STUDIES ON TAXONOMY, DISTRIBUTION, ECOLOGY AND REPRODUCTIVE POTENTIAL OF ROTIFERS FROM SELECTED CENTRES IN COCHIN BACKWATER SYSTEM, KERALA

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CERTIFICATE

This is to certify that this thesis entitled "STUDIES ON TAXONOMY, DISTRIBUTION, ECOLOGY AND REPRODUCTIVE POTENTIAL OF ROTIFERS FROM SELECTED CENTRES IN COCHIN BACKWATER SYSTEM, KERALA" is an authentic record of research work carried out by Smt.Molly Varghese (Reg.No.2037), under our guidance and supervision in CMFRI, in partial fulfilment of the requirements for the Ph.D. degree in Fish and Fisheries Science under the Faculty of Marine Sciences of the Cochin University of Science and Technology, and no part of this has previously formed the basis for the award of any other degree in any University.

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GENERAL INTRODUCTION

Aquaculture is a fast growing field in fisheries sector and it is gaining more importance as the fish landings and supply are getting irregular. A consistent supply of fish/shellfish can only be achieved through aquaculture. The success of any culture activity depends on the timely production of seeds of finfishes/shellfishes. The availability of wild seed is seasonal and erratic. So, a dependable source of seed of fishes and shellfishes is possible only through large scale production in hatchery. A successful seed production activity depends on the availability of a variety of suitable live feed organisms in sufficient quantities at the proper time for use in the larval stages. As the live feeds promote high growth rates, easy digestion, assimilation and the quality of not contaminating the culture water when compared to other artificial feeds, make the culture of live feed organisms the principal means of providing food for the larvae of finfishes and shellfishes. Rotifers are considered to be an excellent and indispensable food for larvae of many finfishes and crustaceans. Ito (1960) was the first to culture *Brachionus plicatilis* for feeding marine fish larvae, and now it is being extensively used as live feed in hatcheries all over the world. Rotifers were first studied and described by Leuwenhock in 1703. They are a group of microscopic organisms coming under the Phylum Rotifera which comprises of about 2000 species. Their slow swimming habits, ability to tolerate a wide range of salinities, parthenogenetic mode of reproduction and ability to get enriched easily, make rotifers an ideal live feed organism.

A brief account on the major works carried out on rotifers are given below. A very important work on planktonic rotifers- their biology and taxonomy has been done by Ruttner-Kolisko(1974). In this book, the identification key has been compiled primarily for the general hydrobiologist and not for the specialist. Edmondson(1959) has proposed a key for the identification of rotifers. Koste(1978) gave a detailed account along with figures to identify rotifers which is very useful for the researchers in this field. Koste and Shiel(1987, 1989a, 1990a) described rotifers under the families Epiphanidae, Brachionidae, Euchlanidae, Mytilinidae, Colurellidae,Trichotriidae Lecanidae, Proalidae and Lindidae from Australian inland waters. De Ridder(1987) contributed to the knowledge of African rotifers from Mauritania, W.Africa. Shiel and Koste(1992, 1993) described the rotifers of the families, Trichocercidae, Gastropodidae, Synchaetidae and Asplanchnidae from Australian inland waters. A short history of western European rotifer research was reviewed by Koste and Hollowday(1993). Hillbricht-Ilkowska(1995) compiled one hundred years of Polish rotiferology – scientists and their work. Sudzuki(1995 , 1996) gave two accounts on taxonomy of *B.plicatilis* and its related groups – (1) after discussion and consideration of the papers before 1925 and (2) after discussion and consideration of the papers during 1926-1952. Shiel and Green(1996) recorded rotifers from New Zealand,1859-1995, with comments on zoogeography. Remane(1929/1933) speaks of 900 species of rotifers, while, Ruttner-Kolisko(1974) observed that there are now well over 2000 forms. The speciation in monogonont rotifers was dealt by Serra et al.(1997). Pejler(1998) gave a history of the research on rotifers in northern Europe. Sudzuki(1999) published a detailed account on the identification of the common rotifers.

Many workers opined that the distribution of rotifers is cosmopolitan. But many opposed this view. According to Pejler(1998) "rotifers tend to be cosmopolitan, some species are restricted to one or a few main biogeographical regions. Some taxa are known only from a smaller part of a main region, e.g. 10 species of *Notholca*, exclusively from the Baikal area. The preponderance of the genus *Brachionus* is located in the subtropic-tropic areas, while *Notholca, Argonotholca* and *Kellicottia* are found almost exclusively in the arctic-subarctic and temperate regions. Keratella shows the widest latitudinal range. The earlier view that rotifers are entirely cosmopolitan(Hofsten,1909) has been questioned in recent years(De Ridder,1981; Dumont,1983), based on accumulated information on their geographic distribution patterns." Dumont(1980) opined that care should be taken against too rapid generalizations. He adds to our knowledge about rotifers distribution patterns, on a world scale, still presents numerous and enormous gaps. Citing examples from Berzins(1978) work, he adds that caution should be there in making statements about the geographical behaviour of the group as a whole. Pejler(1977) gave an account on the global distribution of the family Brachionidae.

Ruttner-Kolisko(1974) in her beautiful compilation work on "Planktonic rotifers-Biology and taxonomy" states " the distribution of rotifers is potentially cosmopolitan". She adds "saline waters, including brackish water, must be regarded as extreme biotopes as far as the rotifer fauna is concerned; as the concentration increases the spectrum shows fewer species; at the same time there is the usual spectacular rise in the number of individuals." In the introduction itself she states "only the open sea is without them; they are at home in fresh water, and it is there that they have developed their variety." Thane-Fenchel(1968) reports a decrease in species of rotifers with the increase in salinity. Ruttner-Kolisko(1974) mentioned that very little is known about the extend of their variability in one and the same biotope. She also mentioned the possibility of correlation between morphological features and certain factors in the environment. Ruttner-Kolisko state " in addition to variation within a population in one and the same biotope, quite considerable differences in size and shape, are found when populations of the same species from different waters are compared. To study the relationships between such variations in size and shape with the environmental factors, ~~she~~ Ruttner-Kolisko(1974) applied the theory of 'Formenkreise' as suggested by Rensch, 1929". Polymorphism in the rotifer *Asplanchna sieboldi*: insensitivity of the body wall outgrowth response to temperature, food density, pH and osmolarity differences were studied by Kabay and Gilbert(1978). Marsh *et al.*(1978) described cyclomorphosis of *Keratella cochlearis* while studying the rotifer population in a southeast Texas oxbow lake. Shiel(1979) dealt with the synecology of the Rotifera of the river Murray in South Australia. In a recent article, Rob Toonen(2003) comments that the Phylum Rotifera includes about 1800 described species, of which only about 50 are marine or brackish. The remaining species are primarily freshwater. So, the above narrations would give a clear picture of the varying distribution patterns of rotifers and their presence in freshwater, brackishwater and even in higher saline waters.

Culture of rotifers and related aspects have been described by many researchers. The rotifer culture in Japan was discussed by Hirata(1979). Again Hirata(1980) described the culture methods of the marine rotifer *Brachionus plicatilis*. Clark and Revera(1980) conducted mass culture of *B.plicatilis* for use as foodstuff in aquaculture. Trotta(1980,1981) described simple and inexpensive systems for continuous mass culture of the rotifer, *B.plicatilis* as well as marine microalgae. The resting egg of rotifer and its application to marine aquaculture was dealt by Lubzens(1981). The production of food organisms with particular emphasis on rotifers was dealt by Watanabe(1982). King *et al.*(1983) dealt with cryopreservation of monogonont rotifers. The production of

B.plicatilis for aquaculture in Kuwait was studied by James *et al.*(1983). Walz(1983) dealt with the continuous culture of the pelagic rotifers *Keratella cochlearis* and *Brachionus angularis*. A modular system for mass production of the rotifer, *B.plicatilis* was developed by Meragelman *et al.*(1985). Hirayama(1987) analysed the reason for the unstability in the mass culture of the rotifer, *B.plicatilis* with baker's yeast. Raising rotifers for use in aquaculture was explained by Lubzens(1987). Snell *et al.*(1987) assessed the status of rotifer mass cultures. The biology and mass production of *B.plicatilis* was described by Fukusho(1989). James and Abu Rezeq(1989) developed an intensive chemostat culture system for the production of rotifers for aquaculture. Lubzens *et al.*(1989) studied rotifers as food for aquaculture. Fushimi(1989) developed systematic methods for large-scale production of rotifer, *B.plicatilis*. Yu *et al.*(1990) studied the role of bacteria in mass culture of the rotifer, *B.plicatilis*. Arnold and Holt(1991) discussed various methods for the culture of *B.plicatilis* in Texas. Orhun *et al.*(1991) made a practical approach to high density production of *B.plicatilis*. The culture of *B.calyciflorus* was described by Martinez and Dodson(1992). Bibiloni *et al.*(1993) studied the rotifer productivity in a fish farm using different culture methods. The survival analysis of three clones of *B.plicatilis* was made by Serra *et al.*(1994). Lavens *et al.*(1994) developed a standard procedure for the mass production of an artificial diet for rotifers with a high nutritional quality for marine fish larvae. Su *et al.*(1994) dealt with the selection of super small sized strain of *B.plicatilis* and its rearing conditions. Alireza(1995) made biological observation of Rotifera in Parishan lake,Iran. Kutikova(1995) studied the larval metamorphosis in sessile rotifers. Hagiwara *et al.*(1995a) analysed the interspecific relations between marine rotifer, *B.rotundiformis* and zooplankton species contaminating, in the rotifer mass culture tank Su *et al.*(1997) discussed the collection and culture of live foods for aquaculture in Taiwan. Lubzens *et al.*(1997) discussed the past achievements and future directions in raising rotifers as food for marine fish larvae in Israel. The interspecific interactions in the marine rotifer microcosm was studied by Jung *et al.*(1997). Studies on different modes in carrying resting eggs of wild S-strain of the rotifer *Brachionus plicatilis* were made by Okauchi and Fukusho(1985).

The significance of rotifers as first food for early larvae was indicated by Fujita in 1979 while using the rotifer, *Brachionus plicatilis* as feed for the larvae of red sea bream, *Pagrus major*. It is generally accepted that rotifers play a pivotal role in the successful rearing of marine fish larvae(Lubzens *et al.*,1989). Nandita and Rao(1993) described the patterns of prey selection in rohu and singhi larvae under light and dark conditions. The larval rearing of marine fishes as well as shellfishes using rotifers have been attempted by Lubzens *et al.*(1989); Fukusho(1989); Theilacker and Mc.Master(1971); Hoff and Snell(1989) etc. Rotifers were successfully employed as live feed in raising important fishes like mullet, *Mugil cephalus*(Nash *et al.*,1974; Tamaru *et al.*,1991), milkfish, *Chanos chanos*(Liao *et al.*,1979; Juario *et al.*,1984), sea bass, *Dicentrarchus labrax*(Barnabe,1974), grouper,*Epinephelus* spp.(Salem Al-Thobaity and James,1996), sole, *Solea solea*(Howell,1973), sea bream, *Acanthopagrus shlegeli*(Fukusho *et al.*,1985) turbot, *Scophthalmus maximus*(Kuhlmann *et al.*, 1981; Olsen and Minck, 1983; Witt *et al.*, 1984) and flounder, *Paralichthys olivaceus*(Fukusho *et al.*, 1985). Recognising that the rotifers' nutritional quality can not only vary, depending on what they are fed, but that it can be manipulated to ensure a nutritionally adequate rotifer, was a major breakthrough in the culture of marine fish larvae(Kitajima *et al.*,1980; Fukusho,1989; Watanabe *et al.*,1983). Again, studies on nutritional aspects of rotifers were conducted by Watanabe and Kiron,1994; Yu *et al.*,1989; Lavens *et al.*,1995). Realising the importance of the size of the live feed in relation to mouth size of the larvae to be fed, the use of the super small(SS) strain of the rotifer, *Brachionus rotundiformis* to the larvae having small mouth opening became popular(Fushimi,1988; Lim,1993; Watanabe *et al.*,1996).

The Indian scenario of rotifer research is still in its infancy. Anderson(1889) initiated the taxonomic studies on Indian rotifers while Nayar and Nair(1969) initiated the taxonomic works on rotifers from Kerala. Vasisht and Battish(1971a, 1972a) studied the rotifer fauna of north India – *Brachionus, Keratella, Platyias, Lecane, Monostyla, Lepadella, Colurella, Filinia, Testudinella, Philodina, Rotaria, Asplanchna,* and *Polyarthra.* A synopsis of taxonomic studies on Indian Rotatoria was prepared by Sharma and Michael(1980). Sharma(1987) remarks " the genus *Brachionus* is of Gondwanian origin and has invaded Eurasia and North America secondarily by dispersal from Africa and India(Dumont,1983)". He adds, it is missing in the arctics but predominates in the tropics and subtropics. Sharma(1987a) also gives a short description related to the distribution of Brachionids of India. Sarma(1988) in the introductory remark on his contribution to the new records of freshwater rotifers from Indian waters quotes "records of rotifer taxa in different countries are helpful in making generalizations on their geographical distribution". Rao and Chandra Mohan(1984) studied ecology of rotifers in Visakhapatnam harbour and commented that very little work has been done on the systematics and ecology of Rotifera in the marine and brackishwater environments in

India. In their work on the distribution and quantitative abundance of benthic rotifers in the north western arm of the Visakhapatnam harbour, they point out that *Encentrum marinum* which they report for the first time from India has a wide distribution ranging from freshwater to salinity conditions. They add that population density of rotifers was considerably high in freshwater conditions whereas it was less where typical marine conditions prevails. They further add as suggested by Remane(1950) that rotifers can mainly be considered as a limnetic element in marine fauna. Laal(1984) dealt with the ecology of planktonic rotifers in a freshwater pond in Bihar. Michael(1985) discussed the use of rotifers as potential bioindicators of Indian freshwater ecosystem. Sharma(1986) made an attempt to study the indicators of pollution in Indian rotifers. The research on the culture of different species of *Brachionus*, especially, *Brachionus plicatilis* were attempted by Muthu(1982 , 1983) ; Rafiuddin and Neelakantan(1990); Santhanam and Velayudhan(1991); Gopakumar(1998); Sarma *et al.*(2002a); Anitha(2003) and Gopakumar(2004). Some experimental studies on the effect of food, food density and temperature on the growth, reproduction and age at maturity of the rotifer, *B.patulus* were conducted by Sarma(1985, 1987, 1989) ; Rao and Sarma(1988) and Sarma and Rao(1990). In India, rotifers were successfully employed as live feed for rearing the sea bass, *Lates calcarifer* (CIBA) and also the clown fish, *Amphiprion* spp.(Gopakumar *et al.*, 2000 ; Boby *et al.*, 2001).

Research on rotifers on culture experiments, mass culture techniques, and nutritional enrichment have been carried out in plenty. However the technology of larval rearing is not yet fully perfected with respect to many marine fishes. This may because of the inadequate supply of suitable live feed, including rotifers at the proper time, and this in turn may be due to problems associated with rotifer cultures. To solve such problems, a proper understanding about the optimum environmental conditions for the growth of rotifers is required. To achieve this objective it is essential to know the natural habitats of rotifers and their relationships with different ecological parameters in which they grow in nature. Information on the interrelationships of rotifers with other planktonic organisms would also help us in better understanding of their position in the natural food web. Information as to what species are better adapted to varying environmental conditions will also help us in utilizing the appropriate species needed for a specific group of larvae. From the review of literature, it can be seen that in brackishwater habitats, studies on rotifers are scanty not only in India but in other countries also. Although some studies have been carried out on taxonomy, distribution, ecology and culture aspects on rotifers in India, only very little information is available on these aspects from the brackishwater environments of Kerala. It is also necessary to isolate new species of rotifers because non-conventional live feeds are being given more importance. Hence, the topic " Studies on taxonomy, distribution, ecology and reproductive potential of rotifers from selected centres in Cochin backwater system, Kerala" was selected for the present study.

The studies were conducted in nine stations with varying ecological characteristics along Cochin backwaters and adjoining canals. The present account is divided into three chapters. In the first chapter, the species/genera of rotifers available in the selected stations are described with their systematic position.

The second chapter deals with the rotifer species diversity, numerical abundance in space and time, its composition in zooplankton assemblages and the interrelationships between rotifers and various physico-chemical parameters in the study area.

The third chapter discusses the influence of salinity, feed type and feed concentration on the reproductive potential of the locally isolated rotifer, *Brachionus rotundiformis* in cultures. This information will be useful in successfully maintaining mass cultures of rotifers, thereby helping in enhanced fish production by aquaculture.

CHAPTER I

TAXONOMIC ACCOUNT OF ROTIFERS IN THE STUDY AREA

INTRODUCTION

There are numerous reports on taxonomy, so also the number of workers in this field. Rotifers were first studied and described by Leeuwenhoek in 1703. Taxonomic investigations on rotifers were initiated by Jennings(1918), Ahlstron(1940) and Edmondson(1959). Sudzuki(1964) made a new systematical approach to the Japanese planktonic Rotatoria. According to Ruttner-Kolisko(1974) the evolution of rotifers were from the acoelomate turbellarians and related to the gnathostomulids. Remane(1929 & 1933) and Koste(1978) included rotifers as a class along with Nematoda , Gastrotricha and Kinorrhyncha under the phylum Aschelminthes. But, Hymann(1951), Barnes(1980), Pearse et al. ~~& Buchsbaum~~(1987) and De Ridder(1989) considered rotifers under a separate phylum. Again, Sudzuki(1977) discussed some puzzling problems in the taxonomy of *Brachionus* and *Keratella*. Koste(1978) published a detailed guide along with 234 plates which are very useful in identifying rotifers. Taxonomic relationship of *Asplanchna brightwelli*, *A.intermedia* and *A.sieboldi* were described by Gilbert *et al.*(1979). Pejler(1980) gave an insight into the variation in the genus *Keratella*. Koste(1980) studied two planktonic rotifers, *Filinia australiensis* n. sp. and *Filinia hofmanni* n. sp. with remarks on the taxonomy of the *longiseta-terminalis* group. The taxonomy of *Brachionus plicatilis* and its allied species were explained by Sudzuki(1982). Parallelism in the evolution of rotifers was studied by Kutikova(1983). According to Ricci(1983) the use of "Rotifera" is preferred over "Rotatoria". Taxonomic studies of the Rotifera from a central Amazonian varzea lake, Lago Camaleao, Brazil was undertaken by Koste and Robertson(1983). Snell and Carrillo(1984) studied the body size variation among strains of the rotifer *B.plicatilis*. Pourriot and Francez(1986) gave a practical introduction to the systematics of rotifers of French continental waters. Sudzuki(1987) studied the intraspecific variability of *Brachionus plicatilis* . Ruttner-Kolisko(1989) examined the problems in taxonomy of rotifers, exemplified by the *Filinia longiseta-terminalis* complex. Markevich and Kutikova(1989) analysed the mastax morphology under SEM and its usefulness in reconstructing rotifer phylogeny and systematics.

According to De Ridder(1989) the phylum Rotifera is classified into two classes – Class Pararotatoria and Class Eurotatoria. The class Eurotatoria is then divided into two subclasses – Subclass Monogononta and Subclass Digononta. Again, the subclass Monogononta is divided into three orders – Order Ploima, Order Flosculariaceae and Order Collothecaceae, where under the subclass Digononta only one Order – Order Bdelloidea is included. According to him, the order Bdelloidea is represented by 4 families, the orders Ploima, Flosculariaceae and Collothecaceae contains 18, 6 and 2 families respectively.

Snell(1989) studied the systematics, and species boundaries in monogonont rotifers. Koste and Robertson(1990) studied the taxonomy of the Rotifera from shallow waters on the island of Maraca, Roraima, Brazil. The rotifers coming under the genus *Brachionus* with descriptions of new species were given by Kuczynski(1991). A nomenclatural note on a primary homonym in the genus *Lecane* was delivered by Segers(1991). Fu *et al.*(1991) described the morphological differences between two types of the rotifer *Brachionus plicatilis.* An additional note on taxonomy of *Anuraeopsis miracleae* from an Austrian alpine lake was given by Jersabek and Koste(1993). The species composition of Rotifera with reference to some taxonomic aspects of Lake Donghu in Wuhan was studied by Zhuge and Huang(1993). Segers(1993) dealt with new species of Rotifera along with other taxonomic considerations of some lakes in the floodplain of the river Niger,Nigeria. Ruttner-Kolisko(1993) investigated taxonomic problems with *Keratella hiemalis.* Segers *et al.*(1993) dealt with the taxonomy of the family Brachionidae with description of *Plationus* n. gen. (Rotifera, Monogononta). Segers *et al.*(1994) described new Rotifera from Kenya, with a revision of the Ituridae. Manuel(1994) studied the taxonomic and zoogeographic considerations on Lecanidae of the Balearic Archipelago, and described a new species, *Lecane margalefi* n.sp.. The taxonomic studies of the genus *Notholca* was undertaken by Nogrady and Wallace(1995). A new and phylogenetically suggestive morphotype of *Keratella lenzi* was recorded from Argentina by Marinone(1995). Sheveleva *et al.*(1995) reviewed the eco-taxonomy of Rotatoria of lake Baikal in Siberia.

The nomenclatural consequences of some recent studies on *Brachionus plicatilis* were explained by Segers(1995). The behavioral reproductive isolation among sympatric strains of *Brachionus plicatilis* with insights into the status of this taxonomic species was described by Gomez and Serra(1995). Sudzuki(1995) gave an account on taxonomy of *B.plicatilis* and its related groups after discussion and consideration of the papers published before 1925. Again, Sudzuki(1996) gave an account on taxonomy of *B.plicatilis* and its related groups after discussion and considerations on the papers during 1926-1952. The sibling species and cryptic speciation in the *Brachionus plicatilis* species complex was narrated by Gomez and Snell(1996). Zhu(1996) made a taxonomical and ecological survey of rotifer communities in Krotten sea(Austria). Segers and Baribwegure(1996) observed the new species *Lecane tanganyikae.*

Virro(1996) studied the taxonomic composition of rotifers in Lake Peipsi. Studies on taxonomy of freshwater rotifers were made by Sarma and Elias-Gutierrez(1997) at Mexico. Segers(1997) revised *Floscularia* Cuvier,1798(Rotifera : Monogononta) along with some notes on some Neotropical taxa while Segers and Pholpunthin(1997) described new and rare rotifers from Thale-Noi lake,Thailand with a note on the taxonomy of *Cephalodella*(Notommatidae). The mating behavior in eight rotifer species were studied by Rico-Martinez and Snell(1997) using cross-mating tests to study species boundaries. Serra *et al.*(1997) dealt with speciation in monogonont rotifers. The genetic variation among marine *Brachionus* strains and function of mate recognition pheromone was described by Kotani *et al.*(1997). Segers and Wang(1997) described a new species of *Keratella*. ~~He(1998)~~ Segers(1998) also studied the taxonomy and distribution of the interstitial Rotifera from a dune pool. A case study on the analysis of taxonomic studies on Rotifera was also conducted ~~by Segers(1998)~~ him. Sudzuki(1998) prepared tentative keys to species groups, species and intraspecies of the common rotifers, *Anuraeopsis* and *Brachionus* ~~. Again, Sudzuki(1999)~~ and later in 1999 published a detailed account on the identification of the common rotifers. The taxonomic problems in the genus *Polyarthra* from Lake Peipsi was analysed by Virro(1999). The classification of rotifers with machine vision by shape moment invariants was given by Yang and Chou(2000). Fontaneto and Melone(2003) redescribed *Pleuretra hystrix*, an endemic alpine bdelloid rotifer. Segers(2003) studied the taxonomy of the genus *Trichocerca* Lamarck,1801.

Anderson(1889) initiated the taxonomic studies on Indian rotifers. Later, Edmondson and Hutchinson(1934), Sewell(1935), Hauer(1936, 1937), Ahlstrom(1943), Brehm(1950, 1951), Donner(1953), Pasha(1961), Arora(1962, 1963, 1966a), Michael(1966), Wulfert(1966), Vasisht and Gupta(1967), Naidu(1967), Nayar(1968), Vasisht and Battish(1969, 1970, 1971a, 1971b, 1971c, 1971d), Rajendran((1971), Michael(1973), Dhanapathi(1973, 1974a, 1974b, 1975, 1976a, 1976b, 1977, 1978), Mohan and Rao(1976), Rao and Chandra Mohan(1976, 1977, 1984), Sharma(1976,1977, 1978a, 1979, 1980a, 1980b, 1980c,1987a, 1987b,1992), Tiwari and Sharma(1977) , Patil(1978,1988), Jyoti and Sehgal(1980), Saksena and Sharma(1981a, 1981b, 1981c, 1982), Saksena et al.(1986), Sharma and Sharma(1987, 1997), Sarma(1988), Govindasamy(1988), Kaushik and Saksena(1991), Kannan and Govindasamy (1991), Sharma(1992), Sharma *et al.*(1992), and Singh and Pandey (1993) studied the rotifer fauna of different states in India. Nayar(1965) gave taxonomic notes on the Indian species of *Keratella.* A synopsis of taxonomic studies on Indian Rotatoria was prepared by Sharma and Michael(1980). The Indian species of the genus *Brachionus* was compiled by Sharma(1983). Sampathkumar(1991) studied the taxonomy and ecology of rotifers in fish ponds and taxonomic composition and distribution of *Brachionus* populations in ponds. Sharma(1991) made a detailed review of the Indian work on rotifers. Battish(1992) gave an account on Rotifera wherein he discussed the classification and descriptions of different species. Fifteen species were added to the rotifer fauna of India by Segers *et al.*(1994). Taxonomic notes on the rotifers from India was given by Dhanapathi(2000).

In Kerala, taxonomic work on the rotifers was initiated by Nayar and Nair(1969) with the studies on Brachionid rotifers. Nair and Nayar(1971) studied rotifer fauna of Irinjalakuda. Segers and Babu(1999) investigated rotifers of Devikulam, a high altitude lake in the western Ghat range of Kerala state and presented a note on the taxonomy of the genus *Polyarthra* also. These three investigations were confined to freshwater habitats. The systematics of rotifers available in brackishwater environments in Kerala was unknown for a long time and only recently, a few studies were undertaken. Shibu(1991), Bijoy Nandan(1991), Harikrishnan(1993), Anuradha Rammohan(1996) and George Thomas(1996) recorded the availability and abundance of rotifers in certain brackish water regions of southern Kerala while studying the general plankton communities in these areas. Gopakumar(1998) studied the rotifers of Pozhiyoor lake, Veli lake, Kadinamkulam lake, Edava-Nadayara lake, Paravur lake and Ashtamudi lake and, systematic account of rotifers in these brackishwater habitats were documented. Anitha(2003) investigated the systematics of rotifers with special emphasis on the family Brachionidae of Veli-Aakulam and Poonthura estuaries.

The foregoing review reveals that only very little attention was given to the systematic studies on rotifers of Kerala when compared to that of other states in India and that studies in the brackish water habitats of Kerala were confined only to the southern region of the state. No attempt was made so far to study the systematics of rotifers of the brackishwater habitats in the central part of Kerala. Hence, an attempt is made here to study the taxonomy of rotifers in different habitats along the Cochin backwater system in the central part of Kerala.

MATERIALS AND METHODS

The Cochin backwaters and certain canals adjoining the system extending to around 50 kms were selected for the study. The present study was conducted during the period August,2000 to July,2002. Monthly collections of rotifers were made from nine stations viz. Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Fisheries Harbour, Ernakulam market canal, Mangalavanam and Poothotta. The collection sites are shown in Fig.1& Plates 1-5.

The plankton samples were taken from each station by filtering 500 litres of water through a conical plankton net made up of bolting silk having a mesh size of 40 microns. In order to avoid sampling errors, care was taken to collect the samples from an area, instead of taking from a particular point. The filtered plankton samples were preserved using 4% formaldehyde. The rotifers were identified using a number of taxonomic papers and keys published by various authors, especially Edmondson(1959), Koste(1978), Battish(1992), Sharma(1983) and Sudzuki(1999). The figure of a typical rotifer, showing characters of taxonomic value as given by Battish(1992) is given in Fig.2. The length and width of specimens were measured. For illustrations, photographs of specimens were taken using Zeiss Axiostar microscope fitted with SVMICRO Soundvision Camera and image captured using the software Axiovision 2.05.

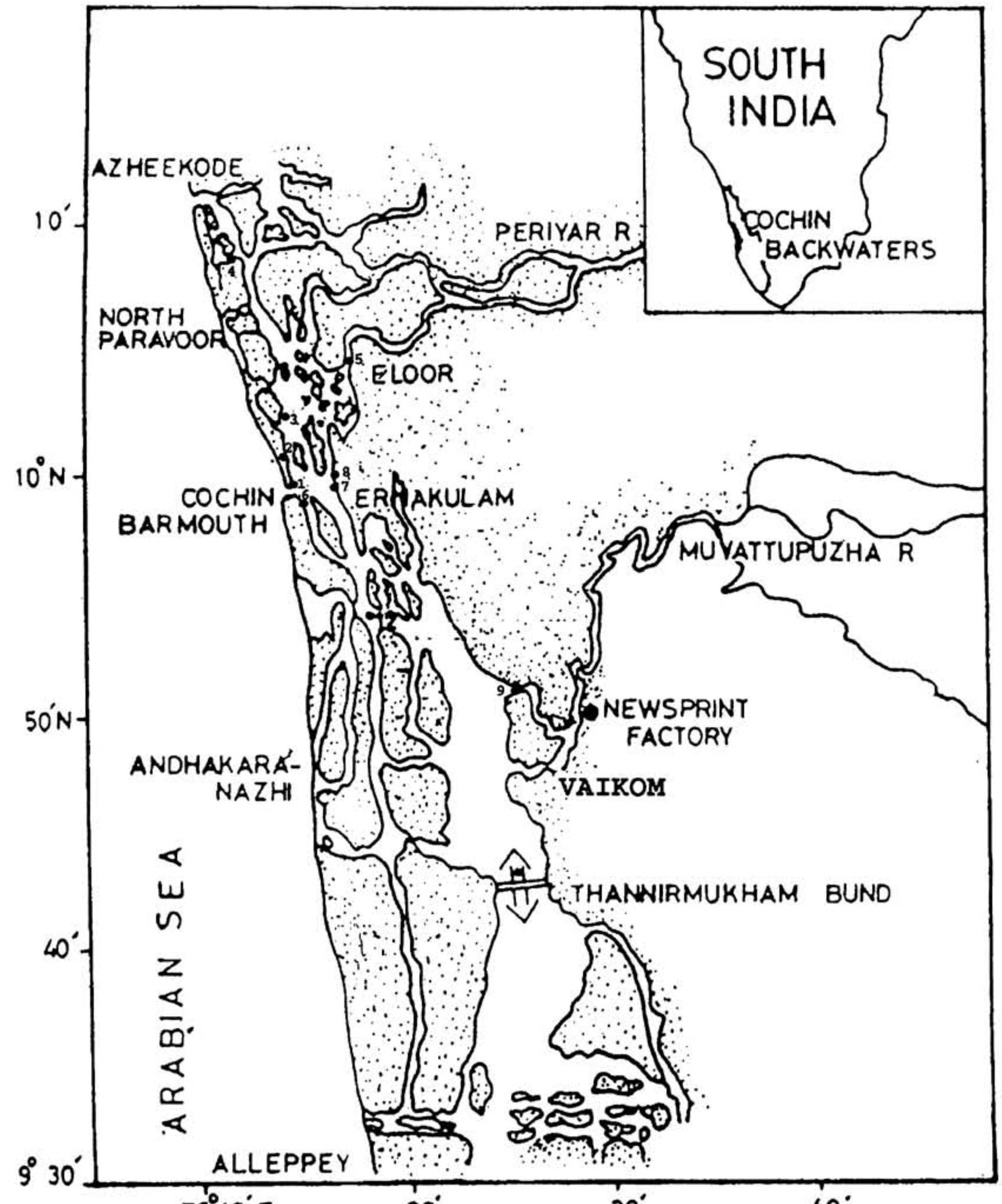
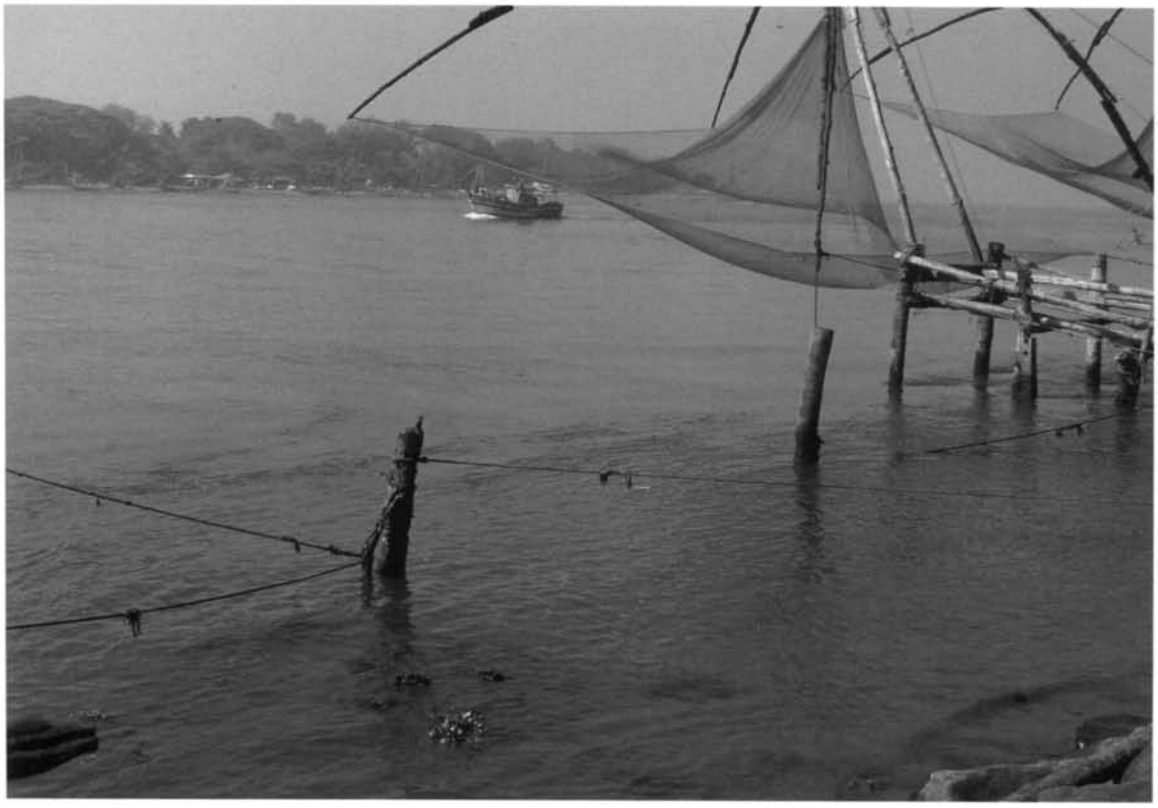


