The number of adult instars also differed in different species with the chydorid Alonella excisa showing the highest number. The male of D.lumholtzi had the lowest number of instars.

Among the five life cycles reported here, the total life span was found to be highest in the chydorid in comparison to the daphnid or the moinid species. Duration of first adult instar was more than that of preadult instars in all studied species. In Moina microura of the present study duration of preadult and adult instars varied in length unlike the uniform duration recorded for the same species earlier.

Total number of eggs as well as the mean brood size was distinctly more in the daphnid Simocephalus exspinosus while the lowest value was recorded in the chydorid species, Alonella excisa. A distinct bimodality was noted in the daphnid species while the nature of egg production was different in the moinid and the chydorid species. In Alonella excisa some animals were observed to pass through one to few moults without any eggs while resuming normal production of 2 eggs/brood. The rate of egg production was highest in Simocephalus exspinosus which is also the second highest value among the cladoceran species observed so far

under Indian conditions, although the value recorded for Alonella excisa is the lowest among the known Indian records.

Findings on the life cycle of the male of Daphnia lumholtzi was in general similar to the female of the same species though not entirely so. Finally, in the light of the present findings, a detailed discussion is presented on the variability of different life cycle parameters of the species studied. This discussion also deals with comparison of the present findings with those of earlier reports from India and elsewhere.

GENERAL CONCLUSION

The present study originally aimed to gain insight into the basic biology of different cladoceran species has yielded certain interesting results. The record of 23 species of Cladocera from 29 artificial impoundments located at an altitude of 1600 m thus adds 9 more species to the earlier report of 14 species from Shillong area.

6 Attempts to correlate the occurrence of a given species to the physical and chemical properties of the environment did not show any conclusive relationships, probably because of the close proximity of the surveyed impoundments with more or less similar physicochemical properties. However, species diversity appears to be positively correlated with increasing size of the habitats. In the present study the incidence of more number of chydorid taxa evidently reflects their successful adjustments to a variety of habitats. The members of Daphnidae which were the second dominant group in the Shillong area, were mostly represented by littoral species obviously adapted to the shallow nature of these systems which practically have no limnetic zone. Among the daphnid species, the ubiquitous occurrence of Scapholeberis kingi in most of the systems could be attributed to less competition encountered by them due to the unique niche they occupy in the surface film. The only bosminid species,

Bosmina longirostris appeared in mostly during winter months evidently showing its preference for lower temperature, although its appearence and population density coincided to some extent with the artificial fertilisation of the ponds, reflective of its preference for enriched waterbodies.

Certain of the species during the present investigations appeared throughout the annual cycle, though few others were restricted in distribution which obviously reflect their intrinsic adaptive abilities. It was also seen that same species exhibited differences in numerical density in different sampling stations, which is thought to be controlled by regulative factors such as nature of the substratum, kind of vegetation present and level of food supply, and possibly the much stressed predation factor.

Population analysis of selected cladoceran species has proved conclusively that the proportions of juveniles, egg bearing and non egg bearing females seemed to be better indices of the actual density of field populations rather than the size-class distribution which is particularly true of Chydoridae. In daphnids, larger brood size was apparently indicative of favourable environmental conditions while the occurrence of sexual females without the presence

of males corroborated earlier findings.

A comparison of the cladoceran species studied under field and laboratory conditions showed better growth and larger brood size in the latter case. It is quite possible that such favourable growth and reproduction of the laboratory populations are mainly the result of lack of any competition due to rearing of animals individually.

Observations on the life cycle pattern of the male daphnid, Daphnia lumholtzi show much resemblance to that of the female in general details. The present findings on the life cycle of the chydorid, Alonella excisa was found to be closely similar to the findings on Pleuroxus denticulatus which lend support to the view that chydorids in general have similar life cycle pattern.

In the context of attempts to mass culture of Cladocera with a view to use them as fish food organisms, Simocephalus exspinosus seems to be the most ideal species for this purpose as it showed the highest rate of egg production as well as remarkable adaptability to culture conditions.

In conclusion it may be added that the present studies on the various biological aspects of these cladocerans have raised a vast number of quarried which

need to be answered. These studies, inspite of being one of the few detailed works under Indian conditions, appear to have hardly resolved the intricate relationships of these organisms with reference to their environmental requirements. However, the present work has yielded certain fundamental information on the species composition, seasonal distribution, population structure and density of different species under the present altitudinal conditions. It is hoped that the above data will form the basis for more intensive studies in the years to come.

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