Fig 1. Map of Cochin backwater system and location of stations

PLATE 1



Station 1-Vypeen

Station 2-Puthuvypu

PLATE 2

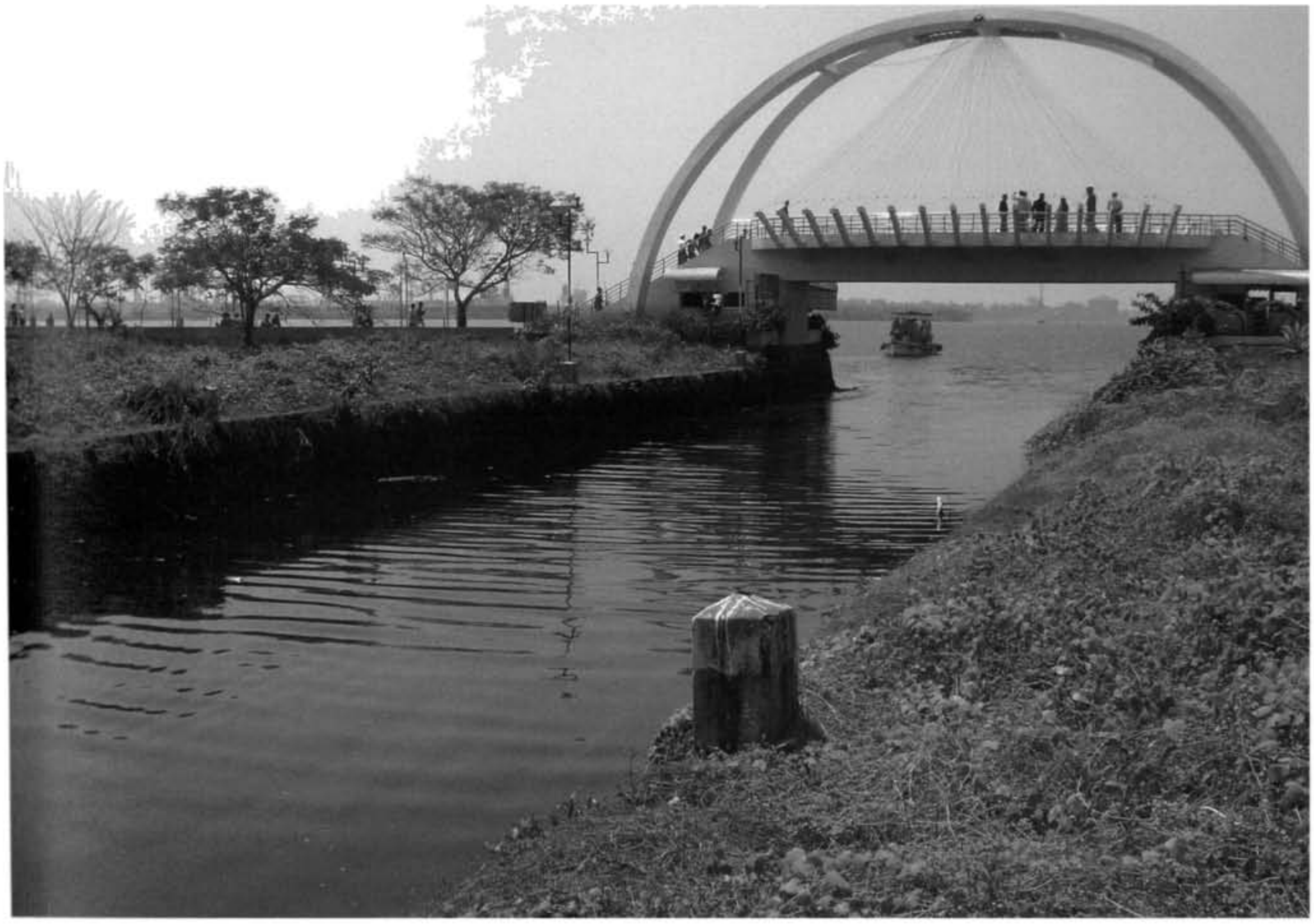
Station 3-Narakkal

Station 4-Cherai

Station 5-Eloor

Station 5-Eloor another view

Station 6-Fisheries Harbour



Station 7-Ernakulam Market Cannal

PLATE 5

Station 8-Mangalavanam

Station 9-Poothotta

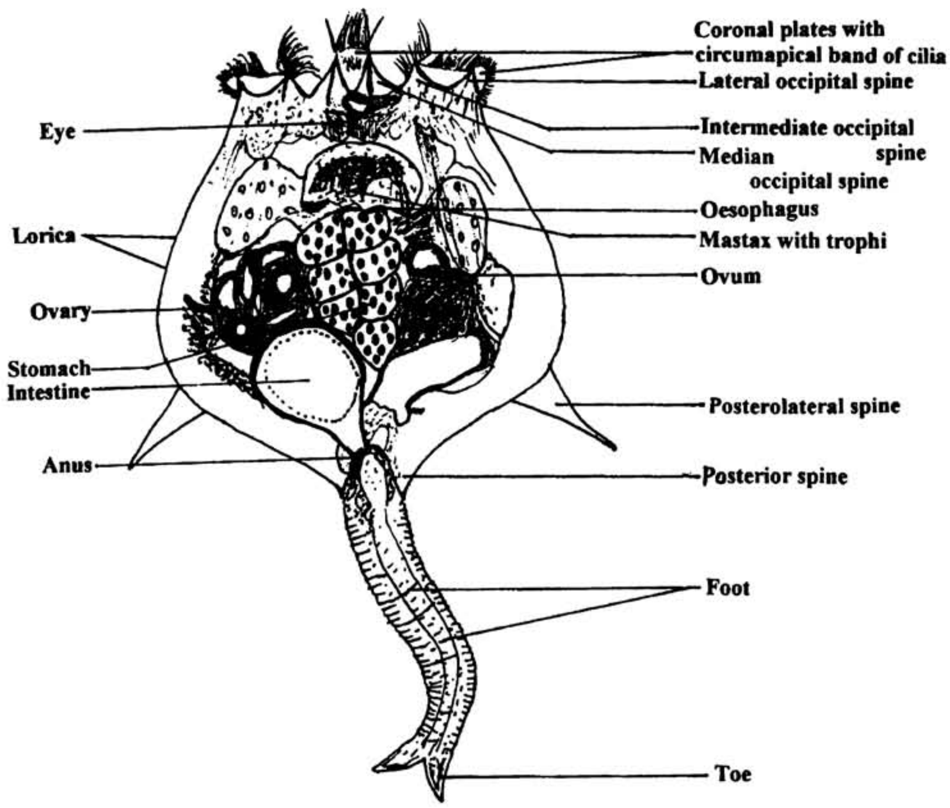


Fig.2. Characters of taxonomic value in Rotifera
(Reproduced from Battish,1992)

RESULTS

The study was carried out for a period of two years and rotifers representing two orders under the class Monogononta were collected from the study area. A total of 20 genera were identified and described. They are listed in Table 1. Apart from this, 13 different species under the genus *Brachionus* were also identified and described.

Table 1.Systematic position of rotifers collected from the study area

Sl.No.	Phylum	Class	Order	Family	Genera
1	Rotifera	Monogononta	Ploimida	Brachionidae	*Brachionus*
2	Rotifera	Monogononta	Ploimida	Brachionidae	*Keratella*
3	Rotifera	Monogononta	Ploimida	Brachionidae	*Platyias*
4	Rotifera	Monogononta	Ploimida	Brachionidae	*Anuraeopsis*
5	Rotifera	Monogononta	Ploimida	Mytilinidae	*Mytilina*
6	Rotifera	Monogononta	Ploimida	Euchlanidae	*Euchlanis*
7	Rotifera	Monogononta	Ploimida	Euchlanidae	*Dipleuchlanis*
8	Rotifera	Monogononta	Ploimida	Epiphanidae	*Epiphanes*
9	Rotifera	Monogononta	Ploimida	Epiphanidae	*Microcodides*
10	Rotifera	Monogononta	Ploimida	Colurellidae	*Lepadella*
11	Rotifera	Monogononta	Ploimida	Lecanidae	*Lecane*
12	Rotifera	Monogononta	Ploimida	Lecanidae	*Monostyla*
13	Rotifera	Monogononta	Ploimida	Notommatidae	*Cephalodella*
14	Rotifera	Monogononta	Ploimida	Notommatidae	*Scaridium*
15	Rotifera	Monogononta	Ploimida	Trichocercidae	*Trichocerca*
16	Rotifera	Monogononta	Ploimida	Synchaetidae	*Polyarthra*
17	Rotifera	Monogononta	Ploimida	Dicranophoridae	*Encentrum*
18	Rotifera	Monogononta	Flosculariacea	Hexarthridae	*Hexarthra*
19	Rotifera	Monogononta	Flosculariacea	Filiniidae	*Filinia*
20	Rotifera	Monogononta	Flosculariacea	Testudinellidae	*Testudinella*

ROTIFERS COLLECTED FROM THE STUDY AREA

PHYLUM : ROTIFERA

CLASS : MONOGONONTA

ORDER : PLOIMIDA

FAMILY : BRACHIONIDAE

1.*Brachionus* Pallas,1776

1.1. *Brachionus plicatilis* Muller, 1786

1.2. *B. rotundiformis* Tschugunoff,1921

1.3. *B.angularis* (Gosse,1851)

1.4. *B.urceolaris* (Muller,1773)

1.5. *B.rubens* Ehrenberg, 1838

1.6. *B.calyciflorus* Pallas, 1776

1.7. *B.caudatus* Barrois and Daday,1894

1.8. *B.falcatus* Zacharias, 1898

1.9. *B.forficula* Wiezejski, 1891

1.10.*B.quadridentatus* Hermann,1783

1.11.*B.patulus* Muller, 1786

1.12.*B.bidentata* Anderson, 1889

1.13.*B.mirabilis* Daday, 1897

2. *Keratella* Bory de St. Vincent, 1822

3. *Platyias* Harring, 1914

4. *Anuraeopsis* Lauterborn, 1900

FAMILY : MYTILINIDAE

5. *Mytilina* Bory de St. Vincent,1836

FAMILY : EUCHLANIDAE

6. *Euchlanis* Ehrenberg, 1832

7.*Dipleuchlanis* Gosse, 1886

FAMILY : EPIPHANIDAE

8. *Epiphanes* Ehrenberg, 1832

9.*Microcodides* Bergendal,1892

FAMILY : COLURELLIDAE

10. *Lepadella* Bory de St. Vincent, 1826

FAMILY : LECANIDAE

11. *Lecane* Nitzsch, 1827

12. *Monostyla* Ehrenberg, 1830

FAMILY : NOTOMMATIDAE

13. *Cephalodella* Bory de St. Vincent,1826

14. *Scaridium* Ehrenberg, 1830

FAMILY : TRICHOCERCIDAE

15. *Trichocerca* Lamarck, 1801

FAMILY : SYNCHAETIDAE

16. *Polyarthra* Ehrenberg, 1834

FAMILY : DICRANOPHORIDAE

17. *Encentrum* Ehrenberg,1838

ORDER : FLOSCULARIACEA

FAMILY : HEXARTHRIDAE

18. *Hexarthra* Schmarda,1854

FAMILY : FILINIIDAE

19. *Filinia* Bory de St. Vincent, 1824

FAMILY : TESTUDINELLIDAE

20. *Testudinella* Bory de St. Vincent, 1826

CLASSIFICATION AND DESCRIPTION

PHYLUM : ROTIFERA (Cuvier, 1798)

The Rotifera or wheel animalcules are a group of small, microscopic, pseudocoelomate animals. They are characterized by the possession of a corona, which is either a ciliated area or a funnel-shaped structure at the anterior end, and a specialized pharynx called the mastax, with its cuticular lining differentiated into trophy, a series of pieces that act as jaws.

KEY TO CLASSES OF ROTIFERA

1. a. Rotifers with paired generative organs..2

   b. Rotifers with single generative organ, males present but mostly reduced..MONOGONONTA

2. a. Marine;corona not with two trochal discs, reduced, males fully developed.. SEISONIDEA

   b. Freshwater; corona with two trochal discs, latter rarely reduced in some forms; males not known ....BDELLOIDEA

CLASS **MONOGONONTA** Ramane,1933

Swimming or sessile Rotifera, with a single germovitellarium; males usually present, reduced, with one testis; mastax not ramate; lateral antennae present; foot present or absent, when present with 2 toes or without toes.

KEY TO ORDERS OF MONOGONONTA

1. a. Free swimming, never fixed; foot when present with toes............PLOIMIDA

   b. Adults rarely free swimming, foot when present without toes....................2

2. a. Mastax malleoramate..FLOSCULARIACEA

   b. Mastax uncinate..COLLOTHECACEA

ORDER : PLOIMIDA (Hudson and Gosse,1889)

Body shape vermiform, sacciform or dorsoventrally flattened; corona not with trochal and cingular circlets; foot normal, with two toes or reduced or even absent in some; eyes present or absent, when present one or two.

Of the 17 families(Koste and Shiel, 1987) in this order, only 13 were available during the present study.

FAMILY : BRACHIONIDAE

Most of the forms heavily loricated; corona often with several dorso-transverse prominences bearing tufts of strong cilia, the pseudotroch, buccal field mostly supraoral, oblique or terminal; mouth funnel-like, situated in buccal field. Foot present or absent, when present with 2 toes.

This family was represented by 4 genera namely *Brachionus, Keratella, Platyias* and *Anuraeopsis* in the present account.

Genus: *Brachionus* Pallas, 1776

Heavily loricate forms; lorica broad and covers the trunk completely; may be one piece when it continues around the body or two pieces united through flexible cuticle; dorsal piece or plate arched, ornamented in some, whereas ventral piece relatively flat; lorica in some species stippled, anterodorsal edge always with even number of spines, anteroventral edge or mental edge rigid or flexible but may be wavy or smooth with V or U- shaped notch; posterolateral spines present or absent depending upon the species and may seasonally appear or disappear even in the same species; posteromedian spines mostly present and flank the foot, anterior portion of the body projects from lorica in the form of coronal disk which bears a circlet of cilia and three prominences covered with cilia of larger size; foot slender, annulated, with two toes, with no spur or spine, highly contractile and projects from the posteroventral edge of lorica, imparting a subsquare aperture in dorsal plate and a large usually oval aperture in the ventral plate; foot sheath seldom present. Single germovitellarium. Trophi malleate.

Under the genus *Brachionus*, 13 species were identified and recorded in the present study. They are *Brachionus plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens, B.calyciflorus, B.caudatus, B.falcatus, B.forficula, B.quadridentatus, B.patulus, B.bidentata* and *B.mirabilis*.

Brachionus plicatilis Muller, 1786

Material : Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 6 - Fig.1)

Lorica flexible, lightly stippled, more or less oval, greater width about two-thirds length of lorica from anterior end; it narrows anteriorly and not sharply separated into dorsal and ventral plates, slightly compressed dorsoventrally; anterodorsal margin with six broad based saw-toothed spines; nearly equal in length; posterior spines wanting; mental margin four lobed; foot opening with small subsquare aperture dorsally and longer V-shaped aperture ventrally.

Measurements

Length of lorica : 150 – 252 µm

Maximum width of lorica : 105-182 µm

Brachionus rotundiformis Tschugunoff,1921

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 6 - Fig. 2)

Lorica rather flexible, small, more rounded, not sharply separated into dorsal and ventral plates, but little compressed dorso-ventrally, anterior dorsal margin with six acutely pointed spines, nearly equal in length, mental margin rigid, separated into four lobes with considerable variations, lorica without posterior spines, foot opening with small subsquare aperture dorsally and longer V-shaped aperture ventrally, lorica smooth or lightly stippled.

Measurements

Length of lorica : 60-196 µm

Maximum width of lorica : 52-154 µm

B.angularis (Gosse,1851)

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal and Mangalavanam (Plate 6 - Fig. 3,4 & 5)

Lorica firm,lightly or heavily stippled, divided into dorsal and ventral plates; dorsal plate with pattern of cuticular ridges, moderately compressed dorsoventrally; anterodorsal margin with two median spines flanking a V-shaped notch; lateral and intermediate spines usually obliterated, intermediate spines may present in some; mental margin rigid, somewhat elevated with a shallow median notch; foot opening rather large, somewhat variable in shape; larger foot aperture in ventral plate flanked by cuticular protuberances; posterior spines wanting.

Measurements

Length of lorica : 63-128 μm

Maximum width of lorica : 42-105 μm

B.urceolaris (Muller,1773)

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal and Poothotta (Plate 6 - Fig. 6 and Plate 7 - Fig. 7 & 8)

Lorica broad, dorsal and ventral plates separated, anterior margin of ventral plate with ridges, occipital spines six, medians longer than intermediates and laterals; basal plate is absent, no posterior spines, foot opening with small lateral projections.

Measurements

Length of lorica :112-231 μm

Maximum width of lorica : 84-182 μm

B.rubens Ehrenberg, 1838

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Market canal, Mangalavanam and Poothotta (Plate 7 - Fig. 9)

Lorica firm,oval, smooth , compressed dorsoventrally and composed of dorsal and ventral plates; anterior dorsal margin with six spines; medians longest , intermediates somewhat longer than laterals; medians and intermediates with peculiar asymmetric shape, each spine with a narrow anterior part, then rounding outwards and forming broad base; all these spines provided with strengthening ridges; mental margin serrated and markedly elevated towards the centre with a central notch; posterior spines absent; foot opening subsquare and small.

Measurements

Length of lorica : 112-210 μm

Maximum width of lorica : 84-140 μm

B.calyciflorus Pallas, 1776

Material: Several specimens from Cherai (Plate 7 - Fig. 10, 11 & 12)

Lorica flexible, oval, not separated into dorsal and ventral plates; body slightly compressed dorsoventrally, anterior dorsal margin with four broad-based spines of variable length, medians longer than laterals; mental margin flexible, usually somewhat elevated, with shallow V- or U-shaped notch, unflanked; posterior spines present or absent; posterolateral spines usually absent; lorica smooth or lightly stippled.

Measurements

Length of lorica : 168-228 µm

Maximum width of lorica : 105-154 µm

B.caudatus Barrois and Daday,1894

Material: Many specimens from Narakkal (Plate 8 - Fig. 13)

Lorica firm, stippled, with a pattern of cuticular ridges, divided into dorsal and ventral plates, somewhat compressed dorsoventrally; anterodorsal margin with 2 median spines separated by V- or U-shaped notch; laterals mostly longer than medians; intermediate spines reduced or wanting; rarely all six occipital spines present; mental margin more or less straight or wavy; generally, posterolateral spines well developed;foot opening between bases of posterior spines and overhung by a triangular or rounded extension of dorsal plate.

Measurements

Length of lorica : 84-168 µm

Maximum width of lorica : 77-134 µm

B.falcatus Zacharias, 1898

Material: Several specimens from Harbour and Poothotta (Plate 8 - Fig. 14)

Lorica firm, lightly stippled, greatly compressed dorsoventrally and composed of dorsal and ventral plates; anterodorsal margin with six spines; intermediate spines considerably larger than laterals and medians, curve laterally outwards or ventrally towards head of the animal; median spines mostly equal to laterals but sometimes smaller; mental edge firm and wavy without spine and without elevation towards the centre; posterior spines widely separated basally, long, their width much more than anterior spines, parallel or bow outwards , converge, then twist towards their apices, thus completing full arch; foot opening between bases of posterior spines, subsquare hole in ventral plate; foot opening unflanked.

Measurements

Length of lorica : 126-182 µm

Maximum width of lorica : 110-140 µm

B.forficula Wiezejski, 1891

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Market canal and Poothotta (Plate 8 - Fig. 15 & 16)

Lorica firm, stippled, divided into dorsal and ventral plates, moderately compressed dorsoventrally; occipital margin with four spines; laterals always longer than medians; intermediate spines wanting; all occipital spines rounded at tips, rarely pointed;

mental margin rigid with two well-marked lobes; lorica terminates posteriorly in two stout, long and subsquare spines, widely separated basally and tapering to blunt points; geniculate swellings present at bases of posterior spines; foot opening between bases of posterior spines.

Measurements

Length of lorica : 84-119 μm

Maximum width of lorica : 63-112 μm

B.quadridentatus Hermann,1783

Material: Several specimens from Eloor, Harbour, Market canal and Mangalavanam (Plate 8 - Fig. 17 &18)

Lorica firm, moderately compressed dorsoventrally, and divided into dorsal and ventral plates; occipital margin with six spines; medians longest, curved outwards, and when extra long bent downwards over the head; laterals longer than intermediates; mental margin rigid, wavy, elevated, with median notch flanked on either side by a small tooth-like papilla; posterolateral spines usually present but their length varies; ventroposterior portion of lorica prolonged in form of tubular foot-sheath around base of retractile foot; sheath on dorsal side with well-defined subsquare piece.

Measurements

Length of lorica : 126-203 μm

Maximum width of lorica : 98-182 μm

B.patulus Muller, 1786

Material: Several specimens from Eloor and Poothotta (Plate 9 - Fig. 19 & 20)

Lorica firm, subrectanguar , somewhat compressed dorsoventrally, with a pattern of reticulate areolations as well as a simple pattern of ridges on the dorsal plate, both anterodorsal and anteroventral margins with spines, ten in number; occipital medians longest and curve overhead ventrally; pectoral medians shortest, straight; intermediates on both margins and laterals about equal in length; median notch between pectoral medians broader than notch separating occipital median spines; posteriorly, lorica terminates in two spines, foot opening bounded by two short spines, equal in length to posterolaterals or somewhat shorter; foot opening present in ventral plate, asymmetric in shape and position; posterior portion of lorica asymmetrical.

Measurements

Length of lorica : 128-154 µm

Maximum width of lorica : 98-112 µm

B.bidentata Anderson, 1889

Material: Several specimens from Cherai, Market canal and Poothotta (Plate 9 - Fig. 21)

Lorica firm, stippled, with definite pattern of plaques, divided into dorsal , ventral and basal plates; dorsal and ventral plates soldered together for three-fifths length of lorica, where they diverge and are united to a third plate, the basal plate; dorsal margin with six spines; lateral always longer than medians, medians longer than intermediates;

mental margin flexible, elevated in the middle; posterior spines vary in length and position of origin but may be absent; foot opening with foot-sheath.

Measurements

Length of lorica : 161-196 µm

Maximum width of lorica : 126-170 µm

B.mirabilis Daday, 1897

Material: Many specimens from Eloor (Plate 9 - Fig. 22, 23 & 24)

Lorica barrel-shaped, anterior dorsal margin with six well developed spines, medians longest and bent outwards , laterals slightly divergent, antero-median, postero-median, postero-lateral spines very long.

Measurements

Length of lorica : 147-230 µm

Maximum width of lorica : 87-131 µm

Genus: *Keratella* Bory de St. Vincent, 1822

Material: Several specimens from Vypeen, Puthuvypu, Cherai, Eloor, Harbour, Market canal and Poothotta (Plate 10 - Fig. 25, 26 & 27)

Lorica composed of dorsal and ventral plates; dorsal plate convex, sculptured with varying pattern for different species; ventral plate flat or slightly concave; both plates of lorica usually covered with fine areolate network and postulated; anterodorsal margin mostly with six(sometimes four) spines; mental margin rigid and rounded , with median notch; one or two posterior spines often present, when single usually median in position; head retractile and illoricate; foot wanting.

Genus: *Platyias* Harring, 1914

Material: Several specimens from Vypeen, Eloor and Poothotta (Plate 10 - Fig. 28 & 29)

Head illoricate, retractile in loricate body; lorica firm, broad, covers the trunk completely, separated into dorsal and ventral plates, moderately compressed dorsoventrally; anterodorsal margin with 2-6 spines;median spines longest; mental margin variable, with or without spines; posterior spines mostly present; foot non-retractile, joined, with two toes,without spine , foot and toes together shorter than lorica.

Genus: *Anuraeopsis* Lauterborn, 1900

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 10 - Fig. 30 and Plate 11 - Fig. 31)

Lorica flexible and thin, more or less cylindrical, rounded or obtusely pointed posteriorly, with no opening for foot, composed of a dorsal arched plate which may be sculptured and a ventral almost flat plate; lateral edges of these plates connected by flexible cuticular fold forming lateral sulci; anterodorsal margin with a shallow notch in the middle , without spine; mental margin smooth and slightly depressed in the middle.

FAMILY : MYTILINIDAE

Loricate rotifers, cross-sections of lorica mostly triangular or nearly rhombic; ventral plate and dorso-lateral plates firmly fused; long dorsum with or without sulcus, latter common with double keel; three or less foot sections; toes pointed, straight or slightly curved ventralwards.

The family is represented by a single genus, *Mytilina*, in the present work.

Genus: ***Mytilina*** Bory de St. Vincent,1836

Material: Several specimens from Eloor, Market canal and Poothotta (Plate 11 - Fig. 32 & 33)

Heavily loricate form with more or less barrel-shaped body; lorica of one piece, because dorsolaterals and ventral plate firmly fused but lorica with a longitudinal split along dorsum which forms dorsal sulcus; dorsolateral plates may project anteriorly as well as posteriorly in the form of anterolateral and posterolateral spines; foot with two well developed toes,without spur or spine; foot together with toes shorter than lorica.

FAMILY : EUCHLANIDAE

Body loricate, lorica with plates which are connected with sulci, a segmented foot more or less elongated toes.

The family is represented by two genera, *Euchlanis* and *Dipleuchlanis*, in the present work.

Genus: *Euchlanis* Ehrenberg, 1832

Material: Several specimens from Vypeen, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 11 - Fig. 34)

Lorica transparent, sometimes biconvex or vase-like , composed of a wide arched dorsal plate and a narrow flat ventral plate; dorsal and ventral plates united by flexible cuticular membrane forming lateral sulci; anterodorsal margin with V-shaped notch, foot segmented and projects through plates of the lorica posteriorly, with two long toes at the junction of last foot segment.

Genus: *Dipleuchlanis* Gosse, 1886

Material: Several specimens from Eloor, Market canal, Mangalavanam and Poothotta (Plate 11 - Fig. 35)

Body oval; lateral sulci separated by a flange of stiffed cuticle, dorsal plate concave, ventral plate convex; two toes on the posterior side, slender and long.

FAMILY : EPIPHANIDAE

Body soft; mouth in funnel-shaped buccal area; manubria of normal length, larger species; no real lorica, trophi malleate.

Represented by two genera, *Epiphanes* and *Microcodides* during the study.

Genus: ***Epiphanes*** Ehrenberg, 1832

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal and Poothotta (Plate 11 - Fig. 36 and Plate 12 - Fig. 37)

Body cone- or sac-shaped, transparent, soft, cuticula soft or very slightly stiffened, but no real lorica; foot present but varying in length with different species; toes small.

Genus: ***Microcodides*** Bergendal, 1892

Material: Many specimens from Market canal (Plate 12 - Fig. 38)

Body cylindrical, gradually tapering towards posterior end. Corona complex, with an outer band of cilia and an inner band of cilia, sometimes also with accessory rows of cilia and ciliated protuberances. Foot broad, short, segmented, with a single toe. Sometimes a small spur at the base of the toe.

FAMILY : COLURELLIDAE

Lorica thin and composed of dorsal and ventral plates; dorsoventrally or laterally compressed; corona with wide lateral lamellae; dorsal head shield present.

The family is represented by a single genus, *Lepadella* , in the present work.

Genus: ***Lepadella*** Bory de St. Vincent, 1826

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Market canal, Mangalavanam and Poothotta (Plate 12 - Fig.39 & 40)

Lorica thin, broadly ovate, slightly compressed dorsoventrally , composed of dorsal and ventral plates; anterodorsal margin of lorica without spine, concave, straight or slightly convex; anteroventral margin concave or with V-shaped notch; foot groove present on ventral plate, nearly as wide as long; foot jointed, distal joint longest, with two short pointed toes ; foot lies in a groove extending back from foot opening.

FAMILY : LECANIDAE

Heavily loricated forms; lorica composed of dorsal and ventral plates; corona mostly without pseudotrochus , buccal field supra-oral; mouth not funnel-shaped; foot with one or two toes.

Under this family, two genera namely *Lecane* and *Monostyla* were recorded during the present study

Genus: ***Lecane*** Nitzsch, 1827

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 12 - Fig. 41 & 42 and Plate 13 - Fig. 43)

Lorica oval to shield shaped, composed of dorsal and ventral plates, foot projects through the hole in ventral plate near posterior end,bearing two toes, separated,rarely fused at the base.

Genus: ***Monostyla*** Ehrenberg, 1830

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 13 - Fig. 44, 45, 46 & 47)

Lorica firm, broadly ovate, not compressed dorsoventrally , composed of dorsal and ventral plate, separated by flexible membrane; anterodorsal margin straight or concave with a deep notch and sometimes flanked by spines; anteroventral margin mostly with V-shaped , sometimes U-shaped shallow or deep notch; foot with single slender toe of uniform thickness that projects through a hole in the ventral plate near posterior end; claw acutely pointed, sometimes with two basal spicules.

FAMILY : NOTOMMATIDAE

Lorica thin, cylindrical or elongated; corona composed of simple cilia primarily forming a marginal wreath adapted for propulsion, enclosing the thin ciliated apical area, a buccal plate which is evenly ciliated. Foot with two long or short toes.

The family is represented by two genera, *Cephalodella* and *Scaridium* in the present work.

Genus: ***Cephalodella*** Bory de St. Vincent,1826

Material: Several specimens from Vypeen, Puthuvypu, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 13 - Fig. 48)

Lorica delicate, made up of several fairly flexible pieces. They are fusiform notommatid rotifers of various shapes, from elongate to short and stumpy; occasionally illoricate; foot short; toes curved, short to long.

Genus: ***Scaridium*** Ehrenberg, 1830

Material: Many specimens from Cherai and Poothotta (Plate 14 - Fig. 49)

Body cylindric, dorsum of the lorica not bulging; foot 3-segmented and very long, foot and toes together longer than the lorica.

FAMILY : TRICHOCERCIDAE

Lorica poorly developed, flexible, in some with few longitudinal folds or may be twisted; corona frontal, circumapical band dispersed in to laterodorsal and lateroventral arcs, apical area with one or more protuberances accompanied by other papillae and tactile setae; foot with two unequal toes; mastax virgate, generally asymmetric.

The family is represented by a single genus, *Trichocerca*, in the present account.

Genus: *Trichocerca* Lamarck, 1801

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 14 - Fig. 50 & 51)

Lorica elongated, cylindrical or twisted; or short, humped and compact; anterior spines and dorsal striated area with crest not uncommon; asymmetric body; foot small and jointed; toes unequal, needle shaped and often overlap.

FAMILY : SYNCHAETIDAE

Body in some , with flattened cuticular appendages; corona with several prominences, each bearing setae or a long pencil of cilia ; auricles generally present, foot reduced or absent.

Represented by a single genus, *Polyarthra* in the present work.

Genus: *Polyarthra* Ehrenberg, 1834

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 14 - Fig. 52 & 53)

Body more or less oval or subsquare, with flattened cuticular appendages('paddles') attached in four groups to dorsolateral and ventrolateral surfaces near anterior end; in addition setiform projections may be present in some.

FAMILY : DICRANOPHORIDAE

Mastax forcipate, protrusible. Corona under a hook-like rostrum; mouth almost in centre of corona. Lateral tufts like auricles. Forms illoricate or partly loricate.

The family is represented by a single genus, *Encentrum,* in the present study.

Genus: *Encentrum* Ehrenberg ,1838

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Harbour, Market canal, Mangalavanam and Poothotta (Plate 14 - Fig. 54)

Body nearly cylindrical, usually illoricate or only partially loricated; corona oblique, rostrum conspicuous, foot much shorter.

ORDER : FLOSCULARIACEA

Monogononta with circumapical corona generally differentiated into trochal and cingular circlets and possessing a malleoramate trophi. Foot without toes. Free swimming but mostly sessile forms.

Of the 6 families under the order, there were the presence of three families during the present study.

FAMILY : HEXARTHRIDAE

Body illoricate, six arm-like appendages with setae; foot absent.

Genus: ***Hexarthra*** Schmarda,1854

Material: Several specimens from Puthuvypu, Narakkal, Eloor, Harbour and Poothotta (Plate 15 - Fig. 55 & 56)

Body cone or bell shaped; processes arm like, bear bristles, six in number – two laterodorsal, two lateroventral, one dorsal, and one ventral which is prominently long; caudal processes two .

FAMILY : FILINIIDAE

Body illoricate, two anterior and one or two posterior setae, foot absent.

Genus: ***Filinia*** Bory de St. Vincent, 1824

Material: Several specimens from Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Mangalavanam and Poothotta (Plate 15 - Fig. 57 & 58)

Lorica thin, flexible, fusiform, barrel-shaped or cup-shaped; appendages/spines long setiform extensions of cuticle, movable; two anterolateral spines and one posterior spine, may be terminal or lateral, and additional posterior small spine present in some; foot wanting.

FAMILY : TESTUDINELLIDAE

Creeping , semipelagial forms; body with lorica, cylindrical, circular or oval without any appendages. Foot if present, tubiform and terminally ciliated.

PLATE 6

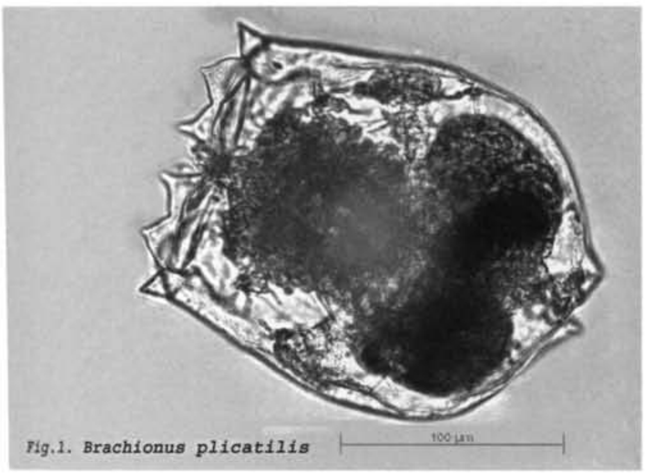


Fig.1. Brachionus plicatilis

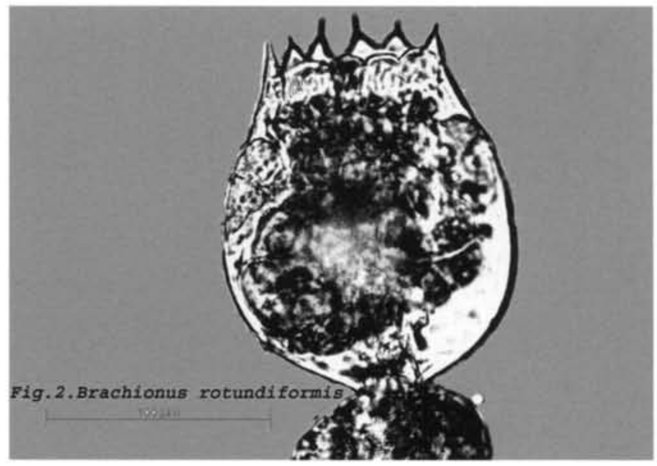


Fig.2.Brachionus rotundiformis

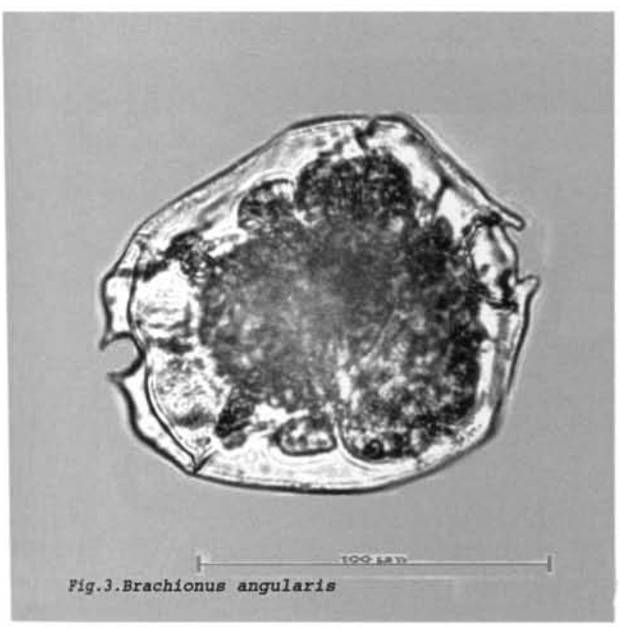


Fig.3.Brachionus angularis

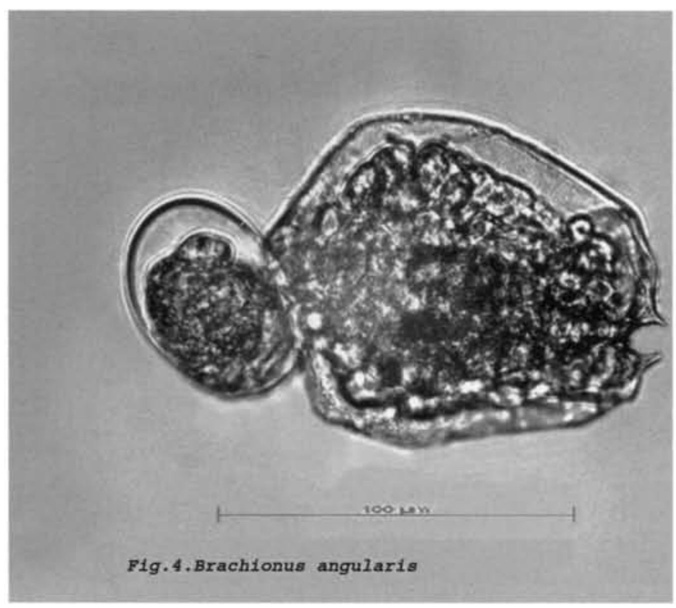


Fig.4.Brachionus angularis

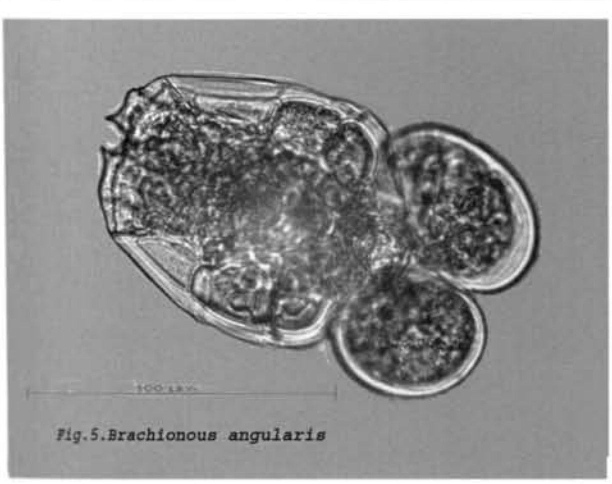


Fig.5.Brachionous angularis

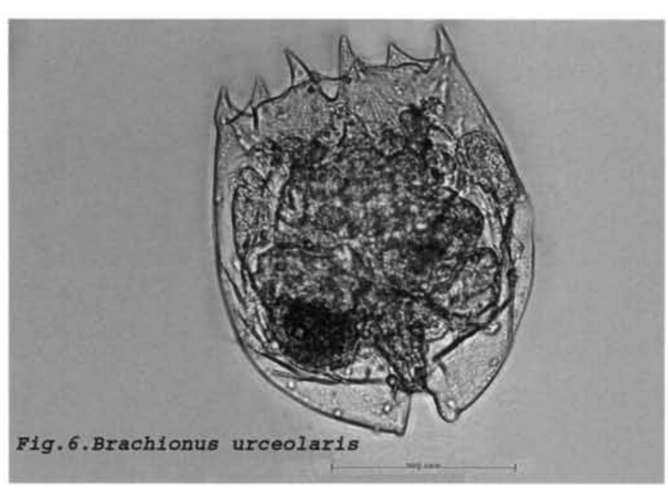


Fig.6.Brachionus urceolaris

PLATE 7

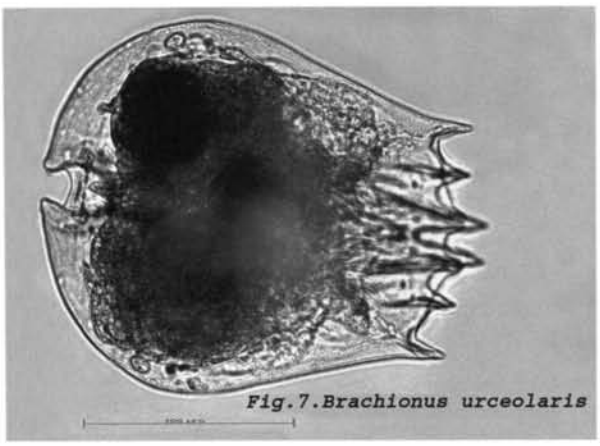


Fig.7.Brachionus urceolaris

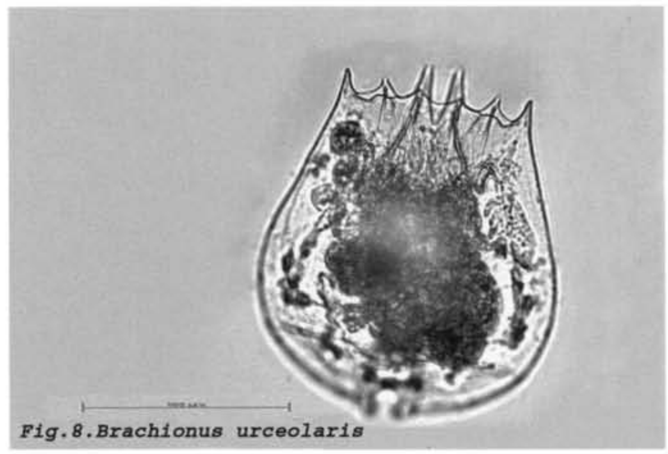


Fig.8.Brachionus urceolaris

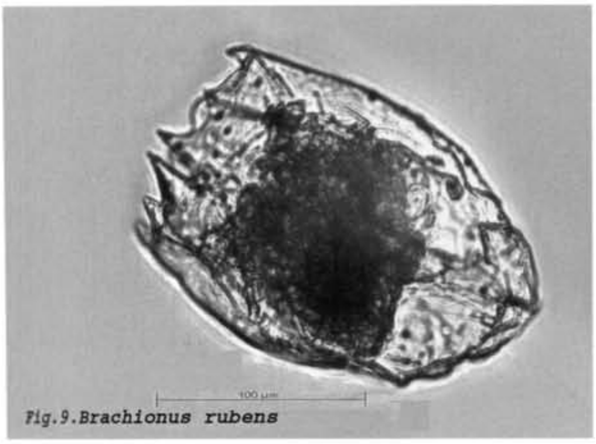


Fig.9.Brachionus rubens

Fig.10.Brachionus calyciflorus

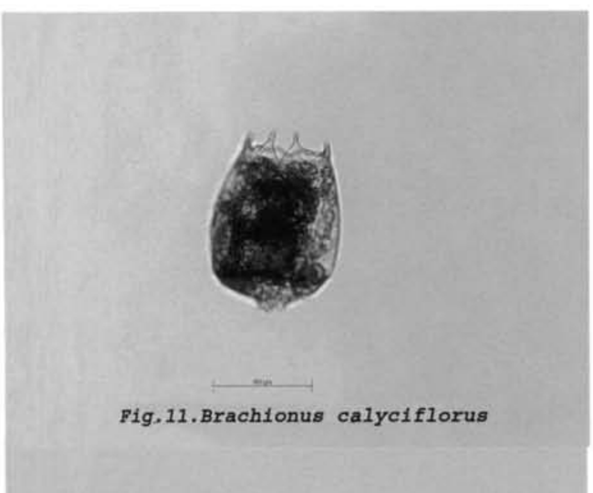


Fig.11.Brachionus calyciflorus

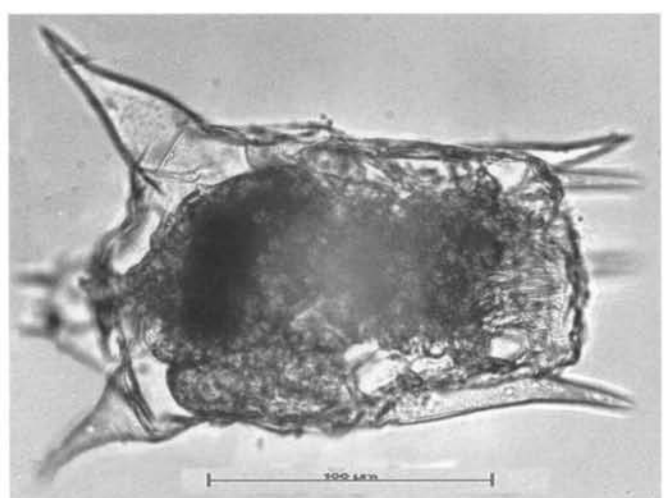


Fig.12.Brachionus calyciflorus

PLATE 8

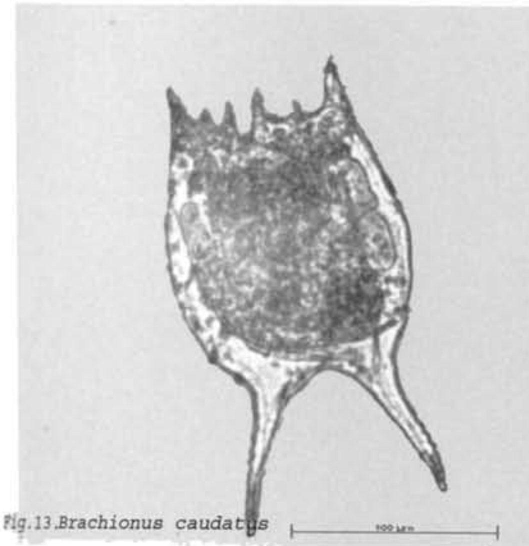


Fig.13.Brachionus caudatus

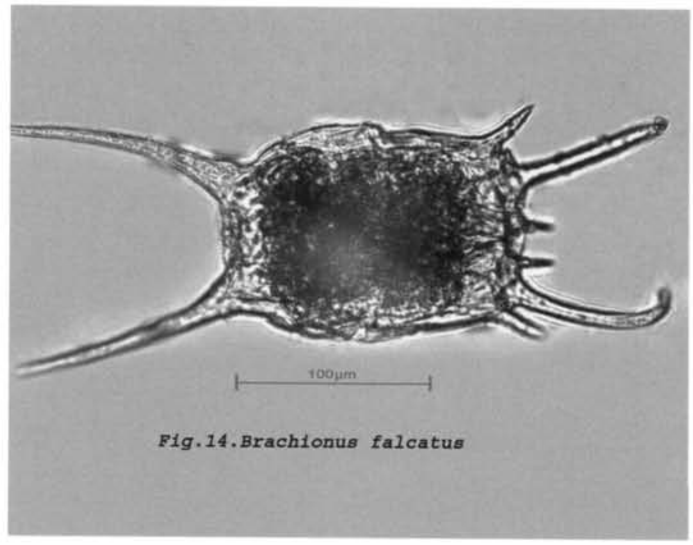


Fig.14.Brachionus falcatus

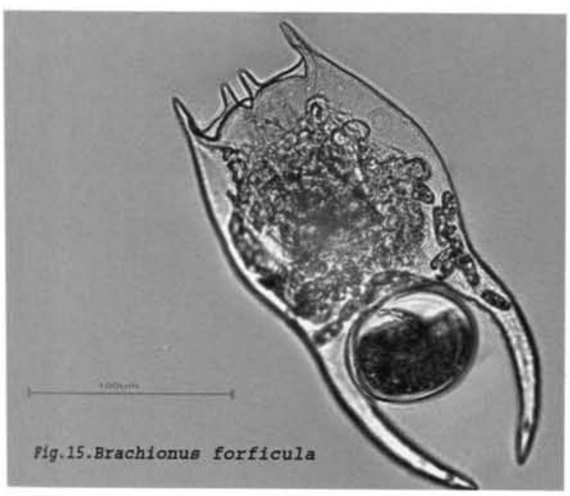


Fig.15.Brachionus forficula

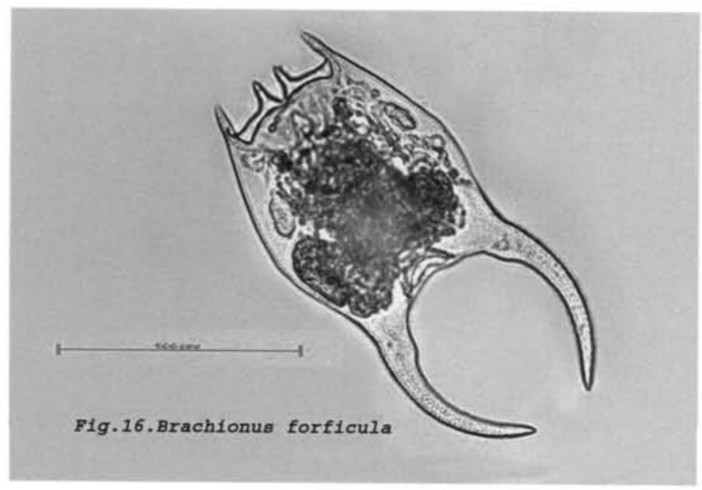


Fig.16.Brachionus forficula

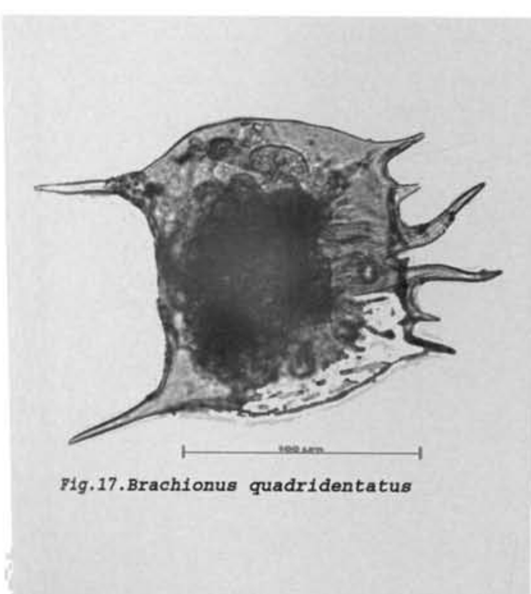


Fig.17.Brachionus quadridentatus

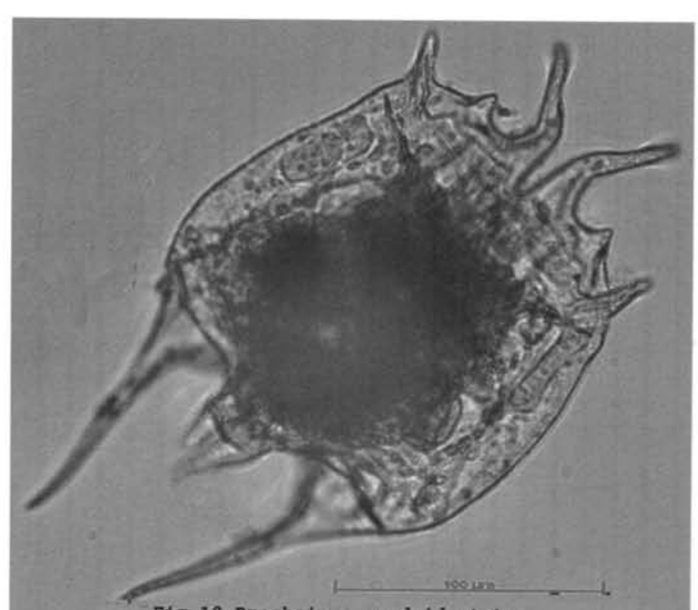


Fig.18.Brachoinus quadridentatus

PLATE 9

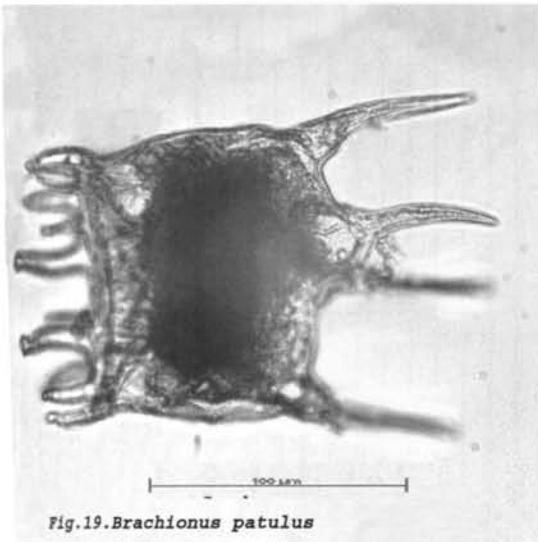


Fig.19.Brachionus patulus

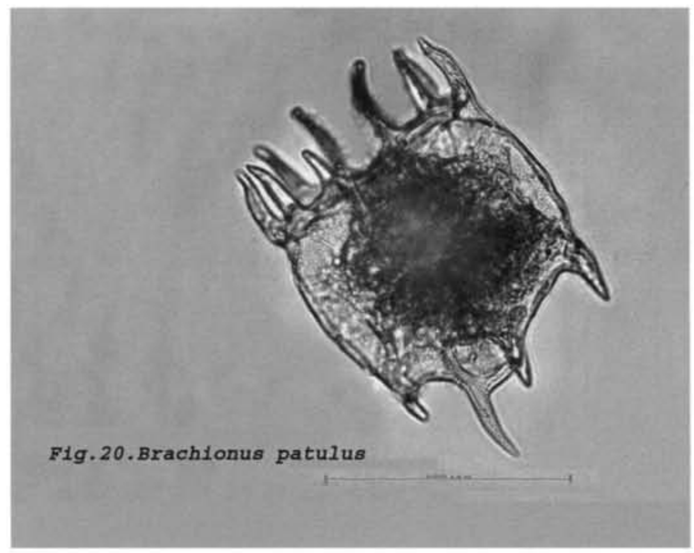


Fig.20.Brachionus patulus

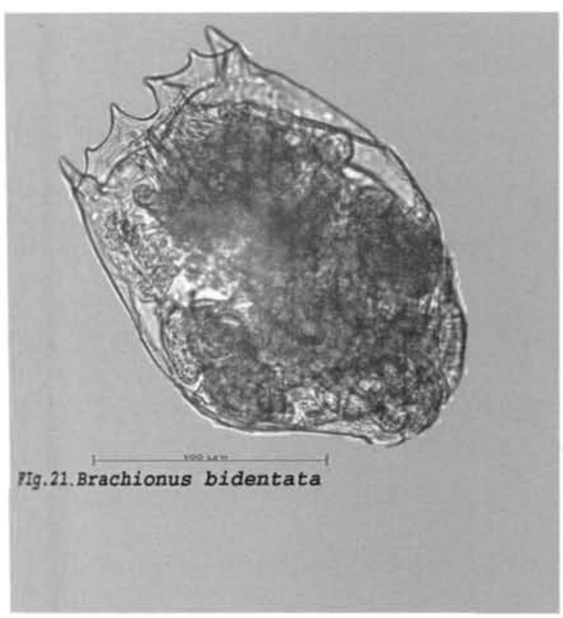


Fig.21.Brachionus bidentata

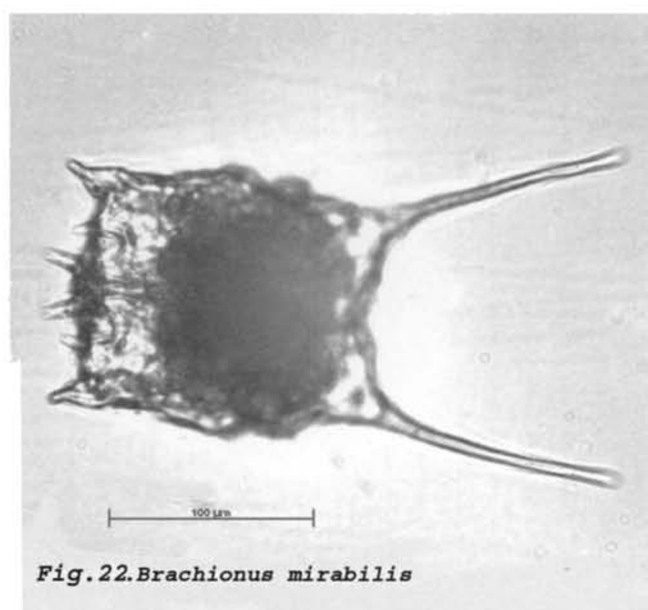


Fig.22.Brachionus mirabilis

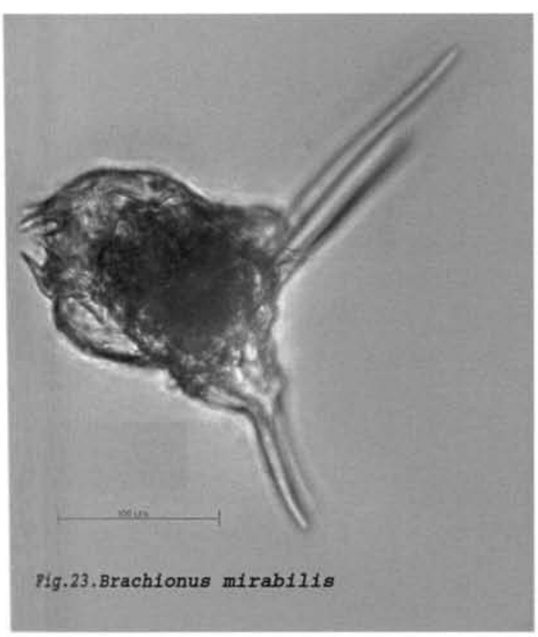


Fig.23.Brachionus mirabilis

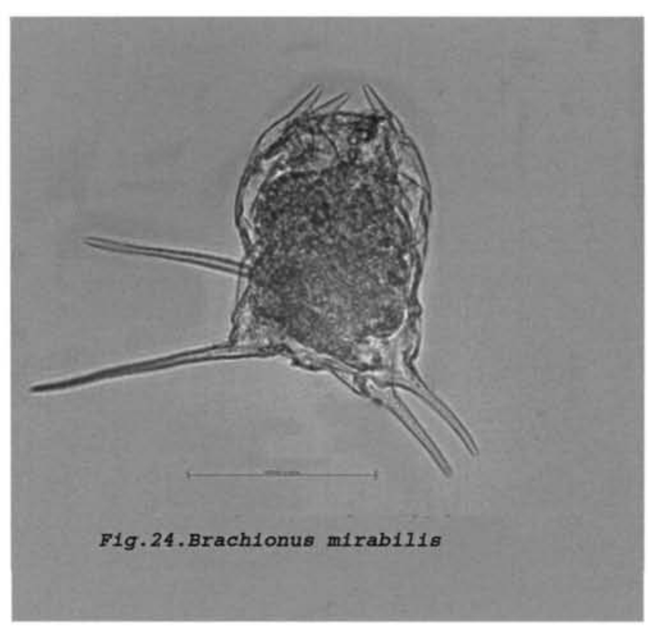


Fig.24.Brachionus mirabilis

PLATE 10

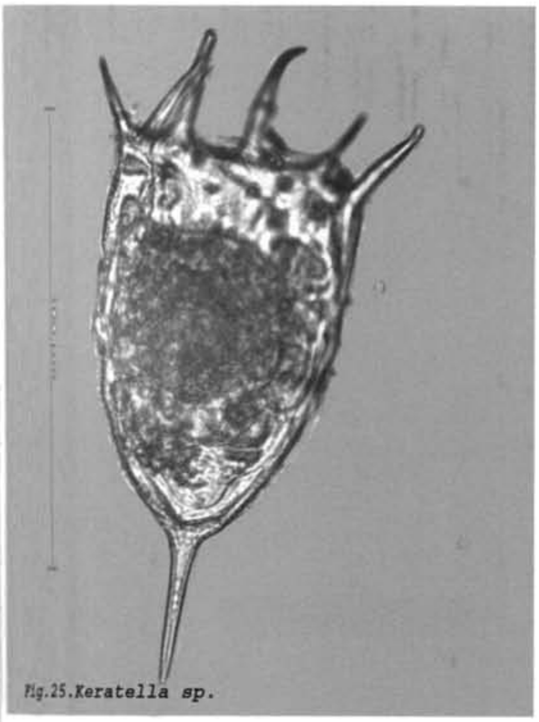
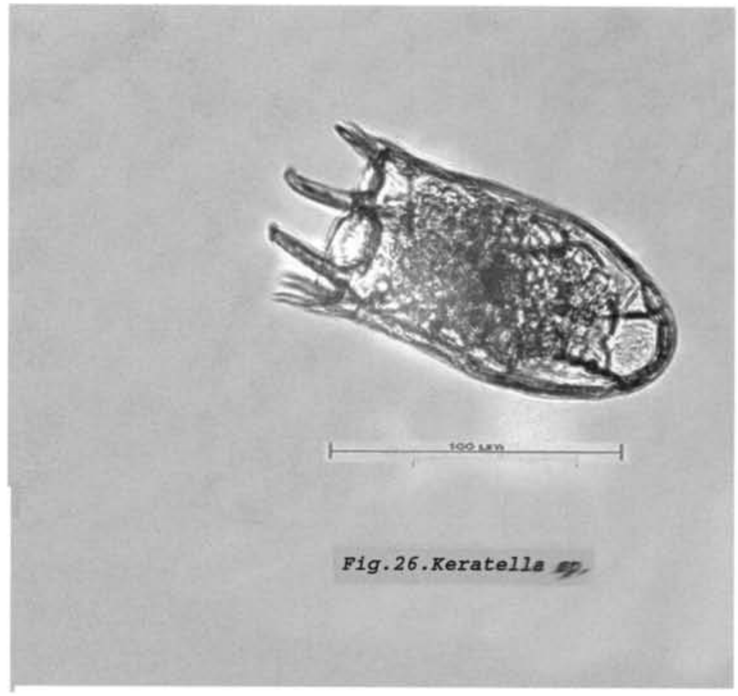


Fig.25.Keratella sp.



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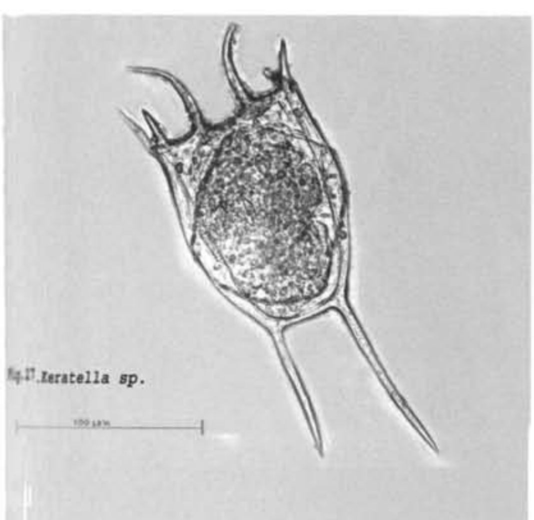

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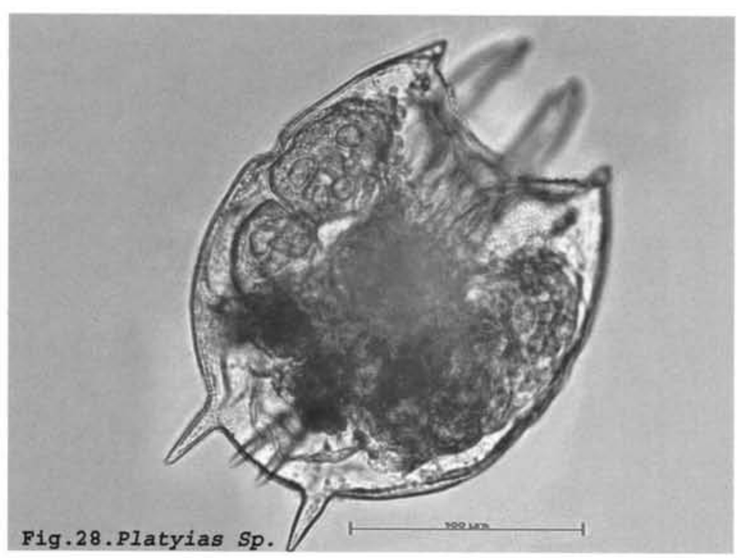
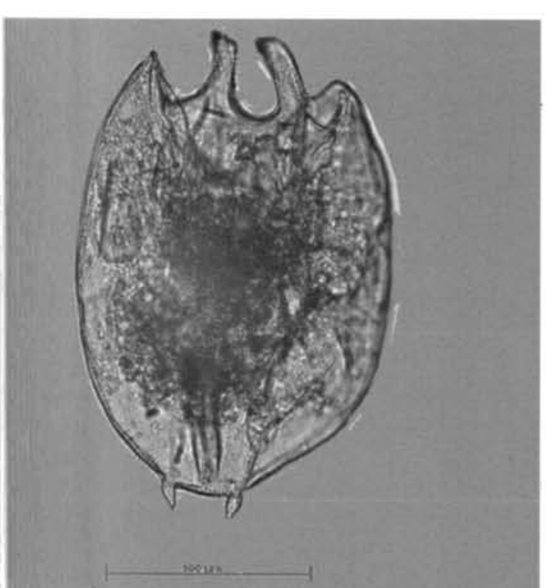


Fig.28.Platyias Sp.



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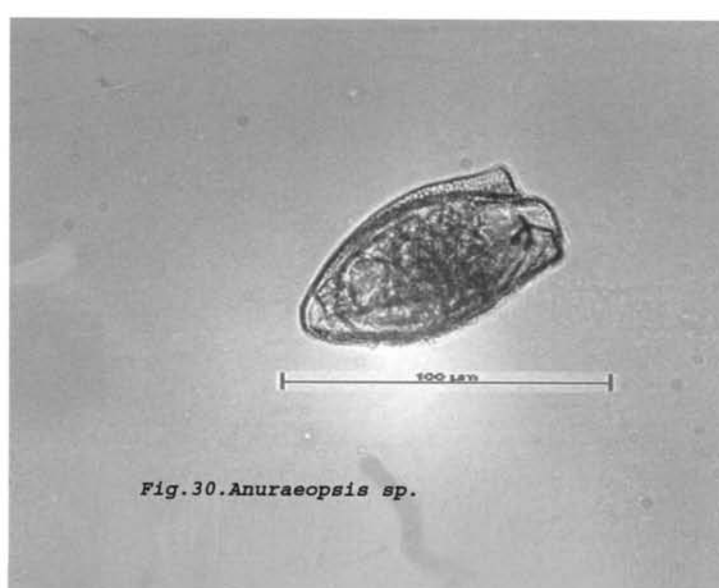


Fig.30.Anuraeopsis sp.

PLATE 11

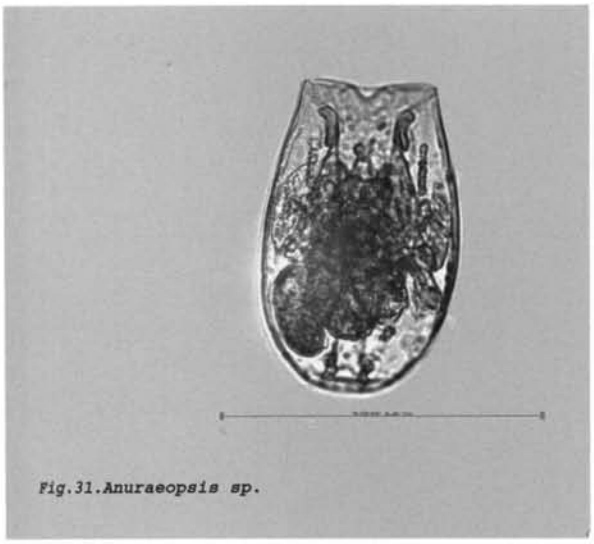


Fig.31.*Anuraeopsis sp.*

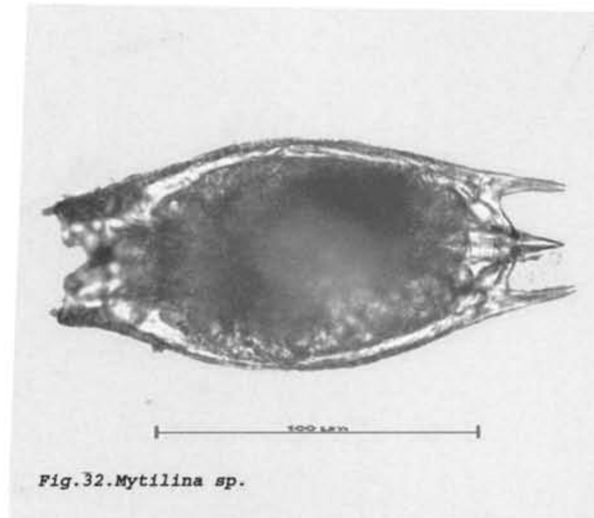


Fig.32.*Mytilina sp.*

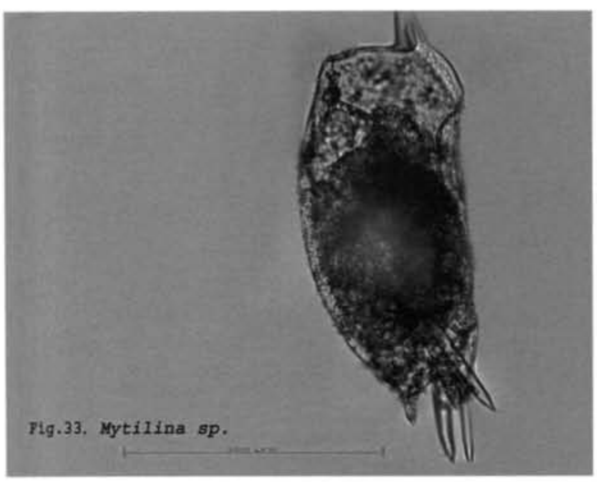


Fig.33. *Mytilina sp.*

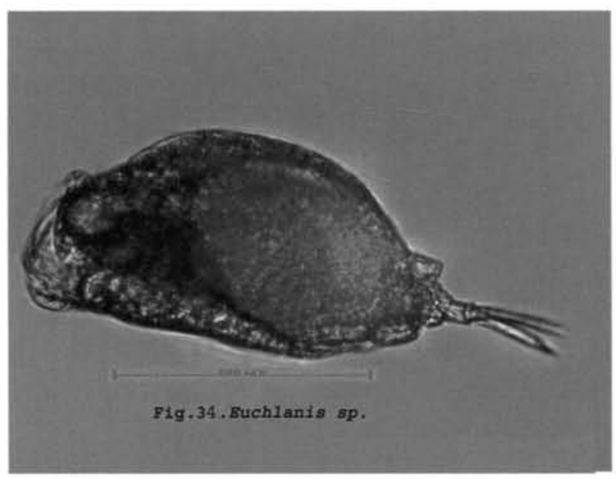


Fig.34.*Euchlanis sp.*

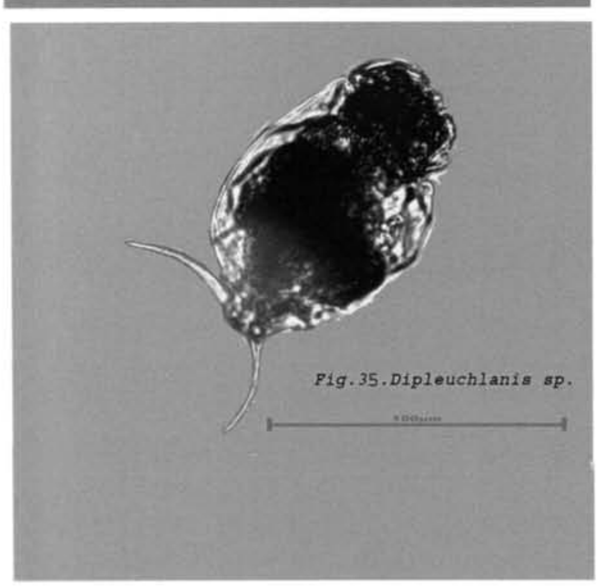


Fig.35.*Dipleuchlanis sp.*

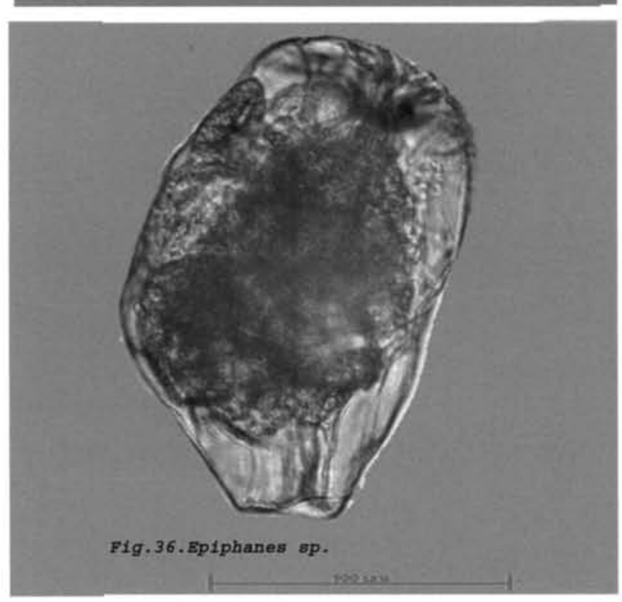


Fig.36.*Epiphanes sp.*

PLATE 12

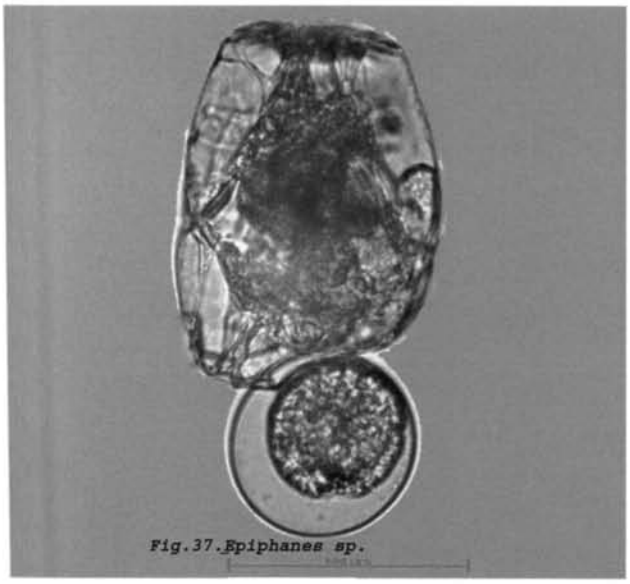


Fig.37.Epiphanes sp.

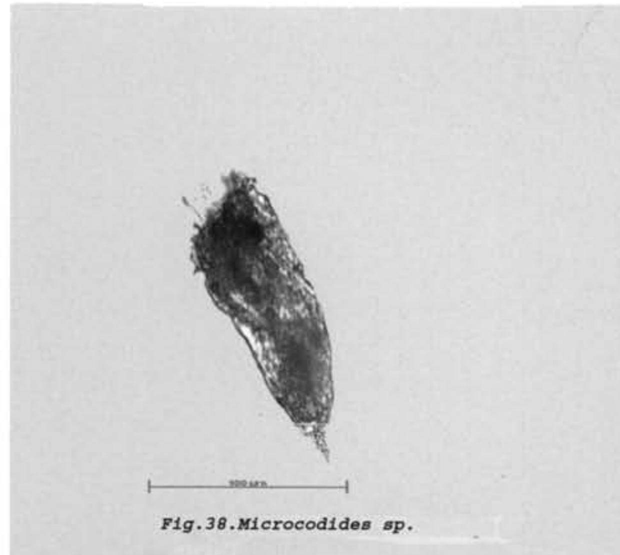


Fig.38.Microcodides sp.

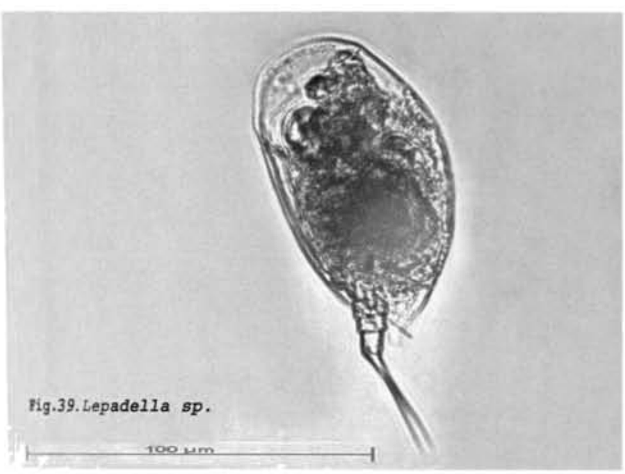


Fig.39.Lepadella sp.

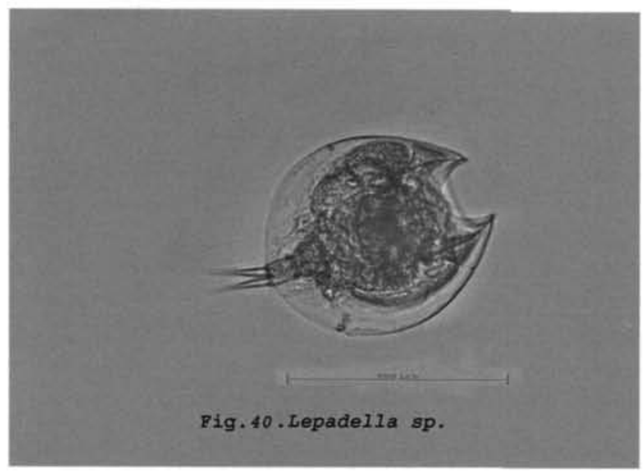


Fig.40.Lepadella sp.

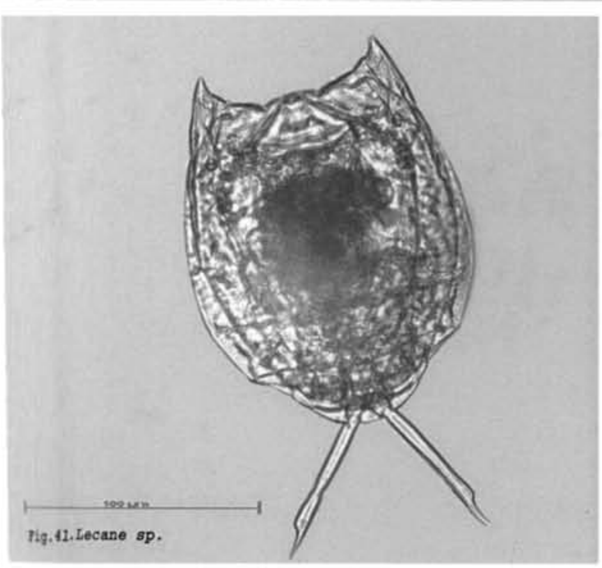


Fig.41.Lecane sp.

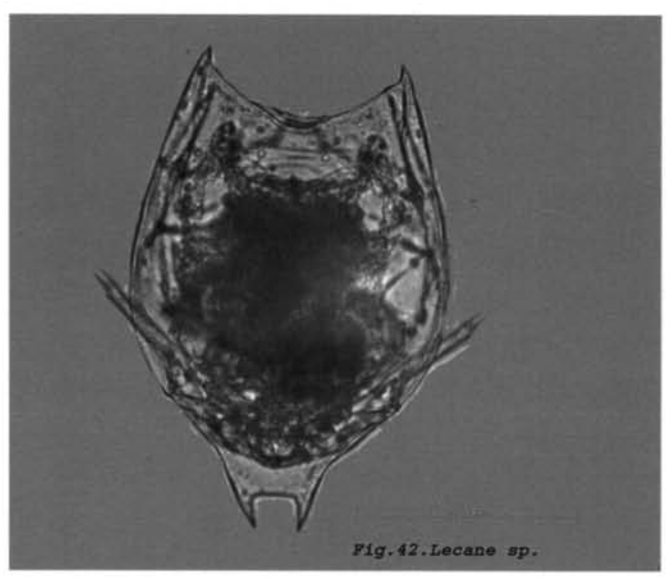


Fig.42.Lecane sp.

PLATE 13

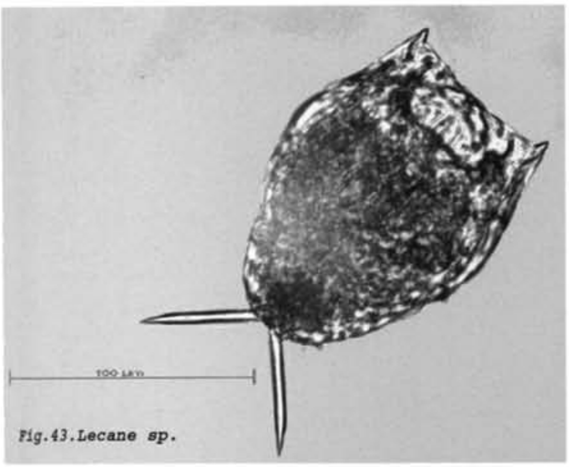


Fig.43.Lecane sp.

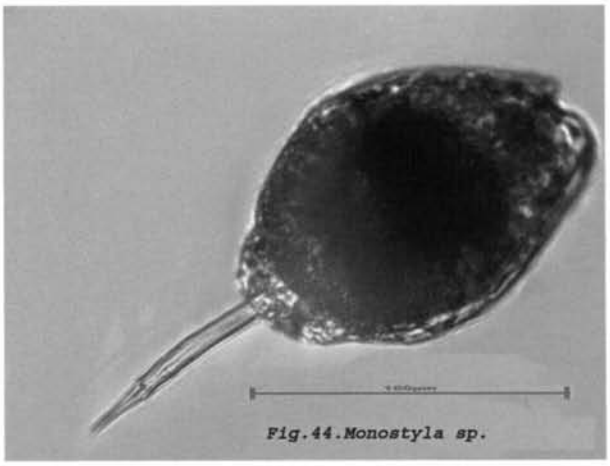


Fig.44.Monostyla sp.

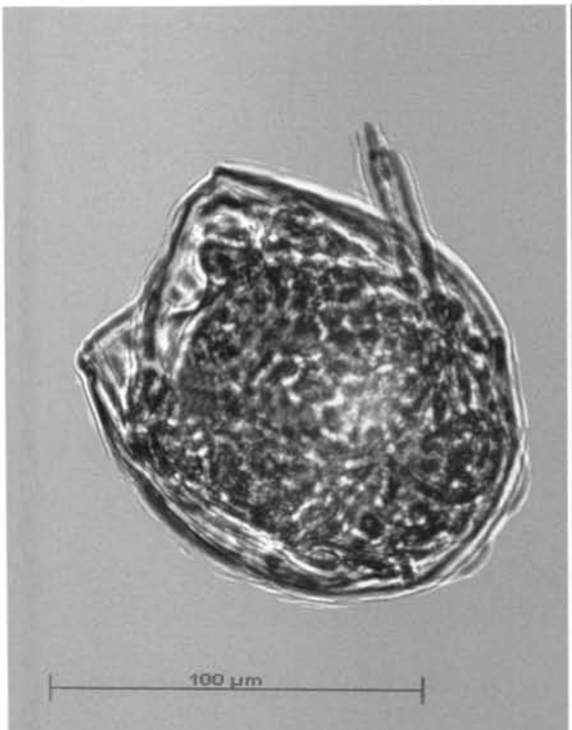


Fig.45.Monostyla sp.

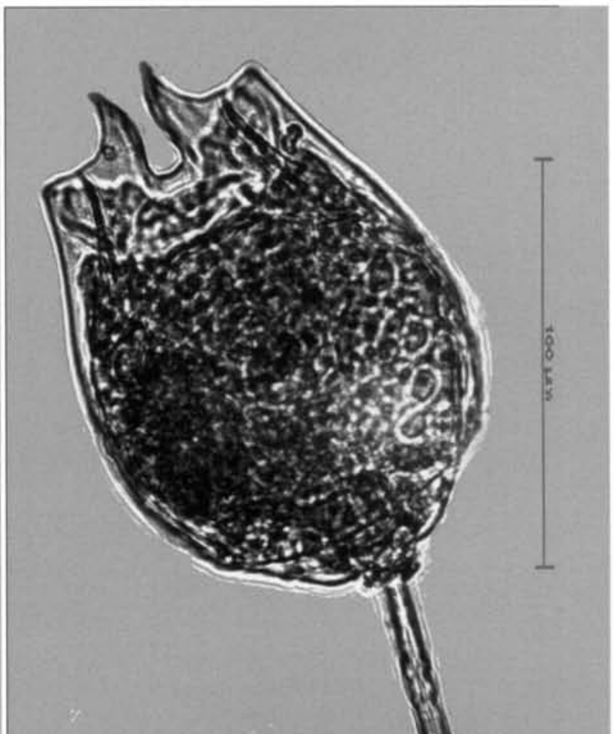


Fig.46.Monostyla sp.

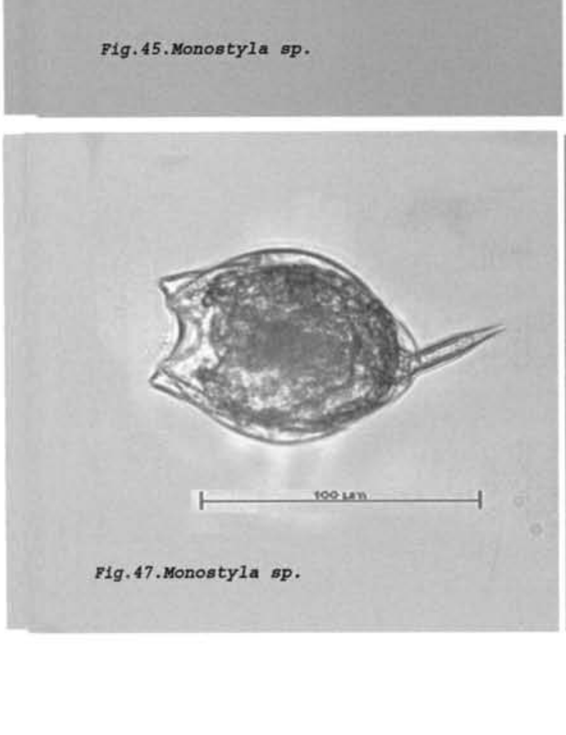


Fig.47.Monostyla sp.

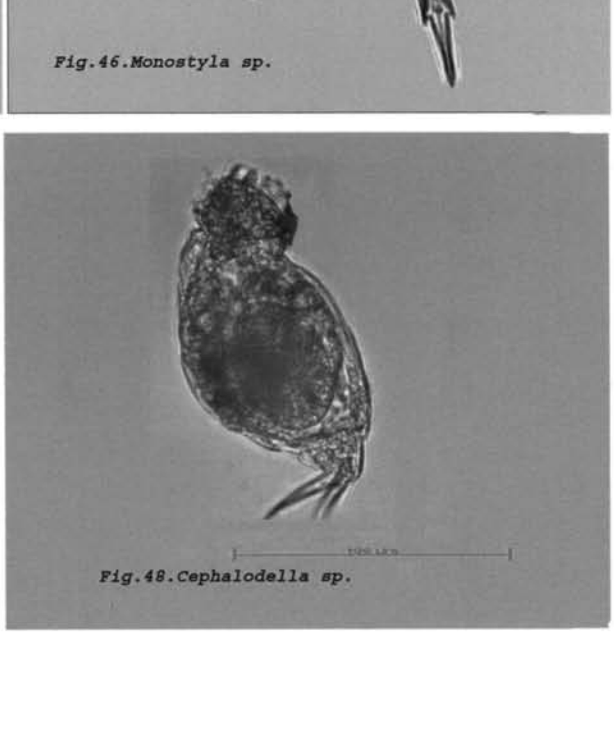


Fig.48.Cephalodella sp.

PLATE 14

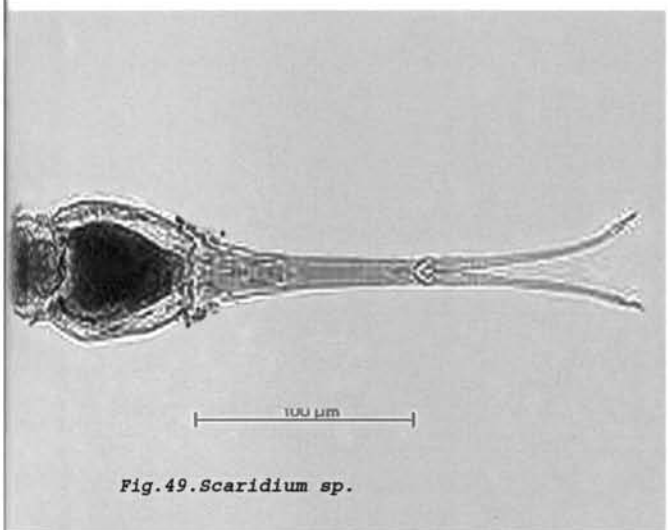


Fig.49.Scaridium sp.

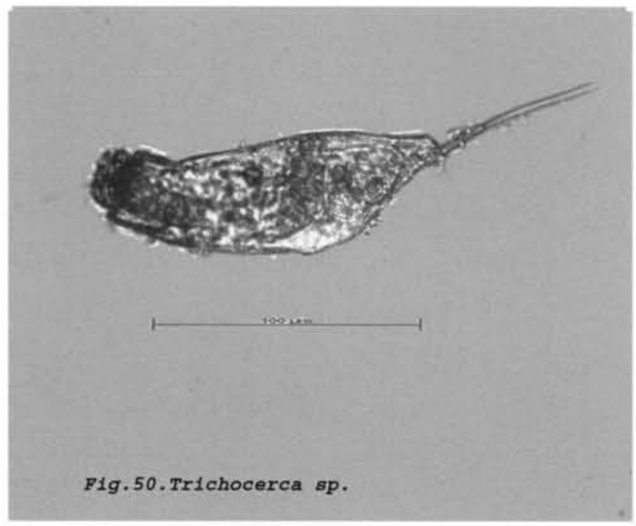


Fig.50.Trichocerca sp.

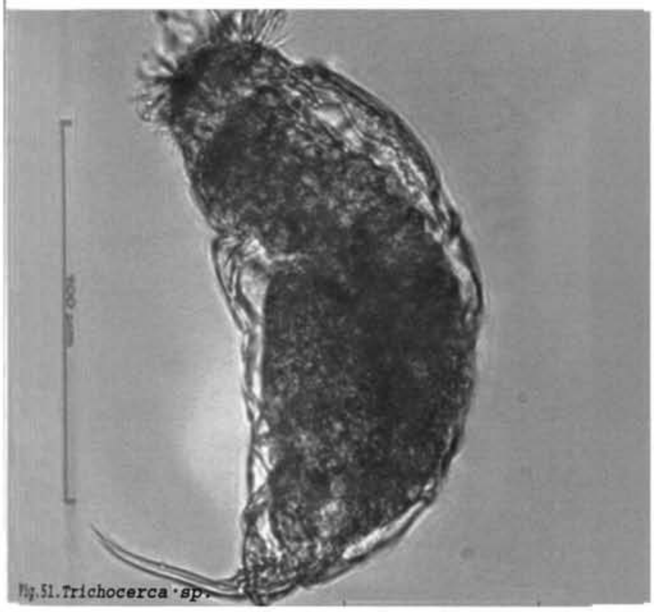


Fig.51.Trichocerca sp.

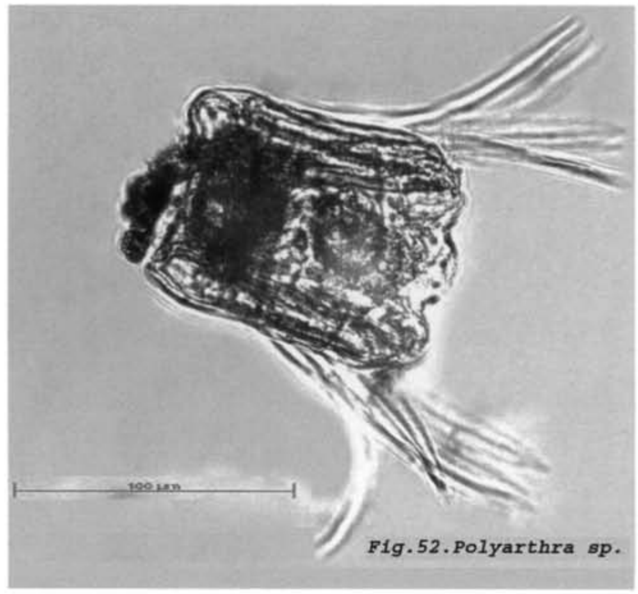


Fig.52.Polyarthra sp.

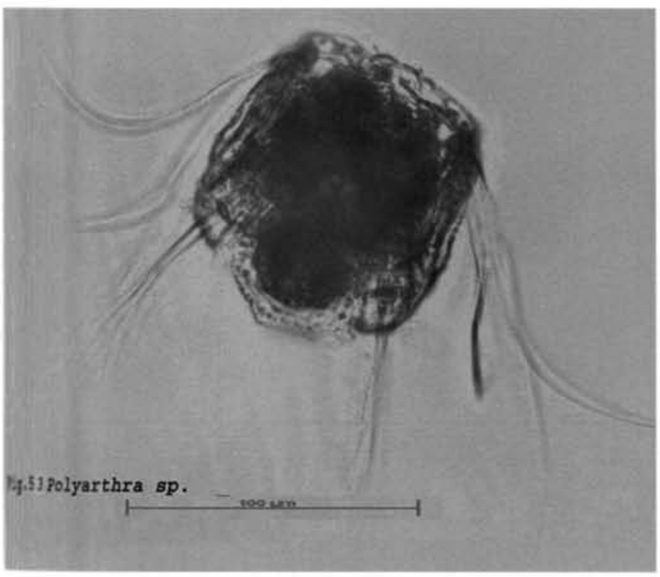


Fig.53 Polyarthra sp.

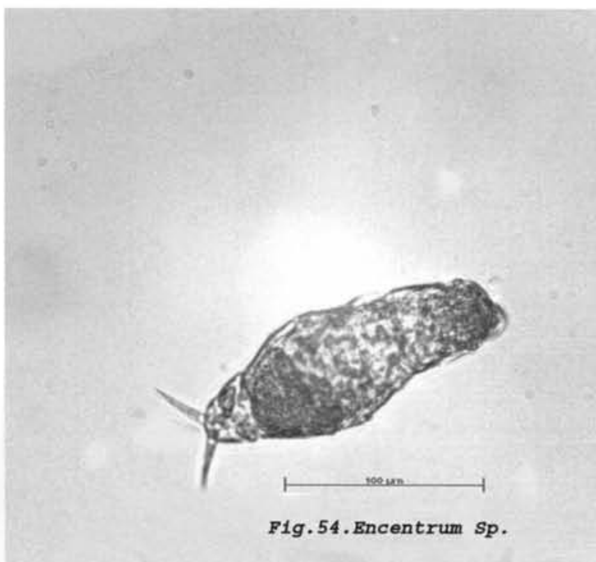


Fig.54.Encentrum Sp.

PLATE 15

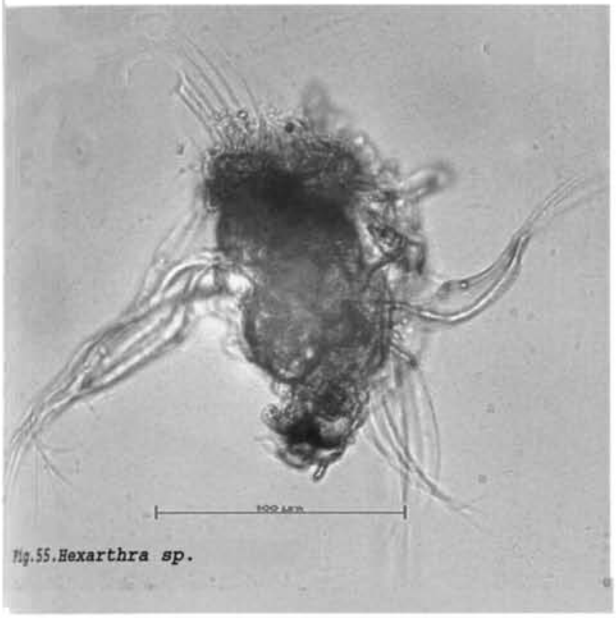


Fig.55.Hexarthra sp.

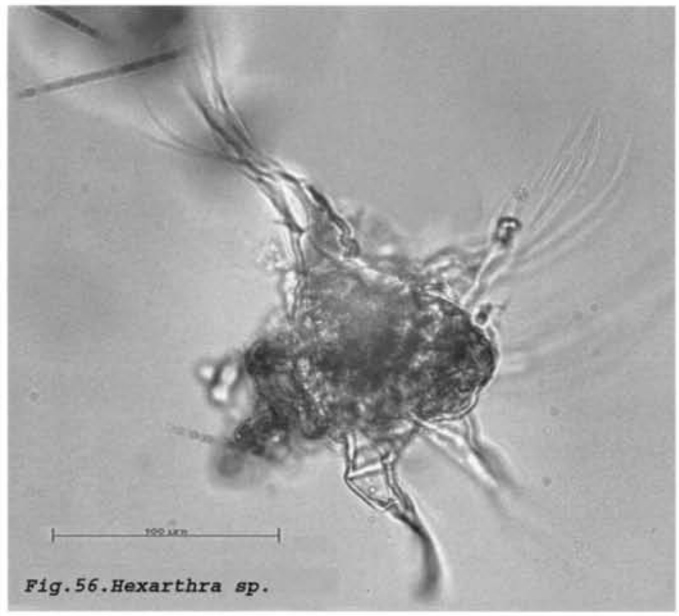


Fig.56.Hexarthra sp.

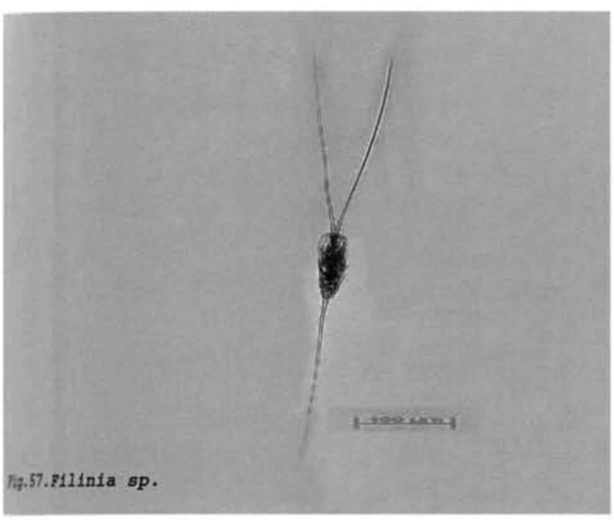


Fig.57.Filinia sp.

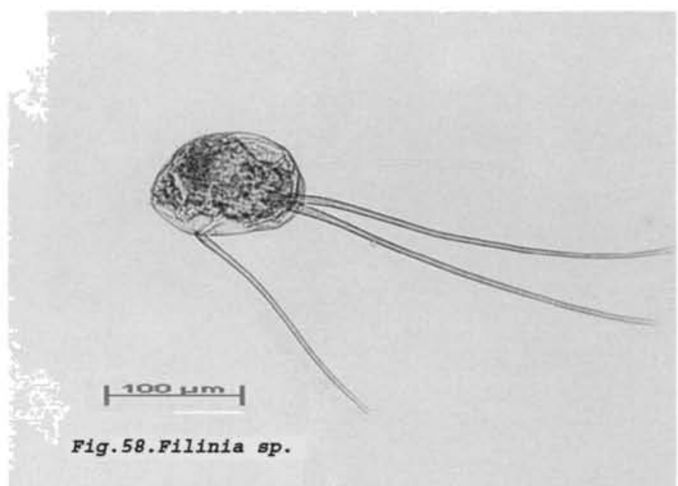


Fig.58.Filinia sp.

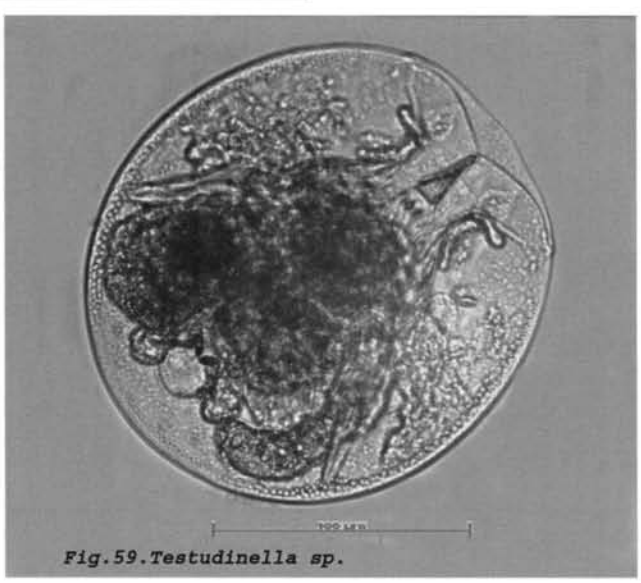


Fig.59.Testudinella sp.

DISCUSSION

The taxonomic investigations on rotifers date back to 18th century. Many researchers have recorded rotifers from different parts of the world, several classifications have been proposed and revised. Many genera, species, subspecies and different ecomorphs have been added to the rotifer fauna. The number of species recorded all over the world reached 1817 (Segers, 2002). A record of 310 species of rotifers belonging to 60 genera under 24 families have been reported from India(Sharma, 1991). Segers *et al.*(1994) added 15 species and hence the total record of rotifer species from India reached 325. According to Sharma(1991), only 24 species were reported from Kerala. Later, Anuradha Rammohan(1996), Gopakumar(1998) and Anitha(2003) recorded 25, 30 and 44 species of rotifers respectively from southern Kerala. The 44 species reported by Anitha(2003) and 30 species recorded by Gopakumar(1998) represented 16 genera; the former author observed 13 families and latter documented 12 families.

During the present investigation, 20 genera of rotifers belonging to 13 families have been recorded from central part of Kerala. Among the 13 families reported, a maximum of 4 genera have been recorded under the family Brachionidae. According to Sharma(1987a), 5 genera namely, *Brachionus, Keratella, Platyias, Anuraeopsis* and *Notholca* are represented in the family Brachionidae in India. But, the genus *Notholca* was not observed during the present study. Green(1972), and Chengalath *et al.*(1974) have shown the absence or near absence of the boreal genus *Notholca* to be characteristic of many tropical waters. Thus, in India, the genus *Notholca* was reported from very few places with low temperature regimes – Ladak and Kashmir(Edmondson and Hutchinson, 1934), Mansbal lake in Kashmir(Qadri and Yousuf, 1982), Anchar lake in

Kashmir(Balkhi *et al.*,1984) and from Yamuna river near Wazirabad, Delhi in November at 16°C(Sarma, 1988).

Under the genus *Brachionus*, 13 species are reported during the present study. It is worthwhile to mention that Gopakumar(1998) reported 12 species while Anitha(2003) documented 14 species under the genus *Brachionus* from southern part of Kerala. The abundance of *Brachionus* species in tropical rotifer fauna has been pointed out by Green(1972), Chengalath *et al.*(1974), Pejler(1977) and Fernando(1980). According to Sharma(1983) " twenty species of *Brachionus* have so far been reported from India which is the highest number from South-East Asia". Thus , the present study is in agreement with the above findings and there are chances for the availability of more number of *Brachionus* species from Kerala.

Among the 13 species of *Brachionus* recorded during the present study, *Brachionus angularis* was the smallest species in size. Among the 20 genera available in this area, the smallest one is the genus *Anuraeopsis*. The smaller size and their shape may enable them to be used as suitable live feeds for the larvae having small mouth opening, which in turn may lead to higher survival rate and enhanced fish production. Hence, further studies in this direction is recommended.

Out of the 60 genera reported from India, only 20 are recorded from backwaters of Kerala during the present investigation, which formed only 33.33%. As the state of Kerala is having several water bodies ranging from freshwater to brakishwater, and their numerous tributaries suitable for the growth of rotifers, and most of the water bodies are unexplored in relation to systematic studies on rotifers, further studies in this direction are highly necessitated.

CHAPTER 2

DISTRIBUTION AND ECOLOGY OF ROTIFERS IN THE SELECTED BIOTOPES

INTRODUCTION

The faunal studies on rotifers and their distribution in different parts of the world have started as early as in 18^{th} century. Realising the importance of rotifers, the studies took momentum and lot of work in this line had been undertaken in 20^{th} century. Rotifers form an important link in the food chain of most finfishes and shell fishes in the aquatic ecosystem. They constitute a considerable portion of the total zooplankton population(Herzig, 1987), since they reproduce parthenogenetically and are capable of existing in dense concentrations. During the course of an year, these organisms are exposed to a variety of changes in the physical, chemical and biological characteristics of the environment in which they live. Some of the minor ecological changes may not affect the rotifer community, as they are capable of acclimatization or modifying their position in the water column. But, certain other changes can affect the rotifer assemblages in the ecosystem. In adverse conditions, rotifers may produce resting eggs and, again, when environmental features become favourable, they can be hatched and amictic females capable of multiplying parthenogenetically, can be produced. The trophic status and rotifer assemblages of an ecosystem are very much related(Nogrady, 1988; Kaushik and Saksena,1995). Since rotifers play an important role in the ecosystem, the ecological investigations on rotifers also gained importance. The level of tolerance and optimum values of different environmental variables that influence the population dynamics of a species of rotifer vary with its geographical distribution (Ahlstrom,1933; Edmondson,1944; Green,1960; Hutchinson,1967). Hence, several researchers studied the ecology of rotifers in different ecosystems. A review on the works already carried out on rotifer fauna, their distribution and ecology are given below.

As early as in 1967, Sudzuki recorded the rotifers from South Australia. The salinity tolerance and osmotic behavior of animals in marine waters were explained by Bayly(1972). The adaptation of rotifers to seasonal variation was discussed by King(1972). Ecological studies on rotifers of near bottom zone of lakes Mikolajskie and Taltowisko were initiated by Klimowicz(1972). Following this, Gilbert(1973) examined the induction and ecological significance of gigantism in the rotifer *Asplanchna sieboldi*. Daems and Dumont(1973) made some interesting remarks on rotifers from the periphyton in Central Belgium. A pelagic rotifer, *Horaella thomassoni* was reported from the Guiana-Brazilian region of Neotropis by Koste(1973). Halbach(1973) made a quantitative study on the rotifer associations in ponds of Germany. Ruttner-Kolisko(1974) pointed out that the variations in the forms of a rotifer species could be influenced by the environmental characteristics prevailing in the area. She applied the theory of 'Formenkreise'(Rensch,1929) to correlate the morphological features with that of the environmental factors. She had clearly illustrated this view by taking *Keratella cochlearis* as an example; its different forms are correlated with salinity, temperature, turbulence and eutrophy. Lindstrom and Pejler(1975) could undertake an experimental study on the seasonal variation of the rotifer, *Keratella cochlearis* in lake Erken in central Sweden. The distribution and biology of *Asplanchna henrietta* in the lower reaches and delta of the Volga was studied by Chujkov(1976). Canadian rotifers were investigated by Nogrady(1976), while rotifers of Rio de Oro(North-Western Sahara) were studied by Dumont and Coussement(1976). Coussement(1976) investigated the rotifer fauna of the

Donk Lake, Belgium. Daems and Dumont(1976) studied rotifers of Nepal, described a new species of *Scaridium* and discussed the Nepalese representatives of the genus *Hexarthra*. De- Ridder(1977) studied the rotifer fauna of Curacao and other Caribbean islands. Pejler(1977) gave an account on the global distribution of the family Brachionidae. The cyclomorphosis of some brachionids of the central Amazon was investigated by Schaden(1977). Kabay and Gilbert(1978) studied the rotifer, *Asplanchna sieboldi*-its insensitivity of the body wall outgrowth response to temperature, food density, pH and osmolarity differences. Marsh *et al.*(1978) described cyclomorphosis of *Keratella cochlearis* while studying the rotifer population in a southeast Texas oxbow lake. An examination of some *Hexarthra* species from western Canada and Nepal was undertaken by Dumont *et al.*(1978). Chengalath(1978) recorded a new species of the genus *Notholca* from Great Slave Lake,N.W.T..

Karunakaran and Johnson(1978) analysed the rotifer fauna of Angapore and Malaysia. The seasonal abundance of planktonic rotifers in a nearshore area of central lake Michigan was studied by Duffy and Liston(1978). Some species of the genera *Lecane* and *Lepadella* of the Argentine rotifer fauna were studied by Paggi(1979). Shiel and Koste(1979) described the rotifers of Australia. New Rotifera from the River Murray, south-eastern Australia, with a review of the Australian species of *Brachionus* and *Keratella* were dealt by Koste(1979). Shiel(1979) dealt with the synecology of the Rotifera of the river Murray in South Australia. Horvath and Hummon(1980) studied the influence of mine acid on planktonic rotifers. Coussement and Dumont(1980) pointed out some peculiar elements in the rotifer fauna of the Atlantic Sahara and of the Atlas mountains. The rotifer fauna of the brackish waters of the Belgian coastal area was studied by De Ridder and Verheye(1980). Turner(1980) gave an account on some rotifers from south-east Virginia. New Rotifera as well as on *Brachionus dichotomus* with a description of a new subspecies, *B.dichotomus reductus* from Australian region was explained by Koste and Shiel(1980a, 1980b).

Preliminary remarks on the characteristics of the rotifer fauna of Australia were made by Koste and Shiel(1980c). Fernando(1980) discussed the tropical rotifer composition while studying the freshwater zooplankton of Sri Lanka and Horvath. An account on Rotifera was given by Pourriot(1980) from Sahel-Sudan area in Africa. Rotifers of Lake Valencia were studied by Infante (1980). Balvay and Laurent(1981) gave an account on the rotifers of Leman Lake. While studying zooplankton of some lakes of Patagonia, Paggi(1981) made observations on rotifers of that area. An account on Rotifera was given by De Ridder(1981) in Scientific results on hydrobiological survey of the lake Bangweulu Luapula river basin.. Fernando and Nora (1981) studied the Rotifera of Malaysia and Singapore with remarks on some species. Kutikova and Vasileva(1982) recorded new and endemic rotifers of the genera *Synchaeta* and *Euchlanis* from Lake Baikal. Planktonic species of rotifers living in shrimp ponds in Brazil were studied by Nogueira and Neumann(1982). *Notholca walterkostei* sp. nov. and other freshwater Rotifera of Potter Peninsula, 25 de Mayo Island-King George, in South Shetland, Antarctica were described by Paggi(1982). Hofmann(1983) studied the temporal variation in the rotifer *Keratella cochlearis.* Nogrady(1983) dealt with succession of planktonic rotifer populations in some lakes of the eastern Rift Valley, Kenya. Matveeva(1983) discussed the community structure of planktonic rotifers in a mesotrophic lake in Estonia. Koste *et al.*(1983) gave a detailed account on Rotifera from western Australian wetlands and that too with descriptions of two new species. The sympatry in natural distribution of two strains of a rotifer, *B.plicatilis* was studied by Fukusho and Okauchi(1983). Godeanu and Zinevici(1983) explained the composition, dynamics and production of Rotatoria in the plankton of some lakes of the Danube Delta. The water quality and the rotifer populations in the Atchafalaya river basin, Louisiana were discussed by Holland *et al.*(1983). Hillbricht – Ilkowska(1983) studied the response of planktonic rotifers to the eutrophication process and to the autumnal shift of blooms in lake Biwa, Japan. Koste and Shiel(1983) studied the morphology, systematics and ecology of new monogonont rotifers from the Alligator rivers region, North Carolina, USA. Biometric analysis of *Brachionus plicatilis* ecotypes from Spanish lagoons were undertaken by Serra and Miracle(1983).

A synopsis of rotifer species was given in Bibliography of Canadian aquatic invertebrates by Chengalath(1984). The taxonomic and zoogeographical remarks on Rotifera from the Ivory coast of W. Africa were made by De Ridder(1984). Information about rotifers of the ponds of the Lower Austrian Waldviertel was given by Naidenow and Wawrik(1984). Vazquez(1984) studied the rotifer communities from the middle Orinoco and lower Caroni rivers and some flooding lagoons in Venezuela. Jiamjit(1984) studied the freshwater rotifers of Thailand. Shiel and Koste(1985) reported new species and made new records of Rotifera from Australian waters while De Ridder(1985) contributed to the knowledge of rotifers from Senegal,Africa. Rotifera from Australian inland waters, coming under the class Bdelloidea and new Rotifera from Tasmania were studied by Koste and Shiel(1986a, 1986b). *Hexarthra longicornicula* n.sp. was recorded from a coastal lake in southeastern Brazil by Turner(1987). Koste and Shiel(1987) described the rotifers under the families Epiphanidae and Brachionidae from Australian inland waters and De Ridder(1987) contributed to the knowledge of African rotifers from Mauritania, W.Africa. The distribution of *Brachionus* species in Spanish Mediterranean wetlands was studied by Miracle *et al.*(1987). Walz(1987) discussed the comparative population dynamics of *B.angularis* and *Keratella cochlearis* from Muggelseedamn, Berlin in Germany.

The analysis of planktonic rotifer populations was made by Alois Herzig(1987) from three European lakes. Wallace(1987) studied the coloniality in the Phylum Rotifera by reviewing the major publications by various authors, all over the world. Serra and Miracle(1987) explained the biometric variation in three strains of *Brachionus plicatilis* as a direct response to abiotic variables. The rotifer occurrence in relation to pH was studied by Berzins and Pejler(1987). Brownell(1988) recorded a new pelagic marine rotifer from the southern Benguela, *Synchaeta hutchingsi,* with notes on its temperature and salinity tolerance. Rotifers from Saladillo river basin,Argentina were recorded by Paggi and Koste(1988). Comments on the Antarctic Rotifera was made by Sudzuki(1988). *Lecane nitzch* from water bodies of eastern Chaco and the Parana floodplain, Argentina was studied by Martinez and Paggi(1988).

Koste and Shiel(1989a, 1989b) described the rotifers under the families Euchlanidae, Mytilinidae, Colurellidae and Trichotriidae, from Australian inland waters. Koste and Boettger(1989) recorded rotifers from Ecuadorian waters while Abdullaev(1989) recorded new and rare species of rotifers from Dagestan water bodies. Rotifers from some provinces in North-Western Argentina were recorded by Paggi(1989). Koste and Tobias (1989) studied rotifers of Selingue Reservoir in Mali, West Africa. Nogrady(1989) dealt with rotifer associations of some wetlands in Ontario,Canada. Pejler and Berzins(1989) discussed the choice of substrate and habitat in brachionid rotifers while Saunders– Davies(1989) explained the horizontal distribution of the plankton rotifers, *Keratella cochlearis* and *Polyarthra vulgaris* in Brooklands lake in U.K. Berzins and Pejler(1989) studied the rotifer occurrence in relation to temperature. The ecological and biogeographical remarks on the rotifer fauna of Argentina were made by Paggi(1990). Rotifers of the families Lecanidae, Proalidae and Lindidae(Rotifera:Monogononta) were recorded by Koste and Shiel(1990a) from inland waters of Australia. Stemberger(1990a, 1990b) recorded *Keratella armadura* for the first time from a Michigan bog lake and gave an account on rotifer species diversity of northern Michigan inland lakes. Turner(1990) observed some rotifers from coastal lakes of Brazil and described a new rotifer, *Lepadella curvicaudata* n.sp.from this area. Smet and Bafort(1990) contributed to the study of monogonont rotifers from Little Cornwallis Island, Northwest Territories of the Canadian High Arctic while Sudzuki(1990) studied the summer rotifers from southwest islands of Japan. Gilbert(1991) gave an account on Rotifera of U.S.A. The rotifers of southwest islands of Japan, Singapore and Taiwan were studied by Sudzuki(1991a, 1991b). Valovaya(1991) recorded a new parasitic rotifer, *Albertis ovagranulata* sp. n.(Dicranophoridae) from the intestine of the oligochaete *Enchytraeus albidus* from the White Sea sublittoral. The planktonic rotifer, *Anuraeopsis miraclei* was recorded from karstic lakes of Spain by Koste(1991).

The population dynamics and production of estuarine planktonic rotifers in the Southern Baltic especially, *Brachionus quadridentatus* were studied by Arndt and Radziejewksa(1991). De Ridder(1991) added some more to the "Annotated checklist of non-marine rotifers from African inland waters". Xu and You(1991) recorded freshwater rotifers from Fujian, China. An investigation on the freshwater rotifers of Shandong Province was made by Wang(1991). Shiel and Koste(1992) described the rotifers of the family Trichocercidae from Australian inland waters while Koste and Boettger(1992) recorded rotifers from Ecuadorian waters. Segers *et al.*(1992) dealt with rotifers from north and northeast Anatolia,Turkey. Again, Silva-Briano and Segers(1992) recorded a new species of the genus *Brachionus* from Mexico. Mirabdullaev(1992) studied the species under the genus *Lophocharis* (Rotifera: Monogononta) from Uzbekistan. Segers and Sarma(1993) dealt with some new or little known Rotifera from Brazil. Shiel and Koste(1993) recorded rotifers under the families Gastropodidae, Synchaetidae and Asplanchnidae(Rotifera:Monogononta) from Australian inland waters. Lopez(1993) recorded new rotifers from inland waterbodies of Venezuela. New additions to the rotifer fauna of Venezuela were made by Zoppi *et al.*(1993).

The distribution of rotifers in a Floridian Saltwater beach, with a note on rotifer dispersal was studied by Turner(1993). The diversity and dominance in planktonic rotifers were studied by Green(1993). Telesh(1993) studied the effect of fish on planktonic rotifers. Miracle and Alfonso(1993) dealt with the vertical distributions of rotifers in a mermictic basin of Lake Banyoles, Spain, while the vertical distribution of planktonic rotifers in a Karstic meromictic lake was discussed by Javier *et al.*(1993). The abundance, succession and morphological variation of planktonic rotifers during autumnal circulation in a hypertrophic lake in Berlin was studied by Fussman(1993). The contribution to the study of the rotifer fauna of subarctic Greenland was made by Smet *et al.*(1993). Segers *et al.*(1993) studied the faunal composition and diversity of rotifers in some lakes in the floodplain of the river Niger, Nigeria. Rico-Martinez and Briano(1993) dealt with rotifers of Mexico. Reale *et al.*(1993) analysed the influence of the concentration of oxygen on the swimming path of *B.plicatilis*. A new species, *Proales christinae*(Rotifera: Proalidae) was recorded from the littoral region of the North Sea and another new species, *Lepadella beyensi* was observed from the Canadian High Arctic by Smet(1994).

Segers *et al.*(1994) studied the Rotifera from Lake Kothia, a high-altitude lake in the Bolivian Andes. The third addition to the inventory of the plankton of Lake Geneva was made by Balvay and Druart(1994). Segers and Meester(1994) recorded Rotifera of Papua New Guinea. Galindo *et al.*(1994) recorded *Lecane donyanaensis* n.sp. from the Donana National Park (Spain). Two more new species of *Lecane* were recorded from Thailand by Segers and Sanoamuang(1994) and a new rotifer species of the genus *Encentrum*(Rotifera: Dicranophoridae) from amphipods of the water bodies of Ukraine was observed by Boshko(1994). Green(1994) discussed the temperate-tropical gradient of planktonic protozoa and Rotifera. Studies on Rotatoria and Crustacea in the various water-bodies of Szigetkoez were made by Gulyas(1994). Vasconcelos(1994) studied the seasonal fluctuation of planktonic rotifers in Azibo Reservoir, Portugal. Pace and Vaque(1994) explained the importance of Daphnia in determining mortality rates of protozoans and rotifers in three lakes of contrasting zooplankton communities. Banik *et al.*(1994) dealt with the occurrence of rotifers in a seasonal wetland in Tripura in relation to some limnological conditions. Egborge(1994) commented on salinity and the distribution of rotifers in the Lagos Harbour – Badagry creek system in Nigeria. The comparisons of laboratory bioassays and a whole-lake experiment on the responses of rotifer to experimental acidification were studied by Gonzalez and Frost(1994). Pejler and Berzins(1994) studied the ecology of *Lecane* sp.. Hillbricht-Ilkowska(1995) compiled one hundred years of Polish rotiferology – scientists and their work. Bielanska-Grajner(1995) studied the influence of temperature on morphological variation in populations of *Keratella cochlearis* in Rybnik Reservoir, southern Poland. The effect of lake fertilization on the rotifers of Seathwaite Tarn, an acidified lake in the English lake district was discussed by May(1995). The effect of the Kola nuclear power plant on the rotifer community of lake Imandra in summer was studied by Timofeev and Bardan(1995). Snell and Janssen(1995) prepared a review on rotifers in ecotoxicology. The swimming behaviour of *Brachionus calyciflorus* under toxic stress and the use of automated trajectometry for determining sublethal effects of chemicals were discussed by Charoy *et al.*(1995). Morales-Baquero *et al.*(1995) studied the effects of temperature on the population dynamics of *Hexarthra bulgarica* from high mountain lakes in Spain. The comparative toxicant sensitivity of sexual and asexual reproduction in the rotifer *Brachionus calyciflorus* was discussed by Snell and Carmona(1995). Oerstan(1995)a recorded a new species of bdelloid rotifer from Sonora,Mexico and new records of rare Bdelloidea and Monogononta rotifers were reported in gravel streams by Schmid-Araya(1995). The genus *Polyarthra* in lake Peipsi was described by Virro(1995). Kutikova and Fernando(1995) dealt with *Brachionus calyciflorus* in inland waters of tropical latitudes. The disturbance and population dynamics of rotifers in bed sediments were studied by Schmid-Araya(1995).

Saunders-Davies(1995) dealt with the factors affecting the distribution of benthic and littoral rotifers in a large tidal marine lagoon in the Fleet, Dorset, U.K. and described a new species. Adamkiewicz-Chojnacka and Heerkloss(1995) discussed the inter-annual variation of rotifer biomass in two coastal lagoons of the southern Baltic, differing by degree of trophy. Walsh(1995) studied the habitat-specific predation susceptibilities of a littoral rotifer to two invertebrate predators. The importance of prey defence mechanisms in the context of prey selection by *Asplanchna girodi* was narrated by Conde-Porcuna and Sarma(1995). Oerstan(1995) dealt with the desiccation survival of the eggs of the rotifer *Adineta vaga*. Segers and Dumont(1995) recorded 102+ rotifer species(Rotifera: Monogononta) in Broa Reservoir in Brazil in 1994, and gave descriptions of three new species. Sanoamuang *et al.*(1995) added new and rare species from North-East Thailand to the rotifer fauna of South-East Asia. Lopez and Ochoa(1995) studied the Rotifera (Monogononta) from the Guasare-Limon River basin, Venezuela. *Keratella mexicana* sp. nov., a new planktonic rotifer from Aguascalientes, Mexico was noticed by Kutikova and Silva-Briano(1995). Telesh(1995) studied the principles of formation, present state and perspectives of rotifer assemblages in the Neva Bay, Russia. Smet(1996) described *Proales litoralis* sp.nov.(Rotifera, Monogononta: Proalidae) from the littoral region of the North Sea.

Rotifer diversity in subtropical waters of Argentina was studied by Paggi(1996) while Pourriot(1996) described rotifers from Petit Saut reservoir,French Guyana. Segers *et al.*(1996) contributed to the knowledge of the monogonont Rotifera of Zanzibar, with a note on *Filinia novaezealandiae* Shiel and Sanoamuang,1993. Akinbuwa and Adeniyi(1996) studied the seasonal variation, distribution and interrelationships of rotifers in Opa reservoir, Nigeria. Shiel and Green(1996) gave an account on rotifers recorded from New Zealand during 1859-1995, with comments on zoogeography.

Lecane segersi n.sp. was recorded by Sanoamuang(1996) from Thailand and Yan and Koste(1996) noticed two new species of rotifers from China. Segers and Mertens(1997) recorded new rotifers from the Korup National Park, Cameroon. Segers and Pourriot(1997) observed a new and puzzling American rotifer, *Lecane difficilis*(Rotifera: Monogononta, Lecanidae). Sanoamuang and Segers(1997) added to the *Lecane* fauna of Thailand. Minoru and ~~Huang~~ xiang-bei (1997) recorded new rotifers from Wuhan. Lin *et al.*(1997) studied the composition of Rotifera in Dongping lake of Shandong Province. Dieguez *et al.*(1997) analysed the influence of abiotic and biotic factors on morphological variation of *Keratella cochlearis* in a small Andean lake. Rotifers in Arctic North America with particular reference to their role in microplankton community structure and response to ecosystem perturbations in Alaskan Arctic lakes were studied by Rublee(1998). Devetter(1998) discussed the influence of environmental factors on the rotifer assemblage in an artificial lake. Njiru(1998) observed rotifers as indicators of water quality in lake Victoria, Kenya. Marneffe *et al.*(1998) assessed the water quality of Bitgenbach lake(Belgium) and its impact on the river Warche using rotifers as bioindicators. The toxicity of the Chrysophyte flagellate *Poterioochromonas malhamensis* to the rotifer, *B.angularis* was studied by Joseph *et al.*(1998). Pollard *et al.*(1998) studied the effects of turbidity and biotic factors on the rotifer community in an Ohio reservoir. Serra *et al.*(1998) discussed the ecological genetics of *Brachionus* sympatric sibling species.

Segers *et al.*(1998) studied the diversity and zoogeography of Rotifera(Monogononta) in a flood plain lake of the Ichilo River, Bolivia, with notes on little-known species. *Brachionus rotundiformis* in Lake Palaeostomi was studied by

Haberman and Sudzuki(1998). Koste and Zhuge(1998) recorded rotifer fauna of the island Hainan,China. Leutbecher and Koste(1998) studied the rotifer fauna of Lake Duemmer with special regard to sessile species. Zhuge *et al.*(1998) recorded *Notholca dongtingensis*(Rotifera: Monogononta: Brachionidae), a new species from Dongting Lake, China. Segers and Rong(1998) recorded two new species of *Keratella* from Inner Mongolia. A new *Keratella* was recorded from Patagonia by Modenutti *et al.*(1998). Soerensen(1998) observed marine Rotifera from a sandy beach at Disko Island, West Greenland and gave description of *Encentrum porsildi* n.sp. Zhuge and Huang(1998) observed a new species of *Keratella* from Yangtze river in China. Jersabek(1998) recorded rotifers under the family Dicranophoridae from the Alps. Zhuge *et al.*(1998) recorded rotifers from China during 1893-1997 and commented on their composition and distribution. Vasquez *et al.*(1998) dealt with rotifers of Venezuela. Snell and Serra(1998) dealt with dynamics of natural rotifer populations.

The planktonic rotifers of Samborombon River basin, Argentina were studied by Modenutti(1998). Kutikova(1998) made some remarks on the rotifer fauna of north and north western Russia. During April-October,1996, a study of rotifers in the River Thames, England was made by May and Bass(1998). Glockling(1998) isolated a new species of fungus, *Olpidium paradokum,* which was found to attack loricate rotifers and their eggs in a pond in Japan. The floodplain biodiversity along with the possible reasons for the occurrence of so many species, was described by Shiel *et al.*(1998) from 112 temporary floodplain waters, in River Murray tributaries in Australia. Sarma and Elias-Gutierrez(1998) studied rotifer diversity in a central Mexican pond, while, Sarma and Elias-Gutierrez(1999) recorded rotifers from four natural water bodies of Central Mexico.

Sanoamuang and Savatenalinton(1999) studied new rotifers from Nakhon Ratchasima province, northeast Thailand, and described *Lecane baimail* n.sp.. The effect of pH on population dynamics of *B.calyciflorus* was observed by Yilong and Xiangfei(1999). Ricci and Balsamo(2000) dealt with the biology and ecology of lotic rotifers. Yakovenko(2000) studied new rotifers of Ukraine (Rotifera, Bdelloidea) of Philodinidae family. Friedrich and De-Smet(2000) recorded rotifer fauna of 'Arctic sea ice', from the Barents sea, Laptev sea and Greenland sea. Funch and Sorensen(2001) studied rotifers in saline waters from Disko island, West Greenland. Smet (2001) recorded freshwater rotifers from plankton of the Kerguelen islands(Subantarctica) while the zoogeography of the southeast Asian Rotifera was dealt by Segers(2001). The structure and densities of urban rotifer communities in water bodies of the Pozna agglomeration area,Western Poland were described by Ejsmont-Karabin and Kuczyska-Kippen(2001). Duggan *et al.*(2001) discussed the distribution of rotifers in north island, New Zealand.

The rotifer fauna of Lake Kud-Thing,a shallow lake in Nong Khai Province, northeast Thailand was studied by Sanoamuang and Savatenalinton(2001). Sorensen(2001) recorded two new species of the family Dicranophoridae(Rotifera, Ploima) from the littoral psammon, and gave notes on other brackish water rotifers in Denmark. Paggi(2001) recorded a new species of *Lepadella* from the Rio Pilcomayo National Park, Argentina while Ricci *et al.*(2001) observed a carnivorous bdelloid rotifer, *Abrochtha carnivora* n.sp. May *et al.*(2001) discussed the relationships between *Trichocerca pusilla* and water temperature in Loch Leven, Scotland, U.K.. Bledzki and Ellison(2003) studied the diversity of rotifers from northeastern U.S.A. bogs, and, recorded new species for North America and New England. Chittapun *et al.*(2003) gave an account on Thai microfauna diversity along with notes on rare peat swamp Rotifera and described a new species of *Lecane* Nitzsch, 1872. Segers(2003) made a biogeographical analysis of rotifers of the genus *Trichocerca* Lamarck, 1801(Trichocercidae, Monogononta, Rotifera).

In India, studies on rotifers were initiated by Anderson in 1889. Edmondson and Hutchinson(1934) reported rotifers of the Yale North Indian Expedition. The freshwater fauna of India was recorded by Brehm(!950) while Pasha(1961) dealt with the freshwater rotifers of Madras. Arora studied the Illoricate rotifers in 1962 and some species of the genus *Brachionus* in 1963 from Nagpur. In 1966, Arora(1966b, 1966c) studied the responses of Rotifera to variations in some ecological factors and also described rotifers as indicators of trophic nature of environment. Nayar(1968) studied the rotifer fauna of Rajasthan. Vasisht and Battish(1971a, 1971b, 1971c, 1971d) studied the rotifer fauna of north India – *Brachionus, Keratella, Platyias, Lecane, Monostyla, Lepadella* and *Colurella.* Again, they(1972a, 1972b, 1972c, 1972d) made observations on *Filinia, Testudinella, Philodina, Rotaria, Asplanchna,* and *Polyarthra*. Dhanapathi(1974a, 1974b) studied the rotifers from Andhra Pradesh and reported a new brachionid rotifer *Platyias quadricornis andhraensis* subsp. nov.. Dhanapathi(1975) observed a new record of the rotifer *Tripleuchlanis plicata.* In 1976 he studied the family Lecanidae and reported two new species from Andhra Pradesh. Mohan and Rao(1976) observed epizoic rotifers on Odonata nymphs from Visakhapatnam. Tiwari and Sharma(1977) observed rotifers of the Indian Museum tank in Calcutta. The seasonal abundance of *Brachionus* spp. in relation to temperature and pH was studied by Vasisht and Sharma(1977). Rao and Chandra Mohan(1977) discussed the rotifers as indicators of pollution. Sharma(1978a, 1978b, 1978c) recorded the rotifer fauna under the family Lecanidae and genus *Lepadella* of West Bengal and reported two new lecanid rotifers. New species of rotifer belonging to the family Brachionidae was noticed by Dhanapathi(1978). Jyoti and Sehgal(1979) studied the ecology of rotifers in a freshwater lake in Jammu, Jammu and Kashmir. In 1979 Sharma made further contributions to the Eurotatoria of West Bengal while in 1980(b), he studied the rotifer fauna of Orissa. Again, he(1980a, 1980c) gave an account on the family Brachionidae of the rotifer fauna of Panjab state and recorded a new lecanid rotifer from West Bengal.

Rao and Chandra Mohan(1984) recorded the brackishwater rotifers and studied the ecology from Visakhapatnam Harbour. The form variations in the rotifer, *Brachionus calyciflorus* from a perennial impoundment was studied by Sharma and Saksena(1984). Laal(1984) dealt with the ecology of planktonic rotifers in a freshwater pond in Bihar. Michael(1985) discussed the use of rotifers as potential bioindicators of Indian freshwater ecosystem. Saksena and Kulkarni(1986) dealt with the rotifers of two sewage channels of Gwalior. Sharma(1986) made an attempt to study the rotifers as pollution indicators in India. The ecology of rotifers in a polluted pond at Aligarh was described by Khan *et al.*(1986), while dealing with zooplankton population ecology. Saksena(1987) studied the rotifers as indicators of water quality. Ramesh and Azariah(1987) discussed the distribution of rotifer biomass in the estuarine region of river Adyar with reference to suspended particulate matter. Deb *et al.*(1987) studied the synecology of a rotifer bloom in a freshwater pisciculture pond in West Bengal. The seasonal abundance of rotifers in a perennial freshwater pond in Calcutta was described by Datta *et al.*(1987). Sharma(1987a, 1987b) studied the distribution of the lecanid rotifers of north-eastern

India and the distribution of Indian Brachionidae. The new records of freshwater rotifers from Indian waters were described by Sarma(1988). Haque *et al.*(1988) discussed the impact of some ecological parameters on the rotifer population in a perennial pond. The distribution of *Brachionus* populations in ponds was dealt by Sampathkumar(1989). A survey of the rotifer fauna of Motihari,Bihar, was undertaken by Singh and Pandey(1989). Sarma and Rao(1990) described the population dynamics of *B.patulus* in relation to food and temperature. Sampathkumar(1991) studied the ecology of rotifers in fish ponds. The rotifers of the Pitchavaram mangroves were studied by Govindasamy and Kannan(1991). While studying the physico-chemical and biological characterization of a temple tank, Gwalior, Madhya Pradesh, Amita and Saksena(1992) dealt with rotifers also. The ecology of freshwater Rotifera in West Bengal was studied by Sharma(1992). Madhyastha(1994) discussed the seasonal variation and diversity of rotifers while studying the zooplankton in a small pond near Mangalore. The vertical distribution of Rotifera in a warm monomictic lake of Kashmir was analysed by Yousuf and Mir(1994). Kaushik and Sharma(1994) dealt with rotifers, while studying physico-chemical characteristics and zooplankton population of a perennial tank in Gwalior. The periodicity and abundance of rotifers in relation to certain physico-chemical characteristics of two ecologically different ponds of Bihar were studied by Kumar(1994). New records of rotifers from India were reported by Segers *et al.*(1994). New records of sessile rotifers from freshwater fishponds of Tripura were reported by Banik and Kar(1995 & 1996). Kaushik and Saksena(1995) studied the trophic status and rotifer fauna of certain water bodies in Central India. Unni and Fole(1997) studied the distribution and diversity of rotifers in Kanhargaov Reservoir, Chhindwara, Madhya

Pradesh. Archana(1998) studied rotifers as indicators for the assessment of water quality. Anupama and Rao(1998) analysed, whether the evasive behavior of *Hexarthra,* influence its competition with cladocerans. Su *et al.*(1998) discussed the distribution of the family, Brachionidae in Mongolian waters. Sharma and Sharma(1997) observed lecanid rotifers from north-eastern India, where as the rotifers from a high altitude lake in southern India, with a note on the taxonomy of *Polyarthra* were dealt with, by Segers and Babu(1999). The biodiversity of rotifers in some tropical floodplain lakes of the Brahmaputra river basin, Assam was studied by Sharma and Sharma(2001). Arora and Mehra(2003) studied the seasonal dynamics of rotifers in relation to physical and chemical conditions of the river Yamuna, Delhi.

The above review of literature indicates that the distribution and ecology of rotifer fauna had been studied considerably in different parts of the world, but in India, the studies are restricted to certain places. Much of the information available, are concentrated to north India. Among the limited works carried out in southern part of India, major studies were carried out in freshwater habitats. The pioneering work on rotifers in Kerala, was by Nair and Nayar(1971) in which they made a preliminary study on the rotifers of Irinjalakuda and neighbouring places. Again, Nair(1972) dealt with sessile rotifers of Kerala. These two works were from freshwater environments. Abdul Aziz(1978), Nair *et al.*(1984), Nair *et al.*(1985), Azis and Nair(1986), Bijoy Nandan(1991), Shibu(1991), Harikrishnan(1993), Bijoy Nandan and Abdul Aziz(1994), Anuradha Rammohan(1996) and George Thomas(1996) gave some information on rotifers, when they dealt with studies on general plankton in different brackishwater ecosystems of Kerala. Gopakumar(1998) studied the brackishwater rotifers of Kerala with special reference to *Brachionus plicatilis* as live feed for aquaculture. The community structure and succession of brackishwater rotifers in relation to ecological parameters were studied by Gopakumar and Jayaprakas(2003), in certain lakes along the southern part of Kerala. Anitha(2003) carried out studies on certain selected live feed organisms used in aquaculture, with special reference to rotifers of the family Brachionidae. But, these two studies gave more emphasis on culture aspects than stuidies on distribution and ecology.

Thus, the fauna, their distribution and ecology of rotifers in many of the brackishwater habitats in Kerala are not well documented. At the same time, we have no information on rotifers from the brackishwater ecosystems in central part of Kerala, except one report on the isolation of *Brachionus rotundiformis* from Cochin backwater(Molly,2004). At the same time, the influence of various environmental characteristics on different species of rotifers and their distribution pattern can be of utmost importance in the culture activities of rotifers, which is considered as an indispensable live feed for many commercially important fish larvae. Hence, an investigation on distribution and ecology of rotifers in nine different brackishwater habitats along Cochin backwater system was chosen for the present study.

MATERIALS AND METHODS

The Cochin backwater and certain canals adjoining the system extending to about 50 kms was selected for the study. The present study was conducted during the period from August 2000 to July 2002. Monthly collections of rotifers and water samples were made from nine stations viz., Vypeen, Puthuvypu, Narakkal, Cherai, Eloor, Fisheries Harbour, Ernakulam Market canal, Mangalavanam and Poothotta. These stations were so selected that each of them showed a unique and different environment.

Sampling stations

The map showing the collection sites and photographs of stations are given in Fig.1 and Plates 1-5 (Chapter 1).

A site at Vypeen, near Kochi barmouth(Plate 1.1) was selected as the first station. Here the Cochin backwater joins the open sea, providing a very dynamic environment. The influence of tide is maximum at this station. The wind and wave action from the sea also influence the water quality in this region. And, salinity at this site ranged from 5 ppt to 30 ppt during the study period.

The second station was at Puthuvypu(Plate 1.2), which is considered as a good nursery area with plenty of finfish and shellfish seeds. The collection spot is a small canal about 2 kms away from the first station. This canal has a direct connection with the sea.

The third station was at Narakkal(Plate 2.1), which is a well known site for aquaculture where the traditional aquaculture methods are being practiced. The collection spot/station gets a good inflow of water from culture ponds of varying types and sizes. The collection site was located in a canal which joins the Cochin backwater about 1 km from the station.

The fourth station was at Cherai(Plate 2.2). The actual sampling site was fixed in a backwater stretch of about 0.5 km wide. The collections were made from both the sides of this backwater and average values taken. The site of collection was located about 5 kms away from the sea. Plenty of Chinese dipnets operated in this area and wastes from small fish & shellfish processing plants were discharged into this tributary at certain spots. Traditional culture activities were also carried out in nearby areas and washouts from such ponds also joined this system.

The fifth station was Eloor(Plate 3), which is a well known spot noted for industrial pollution. Many factories like, FACT (Fertilizers And Chemicals Travancore Limited), Cominco Binani Zinc Limited, TCC(Travancore Cochin Chemicals), TCM(Travancore Chemicals Manufacturing company), Sakthi Papermills, Leather processing factory and several small scale chemicals manufacturing units are located in this region. Water in this region was saffron in colour on many occasions and death of fishes was reported by the local people and newspapers in many instances. In short, this site was a known hot spot of industrial pollution and almost a freshwater environment with salinity range of 0.25 to 4 ppt. This system is about 0.5 km wide and hence samples were taken from the two sides to avoid errors in sampling.

The sixth station was fixed at the Fisheries Harbour, Thoppumpady(Plate 4.1) where plenty of fishing boats land, unloading their catches on a wide platform. A boat repairing yard was also located nearer to the station. Hence the turmoil of a fish landing centre and a busy water way along with the added oil pollution, influenced the water quality. The presence of a deeper shipping channel is characteristic of this station. Among the nine stations, the highest salinity of 32.5 ppt was also noticed from this station.

The seventh station was near to the meeting place of Market canal of Ernakulam Town with the Cochin backwaters(Plate 4.2). The selected site was nearer to the Ernakulam market and all the wastes from the market mainly decayed vegetables were being discharged to this canal.

The eighth station was located at Mangalavanam(Plate 5.1). It is a small mangrove forest which is a bird sanctuary as well as a mangrove reserve. This site acts as a good nursery ground also. The droppings of different types of birds and decayed mangrove leaves affect the quality of water here. The station is connected to the Cochin backwaters through a narrow canal.

The nineth station was at Poothotta(Plate 5.2), which is about 25 kms away from Ernakulam. This station is almost free from pollution and supports a good fishery for Pearl spot and Prawns. The salinity is low in this ecosystem which varied from 0.25 to 6 ppt and thus formed an almost freshwater ecosystem.

These stations were selected assuming that the faunal assemblages as well as many of the physico-chemical characteristics prevailing in each of these stations would be different and so expecting a variety/biodiversity of rotifers. The species diversity and abundance of rotifers in each ecosystems were also presumed to be different.

Sample collection and methodology of analysis of data

Water as well as plankton samples were collected from all the nine stations between 7 a.m. and 10 a.m. in three consecutive days during each sampling period and, collections were made from the surf zone.

Water temperature was recorded at the time of collection using a mercury thermometer with 0-50°C markings.

Water samples for estimating the dissolved oxygen were taken in 125ml bottles and fixed using 1ml each of Winkler A and B at the collection site itself and the dissolved oxygen was analysed in the laboratory, using Winkler's method(Strickland and Parson,1968). The values were expressed in ml/litre.

Having brought the water samples to the laboratory, H_2S was recorded with a Hydrogen sulfide kit (MERCK) by comparing the intensity of colours developed after adding a series of solutions supplied by them, with that given for standard concentrations of H_2S.

Salinity was recorded using a Refractometer (ATAGO, Japan) of high accuracy, and, pH of water was recorded using an ECIL Digital pH meter. The instrument was calibrated using appropriate buffer solutions before taking actual pH measurements.

Water samples for estimating BOD were taken in 300ml BOD bottles in duplicate, without air bubbles, mixed with dilution water, and one set was kept at 20°C in a BOD incubator for 5 days. The second set was fixed using Winkler A and B. After 5 days the incubated samples were also fixed in the same way. The dissolved oxygen in all the bottles were estimated by Winkler's method and BOD was estimated using the formula BOD_5,mg/l = (Initial Oxygen - Final Oxygen after incubation) / P ; where, P = ml. of sample/ volume of BOD bottle (Standard methods, 1998).

For Chlorophyll a estimation, 1 Litre of water sample was filtered through Glass microfibre Filters(GF/C) 47mm Whatman filter paper using a vacuum pump. The filter paper along with residue was transferred to a glass tube, 10 ml of acetone added and kept in darkness, in a refrigerator. After 15-20 hours, the samples were taken out and the absorbances of the extracts were measured at different wavelengths of 7500, 6650, 6450 and 6300 Å, using a spectrophotometer and calculated the concentration of pigment from the equation, Chlorophyll a , $mg/m^3 = C / V$;

where, V is the water filtered in litres and $C = 11.6 \times E_{665} - 1.31 \times E_{645} - 0.14 \times E_{630}$ (Strickland & Parsons method,1968).

Total Suspended Solids(TSS) were determined using Boyd ~~'s method~~ and Tucker (1992). The method involves filtering of 100 ml of water sample through a GF/C Whatman filter paper which was previously dried and weighed. After filtering, the filter paper, along with the residue was dried in a hot air oven and weighed. TSS was calculated using the formula, TSS, mg/litre = (F – I) 1000 / V , where;

F = Final weight of filter paper and residue in milligrammes,

I = Initial weight of filter paper in milligrammes and

V = Sample volume in milliliters.

Total alkalinity was measured by titrating 100 ml of water sample with standard Sulphuric acid solution using methyl orange as the indicator. Alkalinity is quantified using the equation,

Total alkalinity, mg/litre as $CaCO_3$ = (T x N x 50000) / S , where;

T = volume of Sulphuric acid in milliliter,

N = normality of Sulphuric acid and

S = volume of sample in milliliters.

The micronutrients – Phosphates and Nitrites were estimated using Standard methods (APHA,1998) , with the help of a spectrophotometer. The values were expressed in microgram atoms per litre.

Ammonia was determined by the method adopted by Zolorzano (1969). The water sample was treated in an alkaline citrate medium with Sodium hypochlorite and phenol in the presence of Sodium nitroprusside which acts as a catalyzer. The blue indo-phenol colour formed with ammonia was measured spectrophotometrically at 6400 Å. The concentration of ammonia- nitrogen is calculated using the formula,

μg-at N/litre = F x E, where,

E is the corrected extinction and F is the factor which is determined from the calibration graph of ammonia standard solutions.

The zooplankton samples for rotifers and other associated animal assemblages were taken from each station by filtering 500 litres of water through a conical plankton net made of bolting silk having a mesh size of 40 μ. In order to avoid sampling errors, utmost care was taken to collect the zooplankton samples from an area instead of taking from a particular point. The filtered plankton sample was collected in a plastic bottle and preserved using 4% Formaldehyde. The plankton sample brought to the laboratory, was made upto 100 ml. An aliquote of 1ml was taken in a counting chamber and this was observed under a binocular microscope. The different species/genera of rotifers and other zooplankton groups were identified, counted and recorded. From this, the count of organisms present in 1000 litres (m^3) of water was estimated and tabulated.

To extract reliable/true information, the data on environmental parameters and that of rotifers collected for 24 months were pooled together and the resulted average data of 12 months were considered for further analyses and interpretation of the data. For seasonal studies, February – May was treated as premonsoon season; June – September as monsoon season and October – January as postmonsoon season.

The numbers were grouped into total rotifers, family Brachionidae and genus *Brachionus* for better understanding. The statistical analysis of the data were carried out, and Analysis of Variance(ANOVA) between months, between seasons and between stations were worked out.

Analyses were performed to calculate species richness, evenness and diversity indices of rotifers for each station(monthwise and seasonwise), using the PRIMER 5 (Plymouth Routines in Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory, UK(Clarke and Warwick 2001).

Species richness was determined using Margalef's index (d), which provides a measure of the number of species (S) present for a given number of individuals (N) according to the following equation: $d = (S - 1)/\log_2 N$.

Equitability, the evenness of the species distribution, was determined using Pielou's Evenness index (J) = H'(observed)/H' max, where H' max is the maximum possible diversity which would be achieved if all species were equally abundant=$\log_2$ (S).

Diversity was calculated using the Shannon-Weiner index $H' = -\Sigma i\ pi\ (\log 2\ pi)$, where p*i* is the proportion of the total count arising from the *ith* species.

This index is moderately sensitive to sample size and places more weightage on richness and becomes useful while comparing different sites.

Simpson index of diversity was calculated in the form of $\Delta^{o}=1-\Sigma i\{Xi(Xi-1)N(N-1)\}$. This index is heavily weighted towards the most abundant species in the sample and is less sensitive to species richness.

All the above indices were determined using the DIVERSE routine within the PRIMER software package. These indices were tabulated monthwise as well as stationwise and statistically analysed using SPSS 12.00 software. ANOVA tests were carried out between months and between stations and given in separate tables. Charts were prepared representing the seasonwise mean values and standard deviations.

To understand the interrelationships between rotifers and environmental characteristics prevailing in each station, correlation coefficients were calculated using Microsoft Excel and t-test was carried out to assess the levels of significance.

RESULTS

The results are presented in two parts mainly, first part is distribution and the second part is on ecology.

PART I. DISTRIBUTION OF ROTIFERS IN THE NINE SELECTED STATIONS

The distribution of rotifer fauna in the study area are presented, both qualitative and quantitative studies were made. The rotifers were studied upto generic level. Special emphasis was given to the genus *Brachionus* and species composition as well as their distribution in the different stations are presented here. The distribution of zooplankton in the study area along with their relationship with rotifers are also discussed. The biodiversity indices of rotifers are dealt with separately.

A.QUALITATIVE DISTRIBUTION

List of rotifers showing their systematic position is given in Table-1.

Table 1.Systematic position of rotifers collected from the study area

Sl.No.	Phylum	Class	Order	Family	Genera
1	Rotifera	Monogononta	Ploimida	Brachionidae	*Brachionus*
2	Rotifera	Monogononta	Ploimida	Brachionidae	*Keratella*
3	Rotifera	Monogononta	Ploimida	Brachionidae	*Platyias*
4	Rotifera	Monogononta	Ploimida	Brachionidae	*Anuraeopsis*
5	Rotifera	Monogononta	Ploimida	Mytilinidae	*Mytilina*
6	Rotifera	Monogononta	Ploimida	Euchlanidae	*Euchlanis*
7	Rotifera	Monogononta	Ploimida	Euchlanidae	*Dipleuchlanis*
8	Rotifera	Monogononta	Ploimida	Epiphanidae	*Epiphanes*
9	Rotifera	Monogononta	Ploimida	Epiphanidae	*Microcodides*
10	Rotifera	Monogononta	Ploimida	Colurellidae	*Lepadella*
11	Rotifera	Monogononta	Ploimida	Lecanidae	*Lecane*
12	Rotifera	Monogononta	Ploimida	Lecanidae	*Monostyla*
13	Rotifera	Monogononta	Ploimida	Notommatidae	*Cephalodella*
14	Rotifera	Monogononta	Ploimida	Notommatidae	*Scaridium*
15	Rotifera	Monogononta	Ploimida	Trichocercidae	*Trichocerca*
16	Rotifera	Monogononta	Ploimida	Synchaetidae	*Polyarthra*
17	Rotifera	Monogononta	Ploimida	Dicranophoridae	*Encentrum*
18	Rotifera	Monogononta	Flosculariacea	Hexarthridae	*Hexarthra*
19	Rotifera	Monogononta	Flosculariacea	Filiniidae	*Filinia*
20	Rotifera	Monogononta	Flosculariacea	Testudinellidae	*Testudinella*

Out of the 60 genera of rotifers so far reported from Indian waters, 20 genera were recorded from the different stations during the present study. They were *Brachionus, Keratella, Platyias, Anuraeopsis, Mytilina, Euchlanis, Dipleuchlanis, Epiphanes, Microcodides, Lepadella, Lecane, Monostyla, Cephalodella, Scaridium, Trichocerca, Polyarthra, Encentrum, Hexarthra, Filinia* and *Testudinella*. These 20 genera belonged to 13 families viz. Brachionidae, Mytilinidae, Euchlanidae, Epiphanidae, Colurellidae, Lecanidae, Notommatidae, Trichocercidae, Synchaetidae, Dicranophoridae, Hexarthridae Filinidae, and Testudinellidae. A total of 13 species under the genus *Brachionus* were recorded, from the stations studied. The species were *Brachionus plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens, B,forficula, B.caudatus, B.calyciflorus, B.bidentata, B.quadridentatus, B.patulus, B.falcatus and B.mirabilis*. Since the present study was focussed more on *Brachionus* species , other rotifers were studied only upto generic level. Apart from rotifers, total zooplankton assemblages were also studied from each station. The zooplankton, other than rotifers, consisted of copepods, tintinnids, medusae, nematodes, polychaetes, cladocera, ostracods, balanus-nauplii, mysids, amphipods, crab larvae, prawn larvae, gastropods, bivalve larvae/spats, tunicates and fish larvae.

The qualitative distribution of rotifers in different stations are given in Table 2 and that of *Brachionus* species in Table 3. All these species and genera are reported for the first time from these stations. At station I, 15 genera of rotifers and 6 species of *Brachionus, B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens* and *B.forficula* were observed. From station II, 14 genera of rotifers and 6 species of

Table 2. Families and Genera of Rotifers in different localities in the study area

SI. No.	Families	Genera	Station1	Station2	Station3	Station4	Station5	Station6	Station7	Station8	Station9
1	Brachionidae	*Brachionus*	+	+	+	+	+	+	+	+	+
2	"	*Keratella*	+	+		+	+	+	+		+
3	"	*Platyias*	+				+				+
4	"	*Anuraeopsis*	+	+	+	+	+	+	+	+	+
5	Mytilinidae	*Mytilina*					+		+		+
6	Euchlanidae	*Euchlanis*	+		+	+	+	+	+	+	+
7	"	*Dipleuchlanis*					+		+	+	+
8	Epiphanidae	*Epiphanes*	+	+	+	+	+	+	+		+
9	"	*Microcodides*							+		
10	Colurellidae	*Lepadella*	+	+	+	+	+		+	+	+
11	Lecanidae	*Lecane*	+	+	+	+	+	+	+	+	+
12	"	*Monostyla*	+	+	+	+	+	+	+	+	+
13	Notommatidae	*Cephalodella*	+	+		+	+	+	+	+	+
14	"	*Scaridium*				+					+
15	Trichocercidae	*Trichocerca*	+	+	+	+	+	+	+	+	+
16	Synchaetidae	*Polyarthra*	+	+	+	+	+	+	+	+	+
17	Dicranophoridae	*Encentrum*	+	+	+	+	+	+	+	+	+
18	Hexarthridae	*Hexarthra*		+	+		+	+			+
19	Filiniidae	*Filinia*	+	+	+	+	+			+	+
20	Testudinellidae	*Testudinella*	+	+	+	+	+	+	+	+	+

Table 3.Distribution of *Brachionus* species in different stations

SI. No.	Species	Station1	Station2	Station3	Station4	Station5	Station6	Station7	Station8	Station9
1	*B.plicatilis*	+	+	+	+	+	+	+	+	+
2	*B.rotundiformis*	+	+	+	+	+	+	+	+	+
3	*B.angularis*	+	+	+	+	+	+	+	+	
4	*B.urceolaris*	+	+	+	+	+	+	+		+
5	*B.rubens*	+	+	+	+	+		+	+	+
6	*B.forficula*	+	+	+	+	+		+		+
7	*B.caudatus*			+						
8	*B.calyciflorus*				+					
9	*B.bidentata*				+			+		+
10	*B.quadridentatus*					+	+	+	+	
11	*B.patulus*					+				+
12	*B.falcatus*						+			+
13	*B.mirabilis*					+				

Brachionus, B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens and *B.forficula* were recorded. 13 genera under rotifers and 7 species of *Brachionus, B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens, B.caudatus* and *B.forficula* have been identified and recorded from station III. Among these species, *B.caudatus* was observed only from this station. From station IV, 15 genera of rotifers and 8 species of *Brachionus, B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens, B.calyciflorus, B.forficula* and *B.bidentata* were recorded. Of these species, *B.calyciflorus* was recorded only from this station. At station V, 18 genera of rotifers and 9 species of *Brachionus, B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens, B.forficula, B.quadridentatus, B.patulus* and *B.mirabilis* were observed. Among these species, *B.mirabilis* was reported only from this station during the study period. From station VI, 13 genera of rotifers and 6 species of *Brachionus, B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.falcatus* and *B.quadridentatus* were recorded. At station VII, 16 genera of rotifers and 8 species of *Brachionus, B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens, B.forficula, B.quadridentatus* and *B.bidentata* were observed. The genus, *Microcodides* was reported only from this station during the present study. 13 genera of rotifers and 5 species of *Brachionus, B.plicatilis, B.rotundiformis, B.angularis, B.rubens* and *B.quadridentatus* were recorded from station VIII. From station IX, 19 genera of rotifers and 8 species of *Brachionus, B.plicatilis, B.rotundiformis, B.urceolaris, B.rubens, B.falcatus, B.forficula, B.patulus* and *B.bidentata* were recorded.

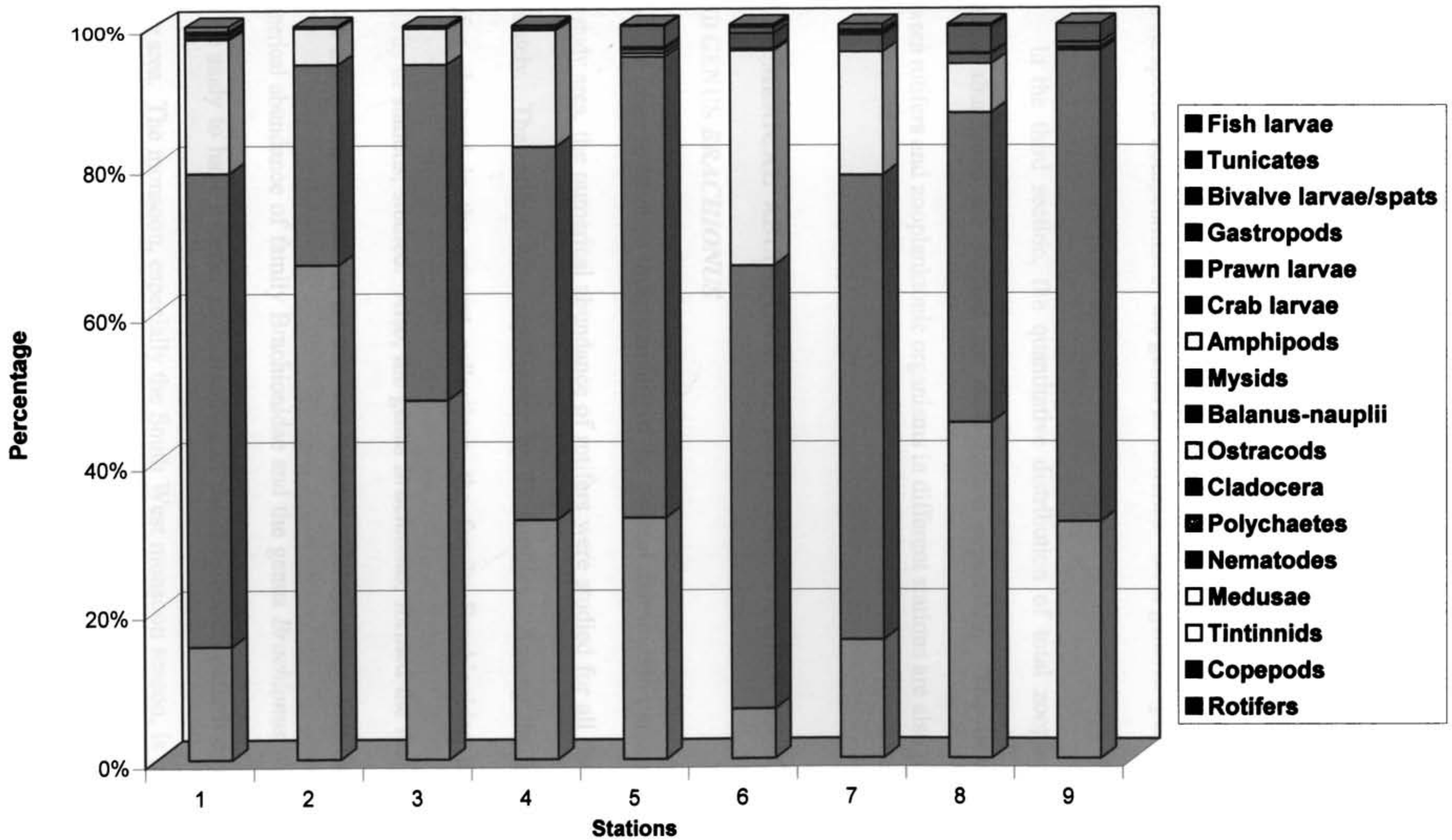
Out of the 20 genera of rotifers recorded during the study period, the maximum of 19 genera were recorded from station IX(Table 2). The lowest number of genera, 13 were observed from stations III, VI and VIII. The genus *Brachionus* was dominant over other genera in all the stations except at station VII, where the genus *Encentrum* was the major component. The genus *Platyias* was recorded from Station No. I, V and IX. The genus *Mytilina* was reported from station No.V,VII and IX during the study period. The genus *Dipleuchlanis* was observed from station No.V,VII,VIII and IX. The genus *Scaridium* was noticed only from 2 stations- Station No.IV and IX. The genus *Hexarthra* was observed from 5 stations, viz., station Nos.II,III,V,VI and IX. Among the 20 genera recorded, *Brachionus, Anuraeopsis, Lecane, Monostyla, Trichocerca, Polyarthra, Encentrum* and *Testudinella* were noticed from all the nine stations, studied.

During the present study, 20 genera belonged to 13 families were reported (Table 2). Among them, the family Brachionidae was found to dominate in all the stations studied except at stations V and VII. At station V, Lecanidae was the major family reported and at station VII, the family Dicranophoridae dominated over other families. However, the family Brachionidae remained to be the dominant one in majority of stations during the present study. Under the family Brachionidae, the genus *Brachionus* formed the major component in all the nine stations studied.

The genus *Brachionus* was represented by 13 species during the present study(Table 3). *Brachionus rotundiformis* dominated over other species in all the nine stations. *B.bidentata* was observed from 3 stations viz. station no. IV,VII and IX. *B.quadridentatus* was recorded from station Nos.V,VI,VII and VIII. *B.patulus* was recorded from station No.V and IX. *B.falcatus* was reported from station No.VI and IX. Of the 13 species of *Brachionus* recorded, *B.plicatilis* and *B.rotundiformis,* were observed in all the stations studied. While considering the distribution of *Brachionus* species in the study area a minimum of 5 species were observed from station No.VIII and a maximum of 9 species were recorded from station No.V.

Out of the 16 groups of other zooplankton, copepods consisting of copepod-nauplii, cyclopoid copepods, calanoid copepods and harpacticoid copepods, formed the dominant group in all the stations studied (Fig.3).

Fig.3. Distribution of Zooplankton groups in the study area



B.QUANTITATIVE DISTRIBUTION

The quantitative distribution of rotifers in the study area are described under two sections. In the first section, the numerical abundance of total rotifers, family Brachionidae and the genus *Brachionus* are discussed to understand the general distribution of rotifer fauna in different stations. The second section deal with the percentage composition of different genera under rotifers and family Brachionidae along with the species composition of the genus *Brachionus*. Both generic/species wise as well as stationwise studies are presented.

In the third section, the quantitative distribution of total zooplankton and its seasonal abundance are studied for each station separately. The interrelationships between rotifers and zooplanktonic organisms in different stations are also presented.

B.1. NUMERICAL ABUNDANCE OF ROTIFERS, FAMILY BRACHIONIDAE AND GENUS *BRACHIONUS*

In order to have an understanding of the general distribution pattern of rotifers in the study area, the numerical abundance of rotifers were studied for all the nine stations separately. The rotifers were represented by 13 families. Among the 13 families of rotifers observed in the present collections, the family Brachionidae dominated the majority of stations, studied. Also, the genus *Brachionus,* formed the major component of the family Brachionidae in all the nine stations. Hence, along with the rotifers, the numerical abundance of family Brachionidae and the genus *Brachionus* were also taken for the study to have a better understanding of the distribution pattern of rotifers in the study area. The monsoon, especially the South West monsoon season, is influencing the physicochemical characteristics of the study area and thereby the biological fauna is also affected. So, a seasonal study in relation to the distribution of rotifers was also carried out and presented here. The seasons were divided into premonsoon (February to May), monsoon (June to September) and postmonsoon (October to January) for the convenience of a detailed study.

The quantitative distribution of rotifers, family Brachionidae and the genus *Brachionus,* in all the 9 stations studied, which are given in Table 4 & Fig.4, where as Fig.5, 6 & 7, depict the stationwise and seasonwise distributions of rotifers, family Brachionidae and the genus *Brachionus* respectively. The monthwise distribution of rotifers, family Brachionidae and the genus *Brachionus* in the 9 stations are given in Tables 5.1 to 5.9.

Station I

An average of 23335 numbers of rotifers per m^3 of water was observed from station I. Seasonal distribution indicated, 33285, 23913 and 12808 numbers per m^3 during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise variation showed a minimum of 3000 numbers per m^3 in December and a maximum of 58840 numbers per m^3 in April.

Among the rotifers at this station, the family Brachionidae dominated (87.5%) and 20427 numbers of Brachionids per m^3 of water were observed. Seasonally, 31515 numbers/m^3 were observed during premonsoon, 21560 numbers/m^3 during monsoon and 8205 numbers/m^3 during the postmonsoon season. The monthwise variation was from 600 numbers per m^3 of water in December to 55040 numbers per m^3 during April.

Table 4.Percentage composition of Rotifers, family Brachionidae and the genus *Brachionus* in the study area

Stations	Total rotifers Nos. per m^3	Family Brachionidae Nos. per m^3	Genus *Brachionus* Nos. per m^3	% of Brachionidae out of total rotifers	% of *Brachionus* out of total rotifers	% of *Brachionus* out of Brachionidae
1	23335.00	20426.67	19591.67	87.54	83.96	95.91
2	1255464.71	1179973.75	1179023.75	93.99	93.91	99.92
3	835603.75	824027.21	823960.54	98.61	98.61	99.99
4	71593.83	63332.17	63113.83	88.46	88.16	99.66
5	9449.54	3006.67	2761.67	31.82	29.23	91.85
6	3354.17	1448.33	1053.33	43.18	31.40	72.73
7	11340.42	2929.17	2559.17	25.83	22.57	87.37
8	88915.42	83092.50	83019.58	93.45	93.37	99.91
9	35083.33	15489.17	13085.00	44.15	37.30	84.48

Fig.4. Stationwise distribution of Rotifers, family Brachionidae and genus *Brachionus* during the study period

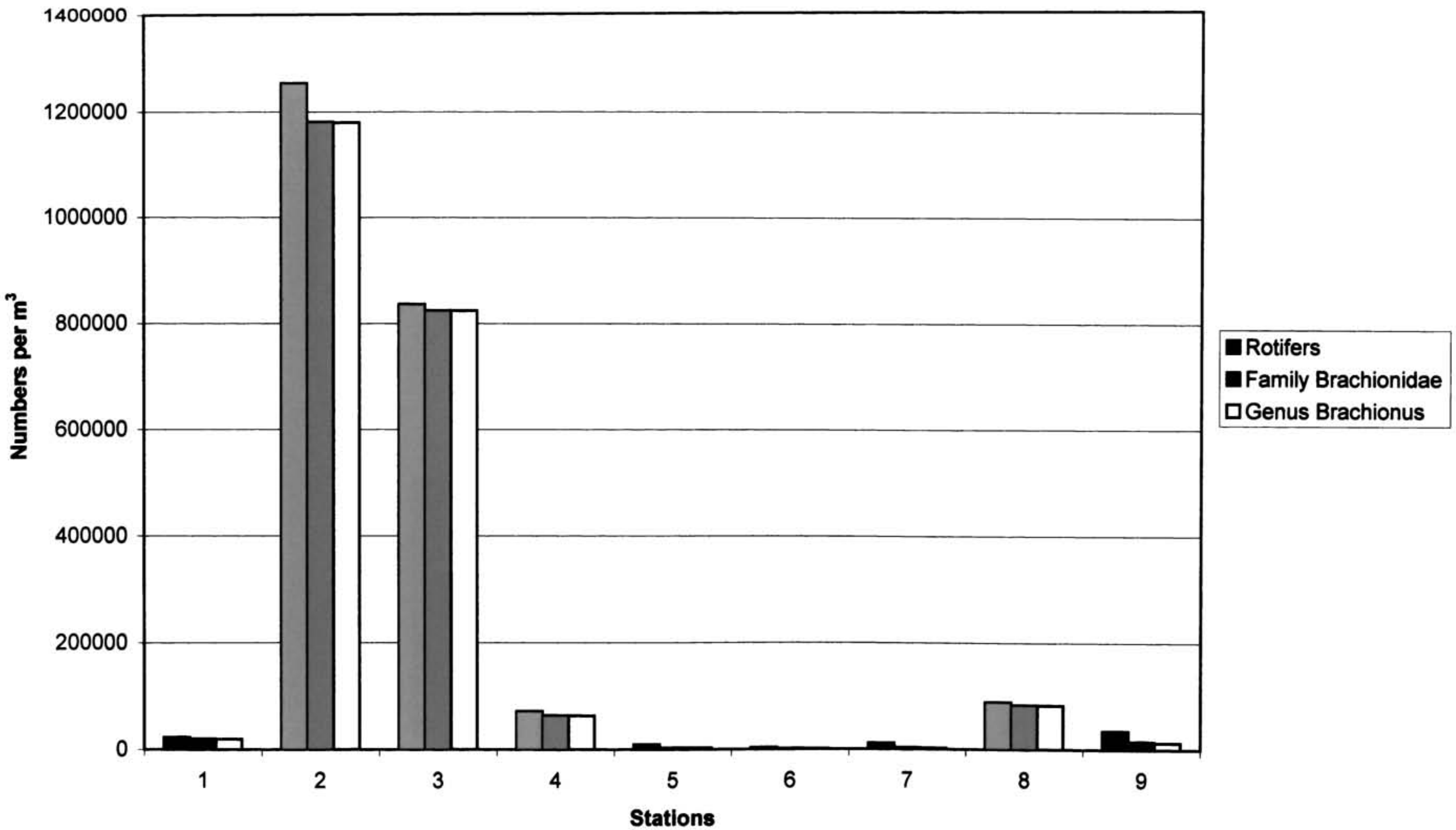


Fig.5. Seasonal distribution of Rotifers in the study area

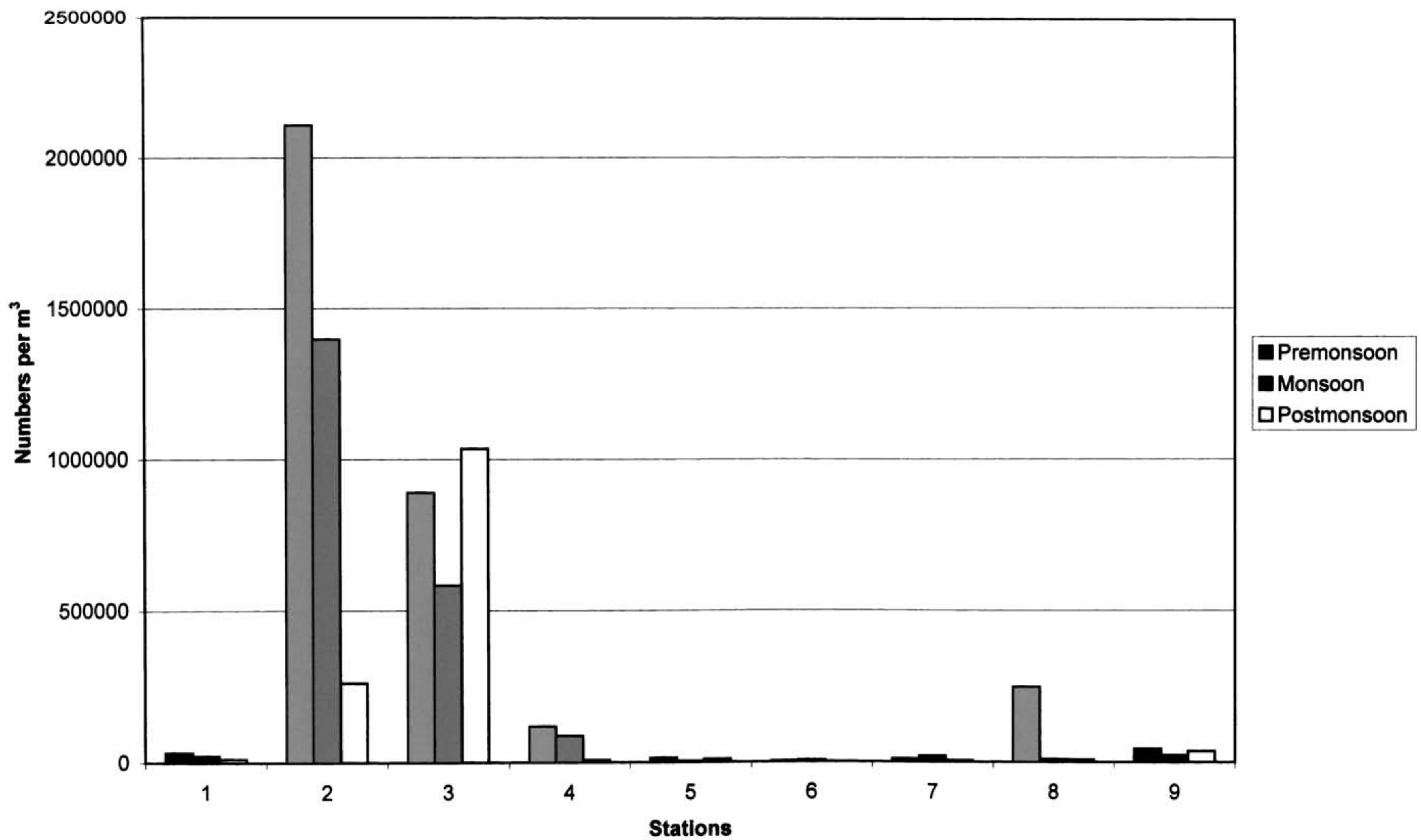


Fig.6. Seasonal distribution of the family Brachionidae in the study area

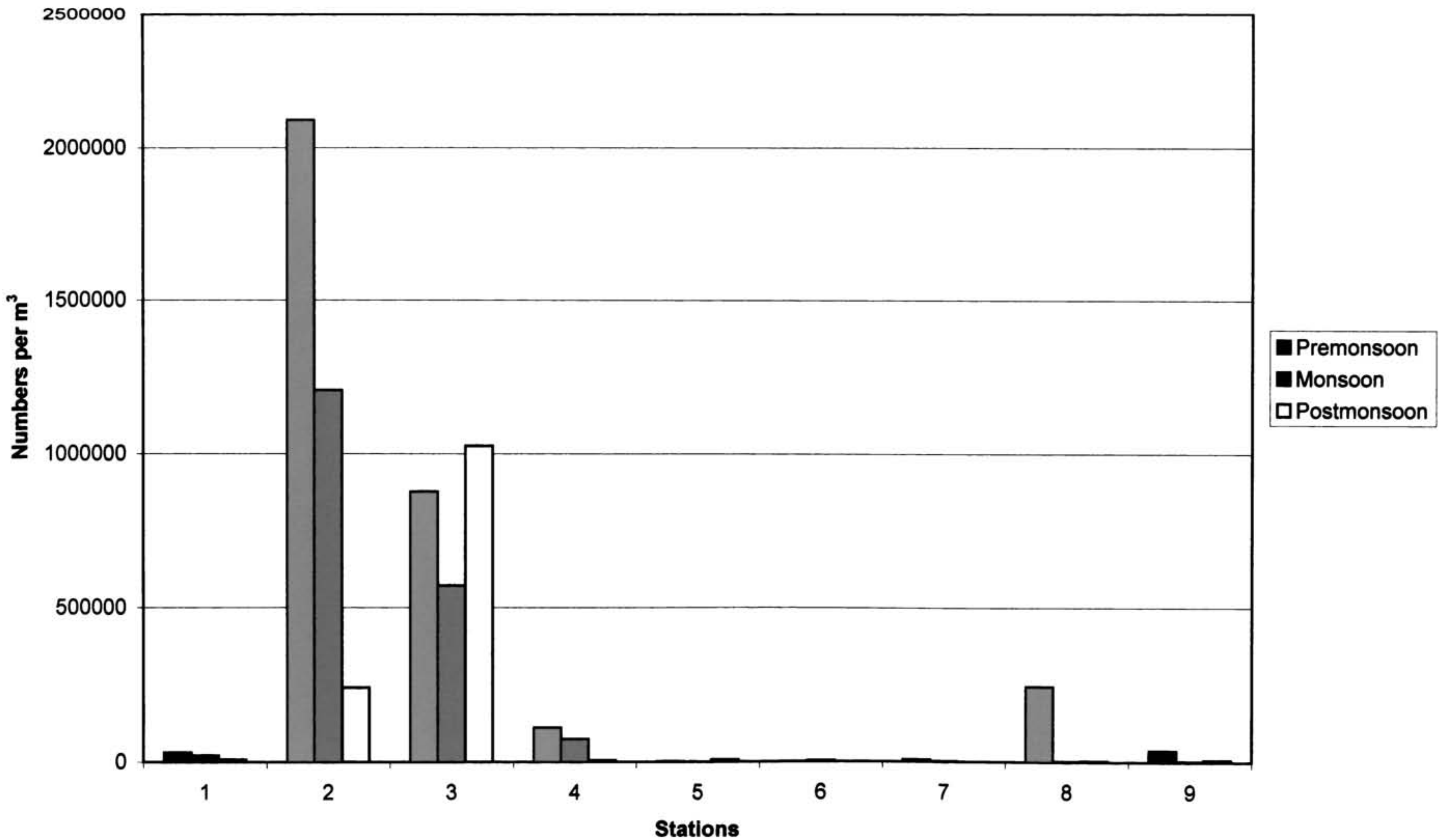


Fig.7. Seasonal distribution of the genus *Brachionus* in the study area

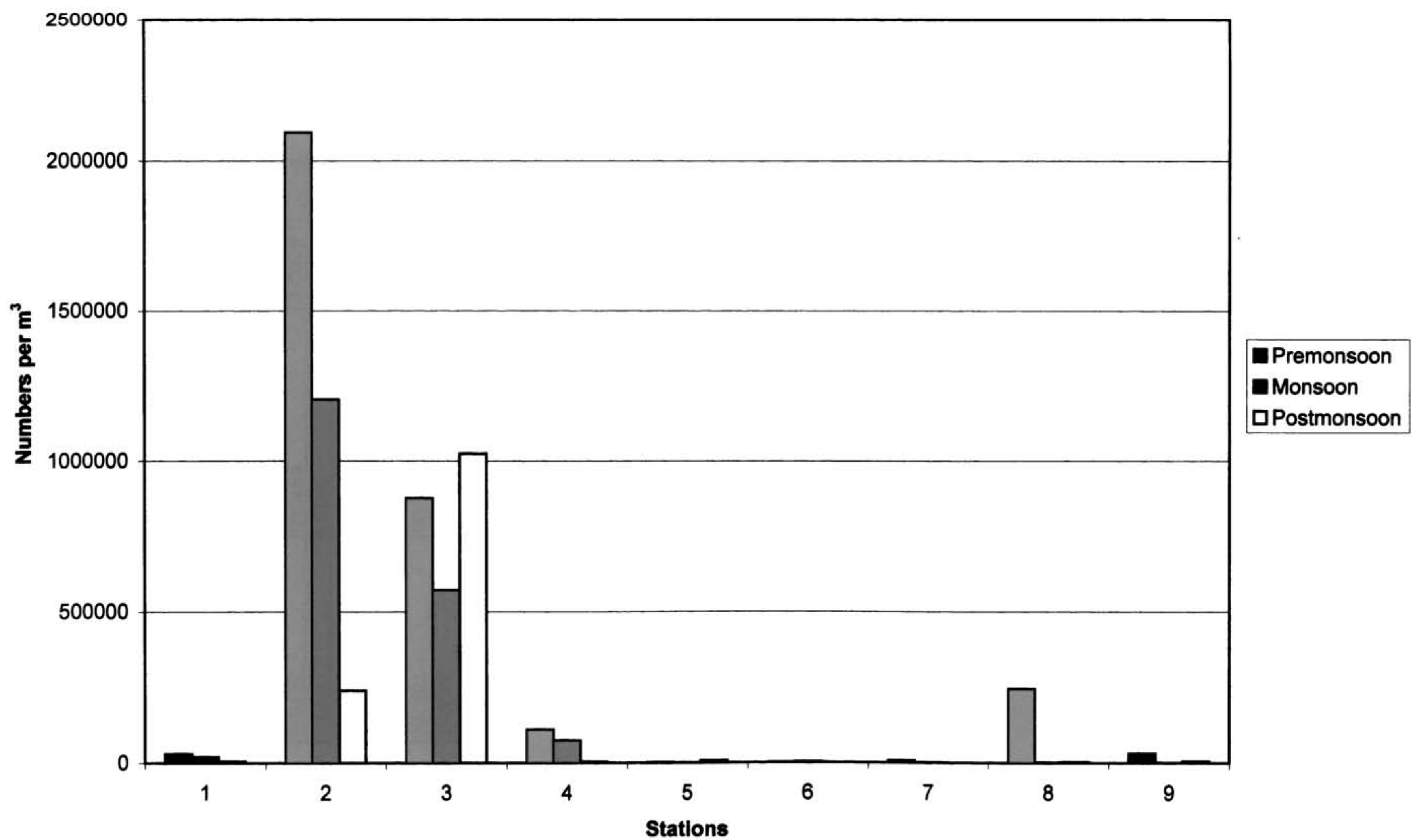


Table 5.1. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 1

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	10020	8020	8020
Mar	13080	13000	13000
Apr	58840	55040	55040
May	51200	50000	50000
Jun	14600	13800	12200
Jul	58800	51600	50800
Aug	5240	3840	3820
Sep	17010	17000	17000
Oct	16430	8420	2420
Nov	25600	17800	16200
Dec	3000	600	600
Jan	6200	6000	6000

Table 5.2. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 2

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	531000	520000	520000
Mar	952835	937235	937235
Apr	2481800	2471600	2471600
May	4464800	4443200	4443200
Jun	2355300	1962800	1962600
Jul	2277200	1967000	1967000
Aug	360300	321100	315900
Sep	595800	572750	572750
Oct	210675	182000	180000
Nov	291333	249533	245533
Dec	191534	184467	184467
Jan	353000	348000	348000

Table 5.3. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 3

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	261334	240667	240667
Mar	739067	732200	732200
Apr	276400	274400	274400
May	2282000	2258000	2258000
Jun	13600	12400	12400
Jul	93200	78200	78200
Aug	875050	857950	857950
Sep	1349225	1335400	1335400
Oct	1053520	1036660	1036460
Nov	1383334	1378534	1377934
Dec	581267	580067	580067
Jan	1119250	1103850	1103850

Table 5.4. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 4

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	12440	11500	11500
Mar	84140	80000	80000
Apr	32040	25000	25000
May	345700	326700	324700
Jun	270000	245500	245500
Jul	8100	3600	3600
Aug	2200	400	400
Sep	71246	48546	48446
Oct	3300	900	800
Nov	6540	2820	2400
Dec	8120	5020	5020
Jan	15300	10000	10000

Table 5.5. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 5

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	18200	3900	3900
Mar	14520	1500	500
Apr	15440	800	800
May	9520	1320	1220
Jun	3199	0	0
Jul	3800	0	0
Aug	4400	1000	0
Sep	4451	500	0
Oct	3800	240	100
Nov	2620	0	0
Dec	4180	2400	2400
Jan	29265	24420	24220

Table 5.6. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 6

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	7200	800	600
Mar	4000	1600	1600
Apr	1820	1400	1400
May	440	40	0
Jun	14240	6240	4200
Jul	6200	3600	2400
Aug	1400	1260	40
Sep	2000	2000	2000
Oct	120	40	0
Nov	1200	0	0
Dec	610	200	200
Jan	1020	200	200

Table 5.7. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 7

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	1020	0	0
Mar	4440	1800	1000
Apr	29400	24400	24400
May	6350	250	250
Jun	25200	3200	1200
Jul	24600	0	0
Aug	15825	400	400
Sep	10480	3680	2040
Oct	7660	1200	1200
Nov	6240	200	200
Dec	2810	0	0
Jan	2060	20	20

Table 5.8. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 8

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	8840	4600	4600
Mar	19400	13800	13000
Apr	102040	100000	100000
May	861500	860000	860000
Jun	18400	2000	2000
Jul	3000	3000	3000
Aug	12900	200	200
Sep	7640	20	10
Oct	4925	50	25
Nov	2320	40	0
Dec	12000	2200	2200
Jan	14020	11200	11200

Table 5.9. Monthwise distribution(Nos./m^3) of total rotifers, family Brachionidae and genus *Brachionus* at Station 9

Months	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	100800	86800	86600
Mar	20040	14400	14400
Apr	33120	28000	28000
May	25000	20200	200
Jun	15000	4600	2200
Jul	33140	420	400
Aug	17310	1650	20
Sep	29240	2400	400
Oct	16400	2800	1200
Nov	84280	1000	0
Dec	6260	1400	1400
Jan	40410	22200	22200

The genus *Brachionus* formed the major component (95.9%) of Brachionidae at station I and an average of 19591 numbers of *Brachionus* per m^3 of water was observed here. Seasonally, 31515, 20955 and 6305 numbers per m^3 were recorded during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise distribution showed the peak in April and a minimum in December ranging between 600 and 55040 numbers per m^3.

Station II

At station II, an average of 1255465 numbers of rotifers were recorded per m^3 of water. Seasonal distribution indicated, 2107609, 1397150 and 261635 numbers/m^3 during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise variation showed an increase from December to May and the maximum number was recorded in May and the minimum was noticed in December, ranging between 191534 and 4464800 numbers per m^3 of water.

Of the rotifers recorded at this station, the family Brachionidae alone contributed 1179974 numbers per m^3 (94%). Seasonally, 2093009 numbers/m^3 were observed during premonsoon season, 1205913 numbers/m^3 during monsoon and 241000 numbers/m^3 during the postmonsoon season. The monthwise distribution pattern indicated an increase from December to May and the numbers ranged from 182000 numbers per m^3 in October to 4443200 numbers per m^3 during May.

Of the family Brachionidae, the genus *Brachionus* formed the major component (99.9%) at this station and the mean number of *Brachionus* recorded was 1179024 per m^3 of water. Seasonally, 2093009, 1204563 and 239500 numbers/m^3 were observed during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise distribution showed an increase from December to May, the maximum was in May and minimum in October; ranging from 180000 to 4443200 numbers per m^3.

Station III

At station III, an average of 835604 numbers of rotifers per m^3 of water were recorded. Seasonal distribution showed, 889700 numbers/m^3 during premonsoon, 582769 numbers/m^3 during monsoon and 1034343 numbers/m^3 during the postmonsoon season. Monthwise distribution indicated the maximum during May and minimum during June. The number of rotifers per m^3 of water during June and May were 13600 and 2282000 respectively.

The rotifers under the family Brachionidae contributed a major share (98.6%) of the rotifers at station III. Out of the rotifers, 824027 numbers of Brachionids per m^3 of water were noticed from this station. Seasonal distribution indicated, 876317 numbers/m^3 during premonsoon, 570988/m^3 during monsoon and 1024778 numbers/m^3 during the postmonsoon season. Monthwise distribution revealed a sharp increase in May and a gradual increase from June to September. The minimum was in June and maximum in May having variation from 12400 to 2258000 numbers per m^3 of water.

The genus *Brachionus* formed a major share (99.99%) of the family Brachionidae and an average of 823961 numbers of *Brachionus* was recorded per m^3 of water from this station. Seasonally, 876317, 570988 and 1024578 numbers per m^3 were observed during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise distribution revealed a major peak in May, the numbers ranged from 12400 per m^3 in June to 2258000 per m^3 in May.

Station IV

An average of 71594 numbers of rotifers per m^3 of water were recorded from this station. Seasonally, 118580, 87887 and 8315 numbers/m^3 were observed during premonsoon, monsoon and postmonsoon seasons respectively. The monthwise variation was from 2200 numbers per m^3 in August to 345700 numbers per m^3 in May.

Among the rotifers at station IV, those coming under the family Brachionidae were found to dominate (88.5%) and an average of 63332 numbers/m^3 of Brachionids were recorded from this station. Seasonal distribution showed, 110800, 74512 and 4685 numbers/m^3 during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise distribution pattern showed a clear maximum in May, and gradually declined to a minimum, in August. At this station, the minimum and maximum concentrations of Brachionids observed were during August and May, numbered 400 and 326700 per m^3 of water.

Of the family Brachionidae, the genus *Brachionus* formed the major component(99.7%) and an average of 63114 numbers per m^3 were observed at this station. Seasonally, 110300, 74487 and 4555 numbers/m^3 were recorded during premonsoon, monsoon and postmonsoon seasons respectively. Monthly distribution showed the peak during May and the numbers of *Brachionus* varied from 400 per m^3 in June to 324700 per m^3 in May.

Station V

An average of 9449 numbers of rotifers per m^3 of water were recorded from station V. Seasonal distribution showed, 14420 numbers/m^3 during premonsoon, 3962 numbers/m^3 during monsoon and 9966 numbers/m^3 during the postmonsoon season. A minimum of 2620 numbers per m^3 was recorded during November and a maximum of 29265 numbers per m^3 was observed during January.

Out of the rotifers recorded at station V, 3007 numbers (31.8%) belonged to the family Brachionidae. Seasonal distribution showed, 1880, 375 and 6765 numbers/m^3 during premonsoon, monsoon and postmonsoon seasons respectively. Rotifers under the family Brachionidae were not recorded during June, July and November from this station. The maximum of 24420 numbers per m^3 of water was noticed during January.

Out of the total Brachionids, the genus *Brachionus* dominated (91.9%) at this station and an average of 2762 numbers of *Brachionus* per m^3 of water was observed. Seasonwise studies showed 1605 numbers/m^3 during premonsoon, 6680 numbers/m^3 during postmonsoon and not recorded during the monsoon season. Monthwise distribution revealed the absence of *Brachionus* at this station during June, July, August, September and November. The maximum of 24220 numbers per m^3 was recorded during January.

Station VI

At station VI, an average of 3354 numbers of rotifers were noticed per m^3 of water. Seasonally, 3365, 5960 and 738 numbers per m^3 of water were recorded during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise distribution of rotifers indicated a minimum value of 120 numbers per m^3 in October and a maximum of 14240 numbers per m^3 in June.

Of the rotifers recorded from this station, 1448 numbers (43.2%) were Brachionids. Seasonally, 960 numbers/m^3 were recorded during premonsoon season, 3275 during monsoon and only 110 numbers/m^3 were noticed during the postmonsoon season. Monthwise distribution showed the maximum of 6240 numbers per m^3 in June. Brachionids were not recorded from this station during November.

At this station, the genus *Brachionus* dominated (72.7%) over other genera under the family Brachionidae and of the Brachionids, 1053 numbers/m^3 were *Brachionus*. Seasonally, 900, 2160 and 100 numbers were recorded during premonsoon, monsoon and postmonsoon seasons respectively. At this station, *Brachionus* was not observed in May, October and November. Two peaks were noticed in the monthwise distribution pattern; the major one in June and the minor one in September, the maximum was 4200 numbers per m^3 in June.

Station VII

An average of 11340 numbers of rotifers per m^3 were observed in Station VII. Seasonal distribution indicated, 10303 numbers/m^3 during premonsoon, 19026 numbers/m^3 during monsoon and 4693 numbers/m^3 during postmonsoon season. Monthwise variation showed a clear maxima during April, from 1020 numbers per m^3 in February to 29400 numbers per m^3 in April.

Out of the rotifers, 2929 numbers (25.8%) were recorded under the family Brachionidae from this station. Seasonally, 6613 numbers/m^3 were contributed during premonsoon, 1820 numbers during monsoon and 355 numbers/m^3 were recorded during the postmonsoon season. Monthwise distribution showed the maximum of 24400 numbers per m^3 of water during April. The Brachionids were not observed during February, July and December.

Out of the rotifers under the family Brachionidae, the genus *Brachionus* dominated (87.4%) and 2559 numbers/ m^3 were observed at station VII. Seasonally, 6413 numbers/m^3 were recorded during premonsoon season, 910/m^3 during monsoon and 355 numbers/m^3 were recorded during the postmonsoon season. Monthwise distribution showed a clear peak of 24400 numbers per m^3 of water in April. The genus *Brachionus* was not recorded during February, July and December.

Station VIII

An average of 88915 numbers per m^3 of rotifers were observed from station VIII. Seasonally, 247945 , 10485 and 8316 numbers per m^3 were recorded during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise distribution indicated a sharp increase during May and the numbers ranged from 2320 per m^3 of water in November to 861500 numbers per m^3 in May.

Out of the rotifers at this station, the family Brachionidae dominated (93.5%) and 83092 numbers of Brachionids were recorded from this station. Seasonally, 244600, 1305 and 3373 numbers/m^3 were observed during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise variation indicated a sharp increase in May. The minimum was in September and maximum in May, the numbers per m^3 during September and May were 20 and 860000 respectively.

In numerical abundance, the genus *Brachionus* was prominent (99.9%) under the family Brachionidae at this station and 83019 numbers of *Brachionus* were noticed per m^3 of water. Seasonally, 244400, 1303 and 3356 numbers/m^3 were recorded during premonsoon, monsoon and postmonsoon seasons respectively. Monthly variation showed a clear peak during May. From February to April there was a gradual increase and from April to May a sharp increase was observed. In May, 860000 numbers per m^3 were noticed and *Brachionus* was not recorded during November at this station.

Station IX

At station IX, the rotifers noticed were 35083 numbers per m^3. Seasonal distribution showed, 44740 numbers during premonsoon, 23673 numbers during monsoon and 36838 numbers during the postmonsoon season from m^3 of water. Two peaks were noticed in the monthwise abundance of rotifers at this station, the primary peak was in February and the secondary one was in November. The monthwise variation was from 6260numbers per m^3 in December to 100800 numbers per m^3 in February.

Out of the rotifers, 15489 numbers (44.2%) belonged to the family Brachionidae. Seasonally, 37350 numbers/m^3 were noticed during premonsoon, 2268 numbers/m^3 during monsoon and 6850 numbers/m^3 during the postmonsoon season. The monthwise distribution showed the minimum of 420 numbers per m^3 in July and a maximum of 86800 numbers per m^3 during February.

Among the genera under the family Brachionidae, the genus *Brachionus* was the prominent one (84.5%) and 13085 numbers of *Brachionus* were observed from this station. Seasonally, 32300 numbers/m^3 were recorded during premonsoon, 755 during monsoon and 6200 numbers/m^3 during the postmonsoon season. Monthwise distribution showed the maximum of 86600 numbers per m^3 during February, and *Brachionus* was not recorded during November.

The analysis of variance (ANOVA) between months, seasons and stations were carried out in the case of rotifers in general and family Brachionidae and genus *Brachionus* in particular to understand the respective variations statistically. Between different stations, the abundance of rotifers, family Brachionidae and genus *Brachionus* showed significant variations ($P<0.01$). In depth analysis showed that the numerical abundance of these three groups at station II varied significantly with that of station Nos. I,IV,V,VI,VII,VIII and IX($P<0.01$). The abundance of these groups at station III also showed similar variations as in the case of station II. However, significant variations were not observed between that of stations II and III, but these two stations showed significant variations with all the other stations.

The abundance of rotifers, family Brachionidae and genus *Brachionus* did not show significant variations between months or seasons.

B.2. PERCENTAGE COMPOSITION

To have an in depth knowledge of the faunal composition of the study area, the percentage composition of the different genera available in each station is described. Since, the present study is more focused on the genus *Brachionus*, under the family Brachionidae, the percentage composition of different species available under the genus *Brachionus* in each station are presented and discussed. The distribution of each genus/species among different stations are also studied.

B.2.a. Percentage composition of different genera under Rotifers, family Brachionidae, and species composition under the genus *Brachionus* in each station.

Rotifers :-The percentage composition of different genera of rotifers in the different stations, are depicted in Fig.8. In the figure, fractional values of percentages are rounded of to the next whole number and those genera contributing less than 1% are not visible, are not given in graphs.

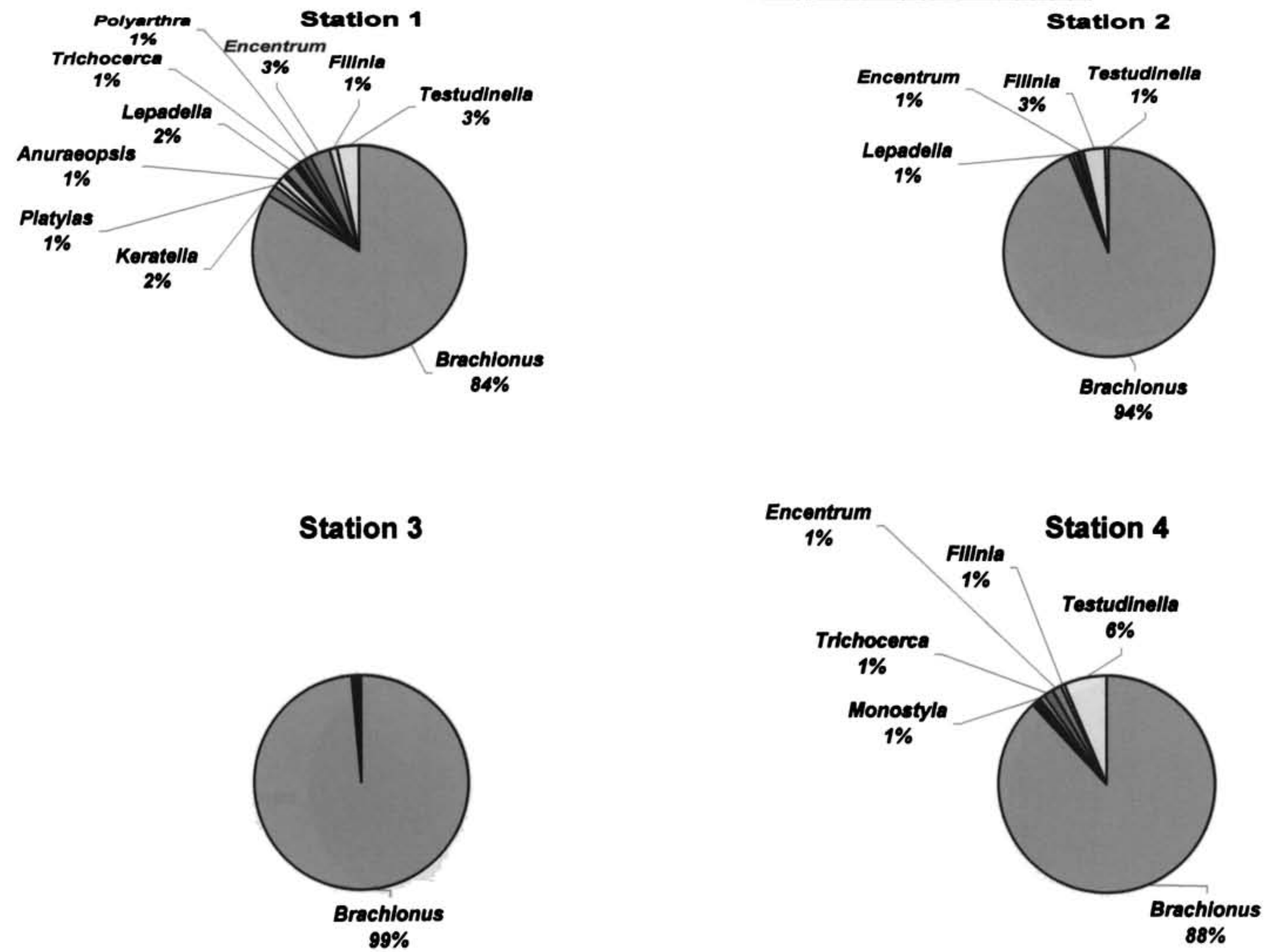
Out of the sixty genera so far reported from India, twenty genera of rotifers(33.33%) were recorded during the present study. Except for station VII, *Brachionus* dominated over other genera in all the 8 stations. At station VII, *Encentrum* was found to be the major component among the rotifers.

At station I, out of the 15 genera of rotifers recorded during the present study, *Brachionus* formed 84% , followed by *Testudinella*(3.2%), *Encentrum*(3%), *Keratella*(1.72%), *Lepadella*(1.71%), *Polyarthra*(1.3%), *Filinia*(1.2%) and *Anuraeopsis*(1.1%). Other genera contributed only less than 1% each.

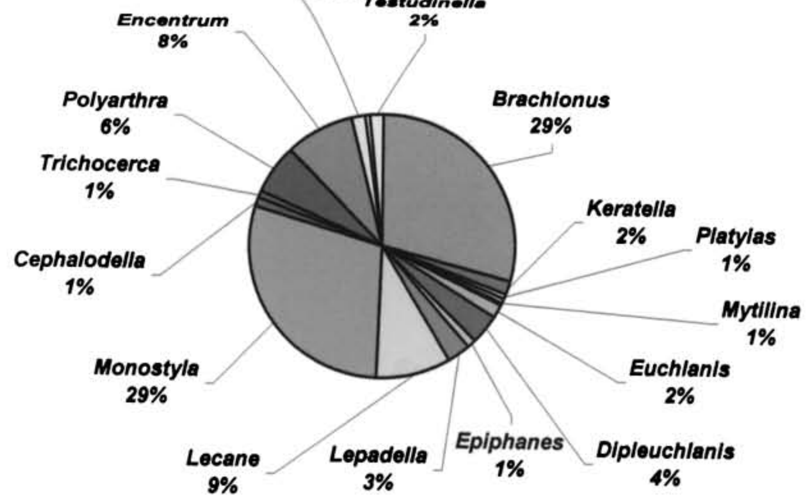
Out of the 14 genera of rotifers recorded from station II, *Brachionus* contributed 94% of total rotifers, followed by *Filinia* forming 3%. All the other genera among rotifers recorded from this station contributed only less than 1%, each.

Brachionus was the only genus contributing to a major share, which formed 99% of rotifers at station III. All the other 12 genera of rotifers together, formed only less than 1% at this station, during the study period.

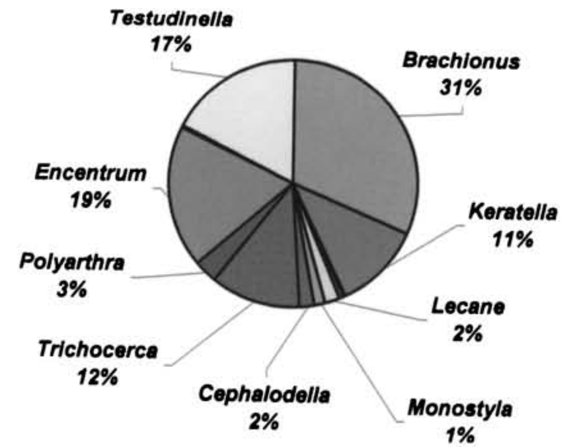
FIG.8. PERCENTAGE COMPOSITION OF ROTIFER GENERA IN EACH STATION



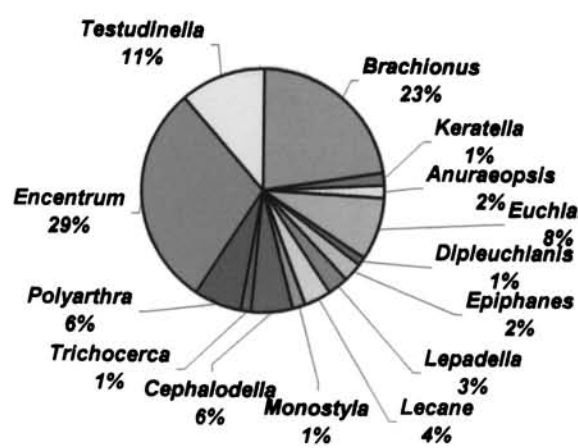
Station 5



Station 6



Station 7



Station 8

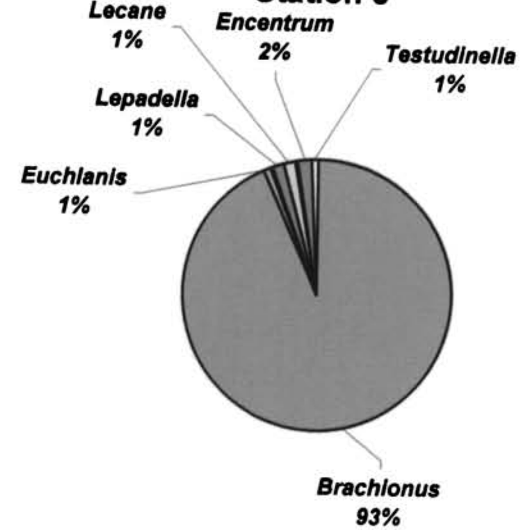
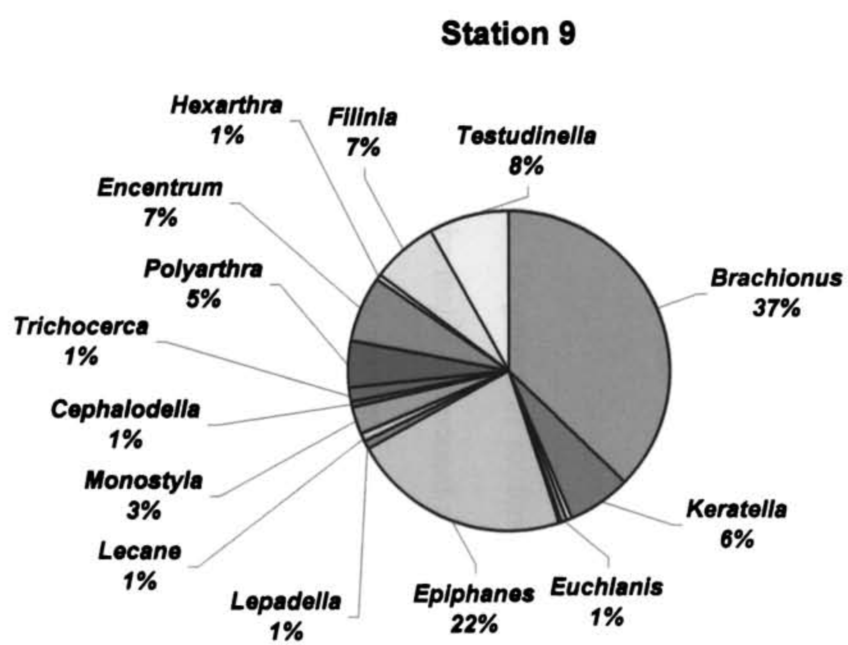


Fig.8 Continued



15 genera of rotifers were recorded from station IV during the present study. Out of these, *Brachionus* dominated with 88%, followed by *Testudinella*(6%), *Encentrum*(1.4%) and *Trichocerca*(1.35%). Other genera formed only less than 1% each, at this station.

At station V, 18 genera of rotifers were recorded during the present study. Eventhough the genus *Brachionus* dominated over other genera, it formed only 29.2%. Almost similar numbers of the genus *Monostyla* was also observed from this station which formed 29.16%. All the other genera contributed their share in the given many; *Lecane* contributed 9%, followed by *Encentrum*(8%), *Polyarthra*(6%), *Dipleuchlanis*(4%), *Lepadella*(3%), *Hexarthra*(1.8%), *Testudinella*(1.7%), *Euchlanis*(1.6%), *Keratella*(1.59%), *Cephalodella*(1.2%), and *Epiphanes*(1.1%). And, the remaining genera contributed only less than 1% each, to the rotifer fauna of this station.

During the present study, 13 genera of rotifers were recorded from station VI. The genus *Brachionus* formed the major component at this station. Some other genera also contributed relatively in reasonable numbers, to the rotifer fauna of this station. The genus *Brachionus* contributed 31%, followed by *Encentrum*(19%), *Testudinella* (17%), *Trichocerca*(12%), and *Keratella*(11%). Other minor components were *Polyarthra*(3%), *Cephalodella*(2.1%), *Lecane*(2%) and *Monostyla*(1%). And all the other genera contributed only less than 1% to the rotifers at this station, during the study period.

The distribution of rotifers at station VII differed in that, the major component was *Encentrum* here, while *Brachionus* dominated in all the other stations. Out of the 16 genera of rotifers recorded from this station during the present study, the genus

Encentrum formed 29% followed by *Brachionus*(23%). Next in abundance were *Testudinella*(11%), followed by *Euchlanis*(8%), *Polyarthra*(7%), *Cephalodella*(6%), *Lecane*(4%), *Lepadella*(3%), *Epiphanes*(2.4%), *Anuraeopsis*(1.8%), *Keratella*(1.5%), *Monostyla*(1.5%), *Trichocerca*(1.3%) and *Dipleuchlanis* (1.2%). And all the other genera recorded from this station formed only less than 1%.

At station VIII, only 13 genera of rotifers were recorded. Among them, the genus *Brachionus* dominated and contributed 93% of the rotifer fauna. *Encentrum* formed 2%, *Lepadella* 1.5%, and *Lecane* contributed 1.3%. Other rotifers formed only less than 1% each.

19 genera of rotifers were recorded from station IX, and, this was the highest number of genera recorded among all the nine stations. The genus, *Brachionus* formed the major component and contributed 37% of the rotifers recorded from this station. Next in abundance was by *Testudinella*(8%), *Encentrum*(6.7%), *Filinia*(6.6%), *Keratella*(6.4%), *Polyarthra*(4.8%), *Monostyla*(3%), *Trichocerca*(1.3%) and *Lepadella*(1%). Other genera contributed only less than 1% each.

Family Brachionidae:-The percentage composition of different genera under the family Brachionidae in the different stations is depicted in Fig.9. In the figure, fractional values of percentages are rounded of to the next whole number, and, those genera which are contributing less than 1%, are not visible in the graphs.

In the present study, under the family Brachionidae, four genera viz. *Brachionus, Keratella, Platyias* and *Anuraeopsis* were recorded and among them *Brachionus* dominated in all the nine stations selected.

FIG.9.PERCENTAGE COMPOSITION OF THE FOUR GENERA IN THE FAMILY BRACHIONIDAE IN EACH STATION

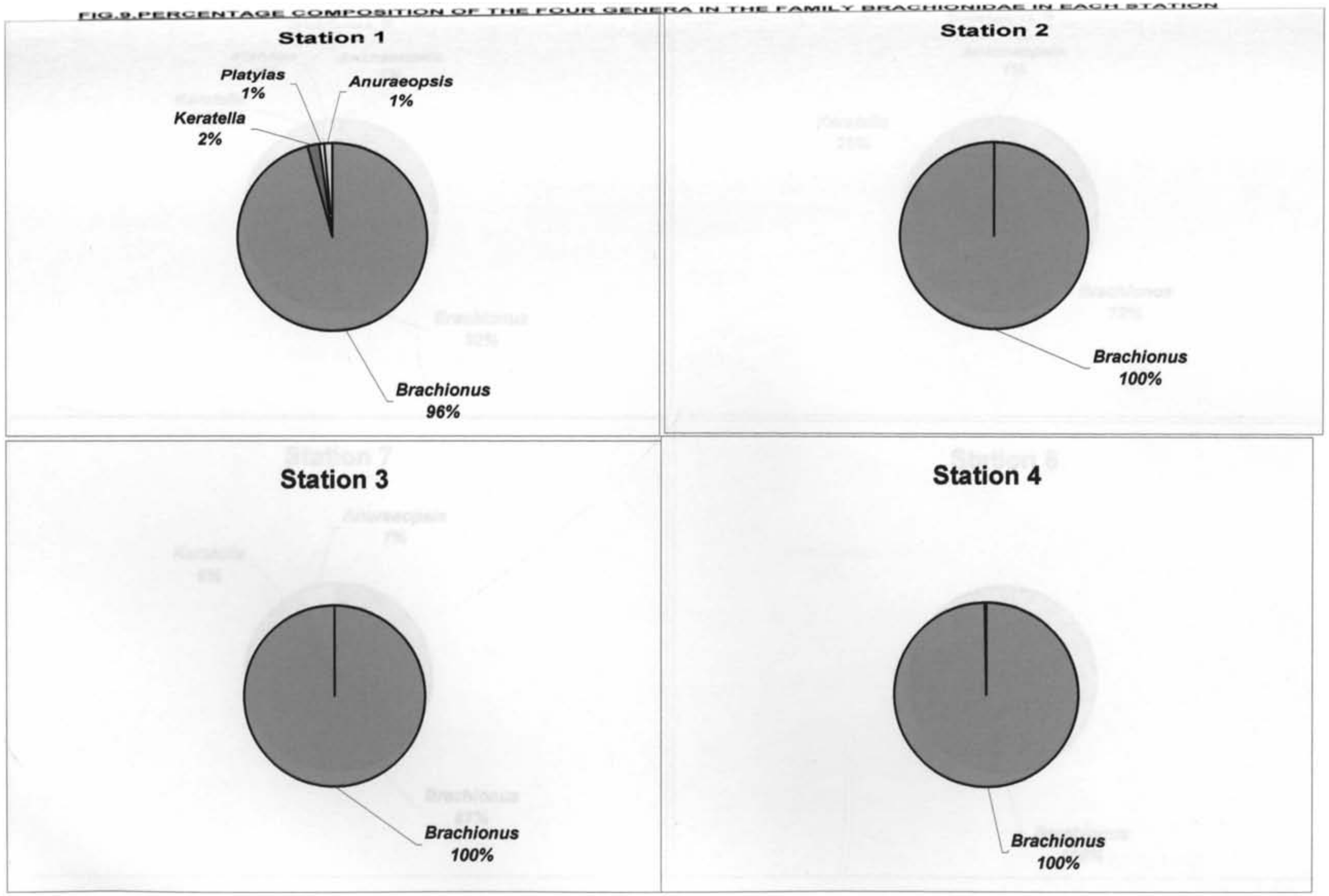


Fig.9 Continued

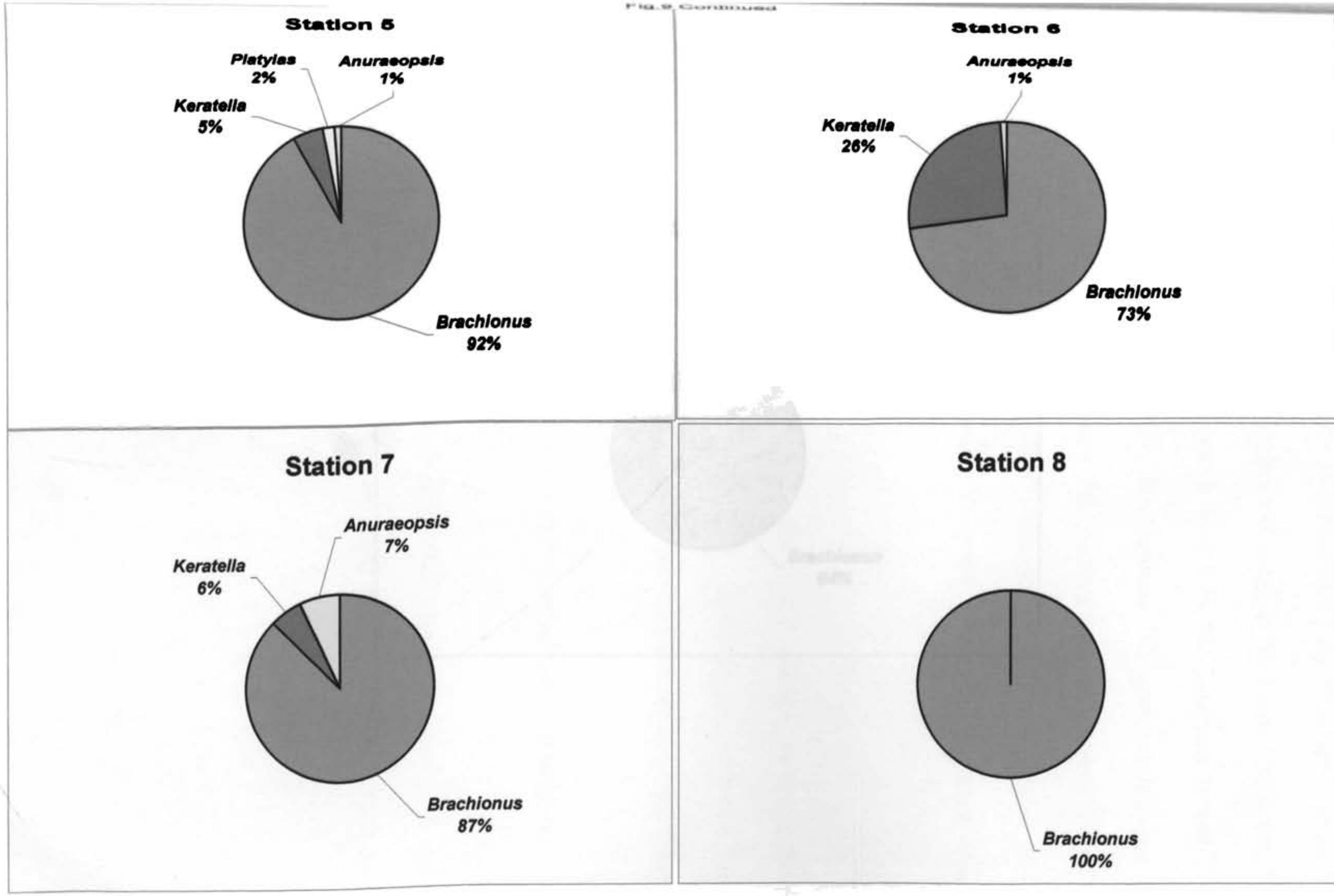
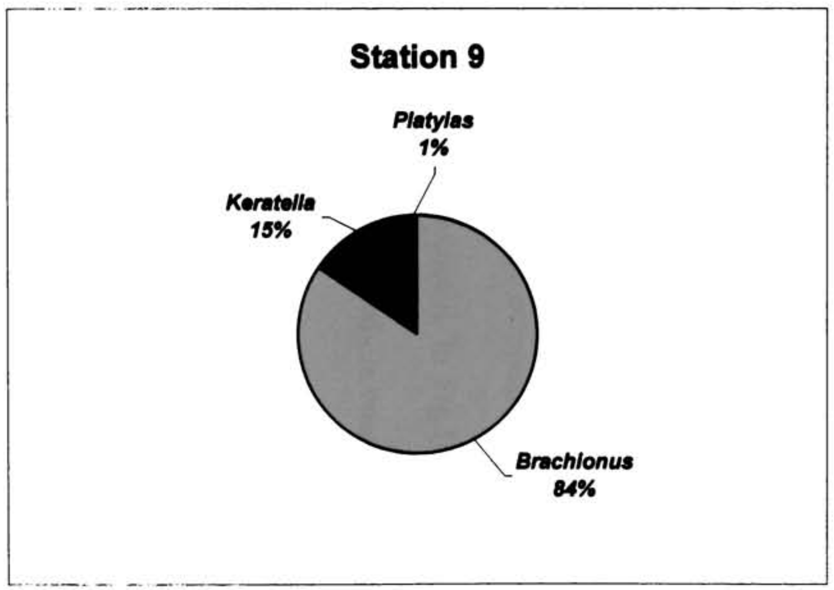


Fig.9 Continued



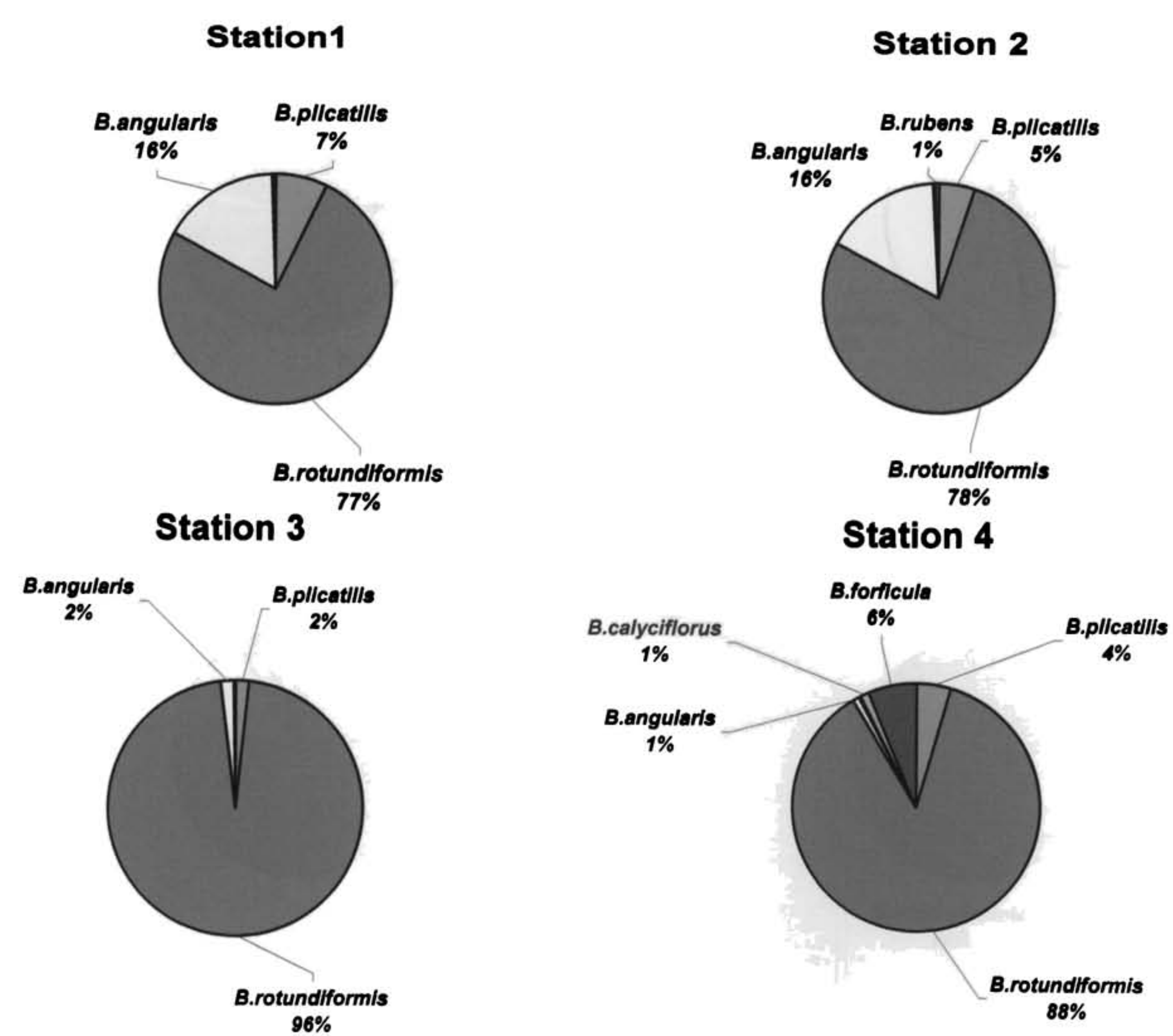
At station I, *Brachionus* formed 96% , *Keratella* and *Anuraeopsis* formed 2% and 1% respectively. *Platyias* formed only less than 1%. At station II, the contribution of *Brachionus* extended to 99.9% and the rest by other three genera. At station III, *Brachionus* formed 99.99%, while 99.7% was contributed by *Brachionus* at station IV. At station V, *Brachionus* , *Keratella, Platyias* and *Anuraeopsis* formed 92%, 5%, 2% and 1% respectively. At station VI, *Brachionus* formed 73%, but *Keratella* formed 26% and *Anuraeopsis* formed only 1% of the family Brachionidae. The genus *Brachionus* formed 87% of the family Brachionidae at station VII. *Anuraeopsis* and *Keratella* contributed 7% and 6% respectively. At station VIII, *Brachionus* contributed 99.9% of the family Brachionidae. At station IX, 84% and 15% were contributed by *Brachionus* and *Keratella* respectively.

***Brachionus* species**:- The percentage composition of different species under the genus *Brachionus* in each station are depicted, in Fig.10. In the figure, fractional values of percentages are rounded off to the next whole number and those species contributing less than 1% are not visible in the graphs.

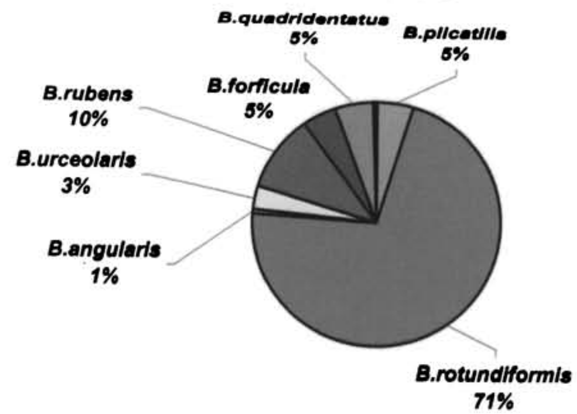
Among the 13 species of *Brachionus* recorded, *Brachionus rotundiformis* showed dominance, in all the stations studied.

At station I, *B.rotundiformis* dominated with 76% out of the 6 species of *Brachionus* recorded from this station. *B.angularis* formed 16% and *B.plicatilis* 7%. Other species constituted of less than 1% each.

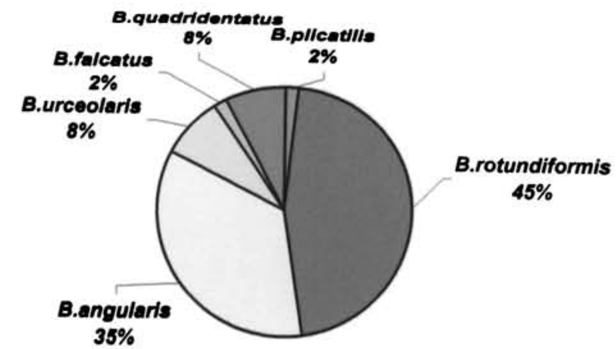
FIG.10. PERCENTAGE COMPOSITION OF *BRACHIONUS* SPECIES IN EACH STATION



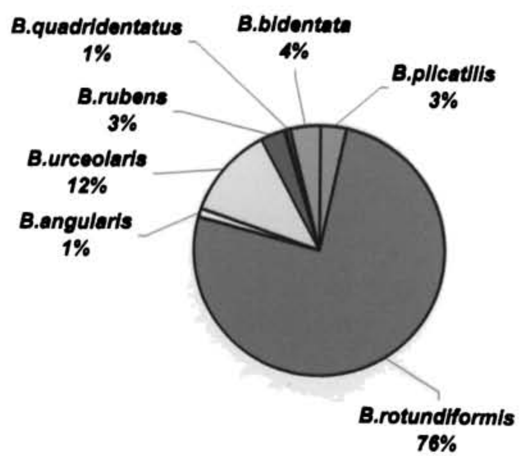
Station 5



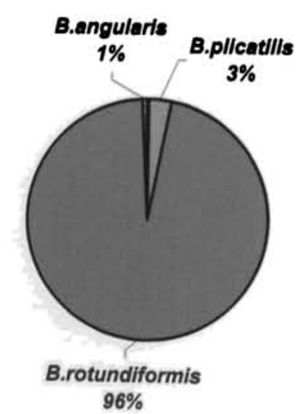
Station 6

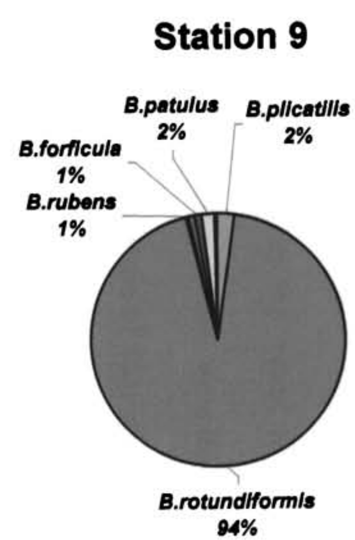


Station 7



Station 8





Station 9
B.patulus
2%
B.plicatilis
2%
B.forficula
1%
B.rubens
1%
B.rotundiformis
94%

At station II, the trend was the same as in the case of station I. 78%, 16% and 5% were contributed by *B.rotundiformis* , *B.angularis* and *B.plicatilis* respectively. Other species constituted less than 1% each.

At station III also, *B.rotundiformis* remained to be the dominant species with a share of 96% among the different species of *Brachionus* recorded from this station. 2% each was contributed by *B.plicatilis* and *B.angularis*. Other species were scarce, with a share of less than 1% each.

At station IV also, *B.rotundiformis* formed the major share of 87%. Next in abundance was *B.forficula* with a share of 6%. *B.plicatilis* and *B.calyciflorus* were constituted by 4% and 1% respectively. Others were rare at this station, with less than 1% each.

At station V, *B.rotundiformis, B.rubens, B.quadridentatus, B.plicatilis, B.forficula* and *B.urceolaris* contributed to the extent of 71%, 10%, 5%, 4.8%, 4.5% and 3% respectively. The share of other species were less than 1% each.

At station VI, a major share of 46% was contributed by *B.rotundiformis,* 35% by *B.angularis*, 8% each by *B.urceolaris* and *B.quadridentatus*. The share of *B.plicatilis* and *B.falcatus* were 1.58% each.

Out of the total *Brachionus* species, 76% was contributed by *B.rotundiformis*, 12% by *B.urceolaris*, 4% by *B.bidentata*, 3% each by *B.rubens* and *B.plicatilis,* and, 1% was contributed by *B.angularis* at station VII. The contribution of other species were less than 1% each.

At station VIII, 96% was contributed by *B.rotundiformis* and 3% by *B.plicatilis*. Other species recorded were rare at this station, and contributed only less than 1% each.

At station IX also, *B.rotundiformis* dominated with a share of 94%. 2% was contributed by *B.plicatilis* and 1.7% by *B.patulus*. The share of other species was 1% each.

B.2.b. Percentage composition of each genus of rotifers and each species of *Brachionus*

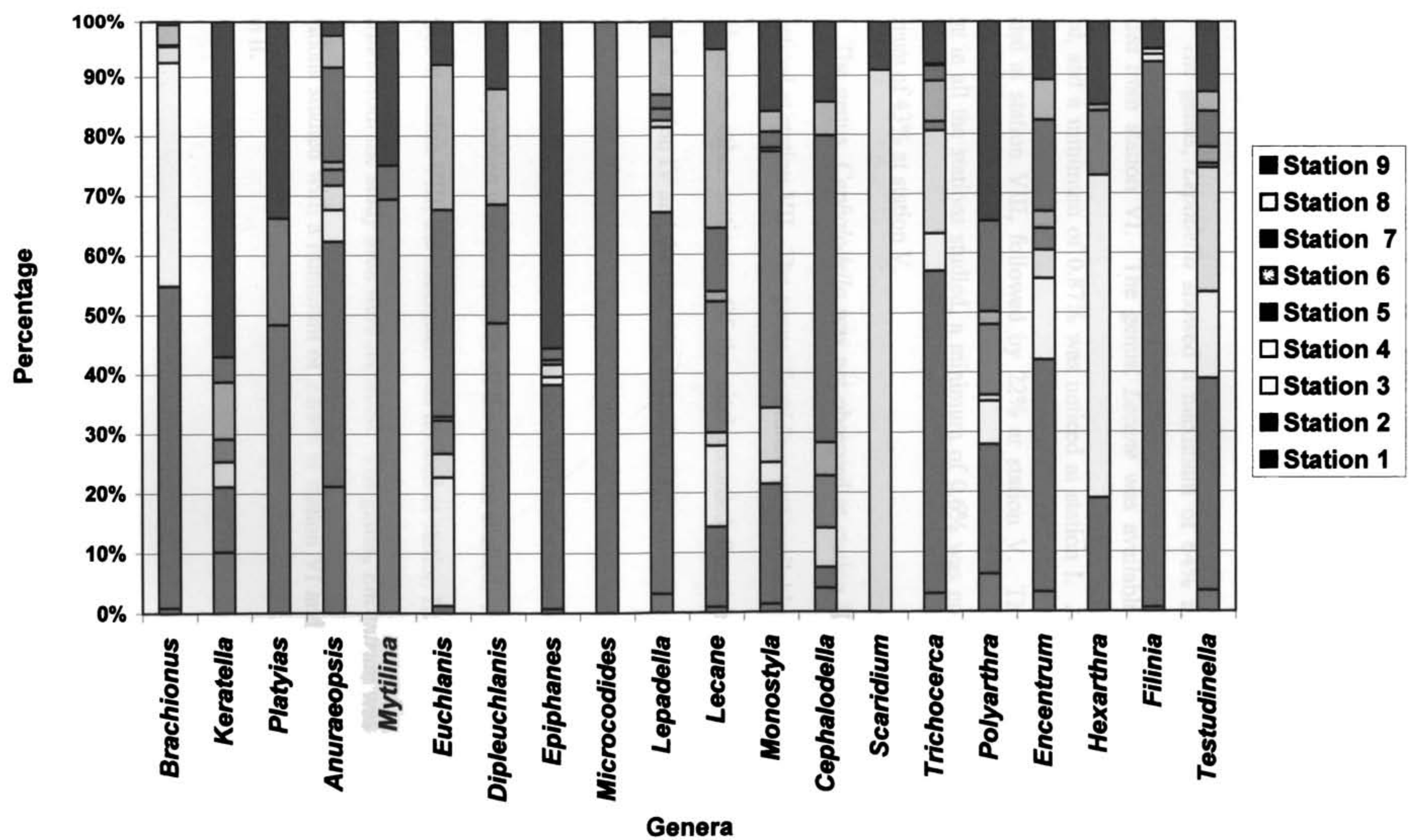
Distribution of different genera of rotifers in the area

The percentage composition of each genus of rotifers among different stations are depicted in Fig. 11. The abundance of *Brachionus* extended to 54% at station II, and this stood as the highest percentage recorded among all the nine stations studied. Next in abundance was 38% at station III. The minimum of 0.05% was noticed at station VI. The genus, *Keratella* was maximum at station IX with 57% of the total recorded from the study area. But, there were no observation of *Keratella* at stations III & VIII.

The genus, *Platyias* was recorded in stations I,V and IX and was absent in other stations. A maximum of 48% was noticed at station I, 34% at station IX and 18% at station V. The genus, *Anuraeopsis* was observed in all the nine stations studied. Of the total *Anuraeopsis* recorded from all the stations, a minimum of 1.3% was noticed at station VI and a maximum of 41% was recorded in station II.

The genus, *Mytilina* was recorded in stations V, VII and IX and was absent in other stations. A maximum of 69% was noticed at station V, followed by 25% at station IX. The genus, *Euchlanis* was not observed at station II. The abundance of *Euchlanis* was maximum at station VII with 35% of the total recorded, from the entire study area. The genus, *Dipleuchlanis* was observed from stations V, VII, VIII and IX and was absent in other stations, and, this genus was maximum at station V(49%).

Fig.11. Percentage composition of Rotifer genera in the area



The genus, *Epiphanes* was absent at station VIII and was available in all the other stations. A maximum of 56% was noticed at station IX. Next in abundance was noticed at station II with 37% of the total *Epiphanes* recorded from the study area. The genus, *Microcodides* was available only at station VII and that was a single occurrence noticed from the study area.

The genus, *Lepadella* showed a maximum of 64% at station II. It was not recorded from station VI. The genus, *Lecane* was available in all the nine stations studied, and a minimum of 0.87% was noticed at station I. A maximum of 30% was recorded at station VIII, followed by 22% at station V. The genus, *Monostyla* was present in all the stations studied, a minimum of 0.6% was noticed at station VI and a maximum of 43% at station V.

The genus, *Cephalodella* was not observed at station III. A maximum of 51% was noticed at station VII. The genus, *Scaridium* was available at stations IV and IX. It was absent in other stations. Of the total recorded from the study area, 91% was observed at station IV and the rest, 9%, at station IX.

The genus, *Trichocerca* was observed in all the stations studied. Out of the total, a minimum of 0.3% was noticed from station VIII and a maximum of 54% at station II. The genus,*Polyarthra* was observed in all the stations studied. A minimum of 0.04% was observed at station VIII, the maximum was noticed at station IX, where 35% of the total *Polyarthra* from the study area were recorded. The genus, *Encentrum* was noticed in all the stations studied with a minimum of 2.86% at station VI and a maximum of 39% at station II.

The genus, *Hexarthra* was not available in stations I,IV,VII and VIII and was present in other stations. Of these, a maximum of 54% was noticed from station III. The genus, *Filinia* was maximum at station II, contributed 92% of the total *Filinia* recorded from the study area. It was not available in stations VII and VIII. The genus, *Testudinella* was available in all the nine stations, in considerable numbers. Taken together, a minimum of 0.74% was noticed in station V and a maximum of 35% was observed from station II.

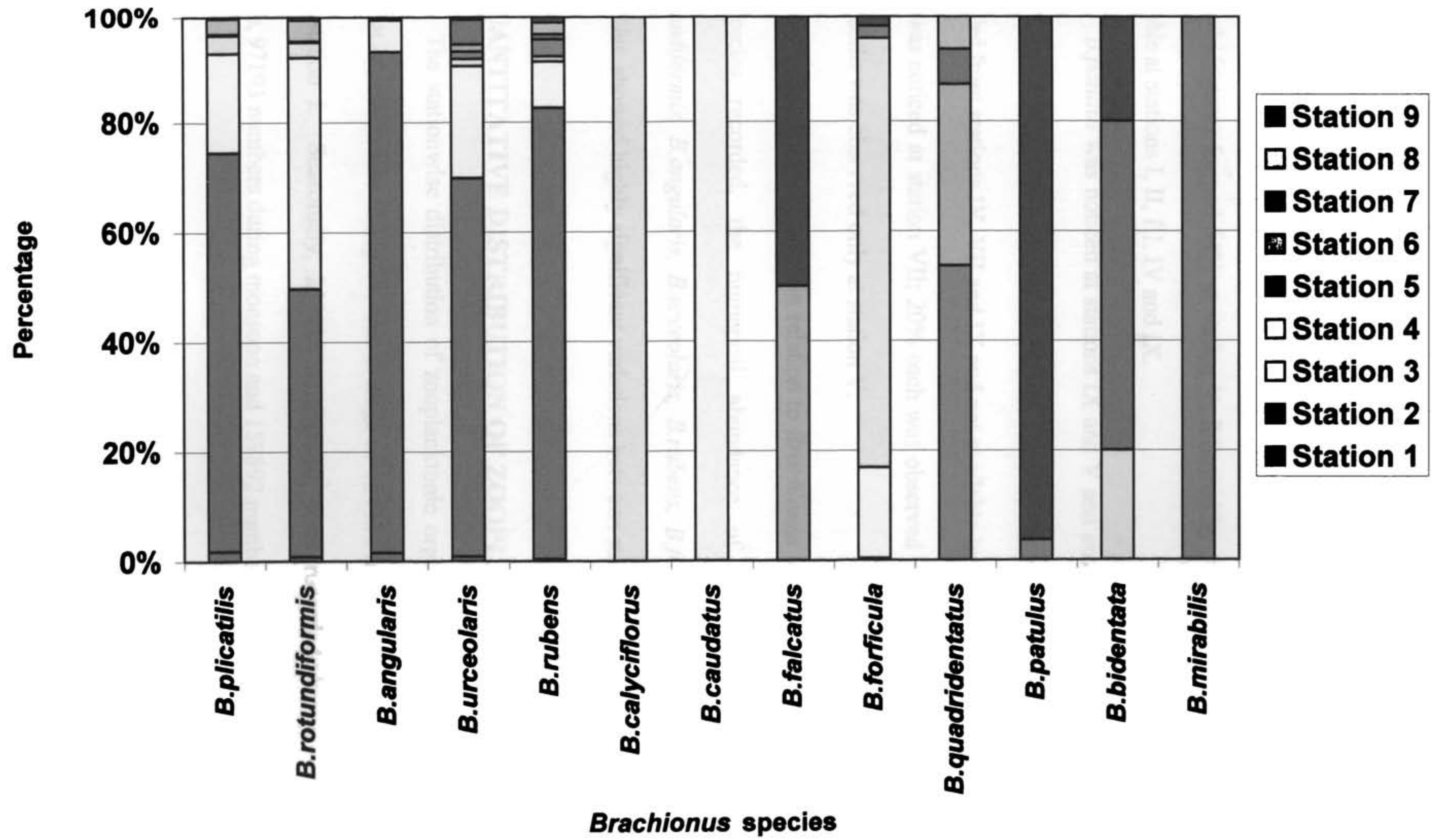
Of the rotifers recorded from the study area, the stationwise distribution showed that rotifers were maximum at station II followed by station III with 54% and 36% respectively, and the minimum of 0.14% was recorded at station VI.

Distribution of different species of *Brachionus*

The percentage composition of each species of the genus *Brachionus* in different stations are depicted in Fig. 12. Among the nine stations studied, *Brachionus plicatilis* was maximum at station II with 73% followed by 18% at station III and the minimum of 0.02% was noticed at station VI. *B.rotundiformis* showed maximum numbers at station II(49%) and next in abundance was noticed at station III with 42%. The minimum numbers were observed at station VI with 0.03%.

Among all the nine stations studied, *B.angularis* was observed with a maximum of 92% at station II, next in abundance was at station III with 6%. It was not recorded at station IX. The highest abundance of *B.urceolaris,* with 69%, was observed at station II, followed by 21% at station III. At station VIII, *B.urceolaris* was not recorded. *B.rubens* was maximum at station II with 82% and it was not noticed from station VI.

Fig.12. Percentage composition of *Brachionus* species in the area



B.calyciflorus was recorded only at station IV among the 9 stations studied. A single occurrence was noticed at station III in the case of *B.caudatus.*

B.falcatus was available at stations VI and IX, recorded to the extent of 50% each in these two stations. A maximum of 79% of *B.forficula* was noticed at station IV, followed by station III with 17%. It was not observed at stations VI and VIII. *B.quadridentatus* formed 54% at station V, followed by 33% at station VI, and was not available at stations I, II, III, IV and IX.

B.patulus was noticed at stations IX and V and absent in all the other stations. A maximum of 96% was recorded at station IX and 4% at station V. *B.bidentata* was recorded from stations IV, VII and IX and not available in other stations. A maximum of 60% was noticed at station VII; 20% each was observed at stations IV and IX, whereas *B.mirabilis* was observed only at station V.

The results of ANOVA in relation to *Brachionus* species showed that, out of the 13 species recorded, the numerical abundance of 8 species viz. *B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens, B.forficula, B.quadridentatus* and *B.patulus* showed highly significant variations between stations ($P<0.01$).

C.QUANTITATIVE DISTRIBUTION OF ZOOPLANKTON IN THE AREA

The stationwise distribution of zooplanktonic organisms are depicted in Fig.13 and that of seasonwise in Fig.14. An average of 154334 numbers per m^3 were observed from station I. Seasonally, 205918 numbers/m^3 were recorded during premonsoon season, 97193 numbers during monsoon and 159892 numbers/m^3 were noticed during the

Fig.13. Stationwise distribution of Zooplankton during the study period

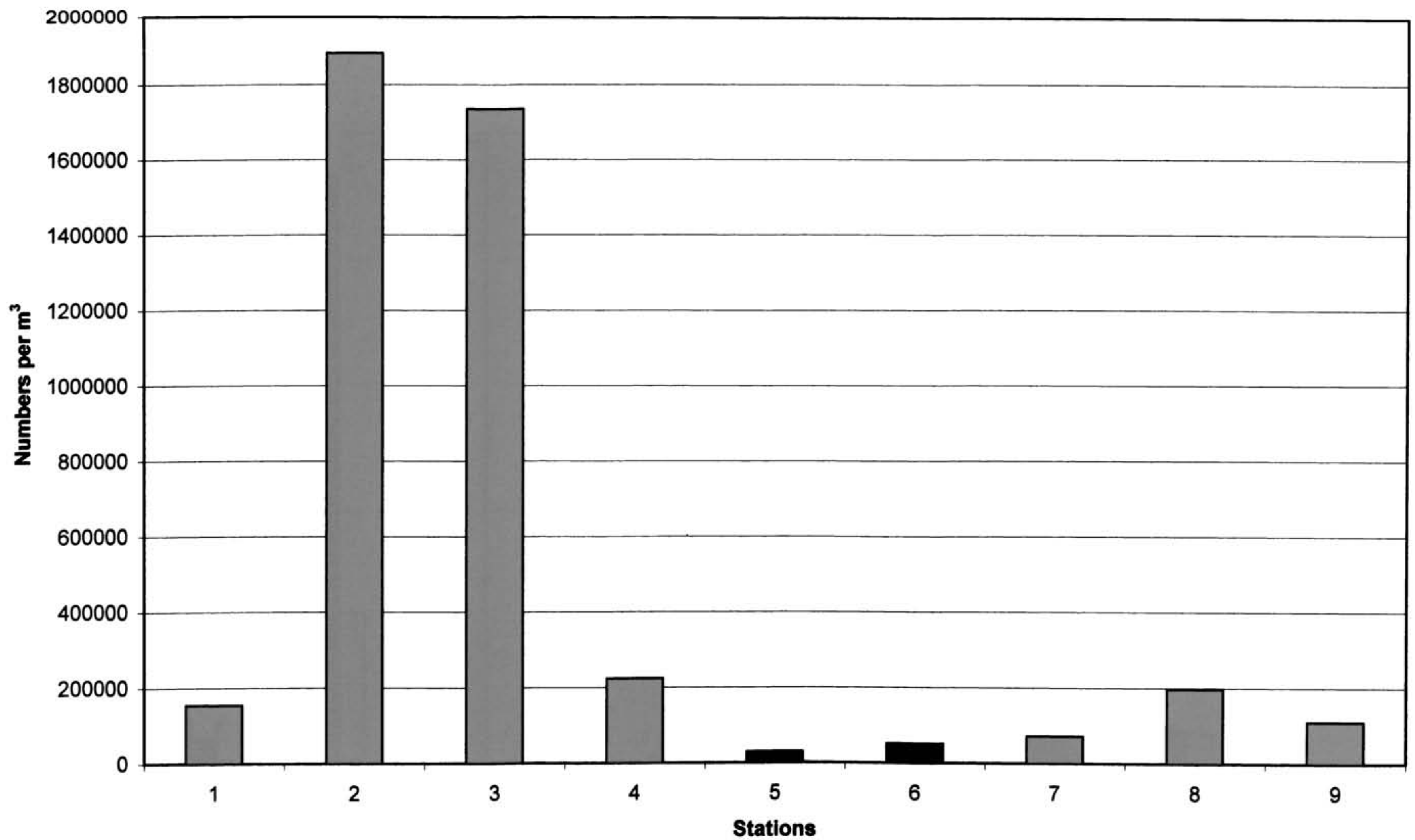
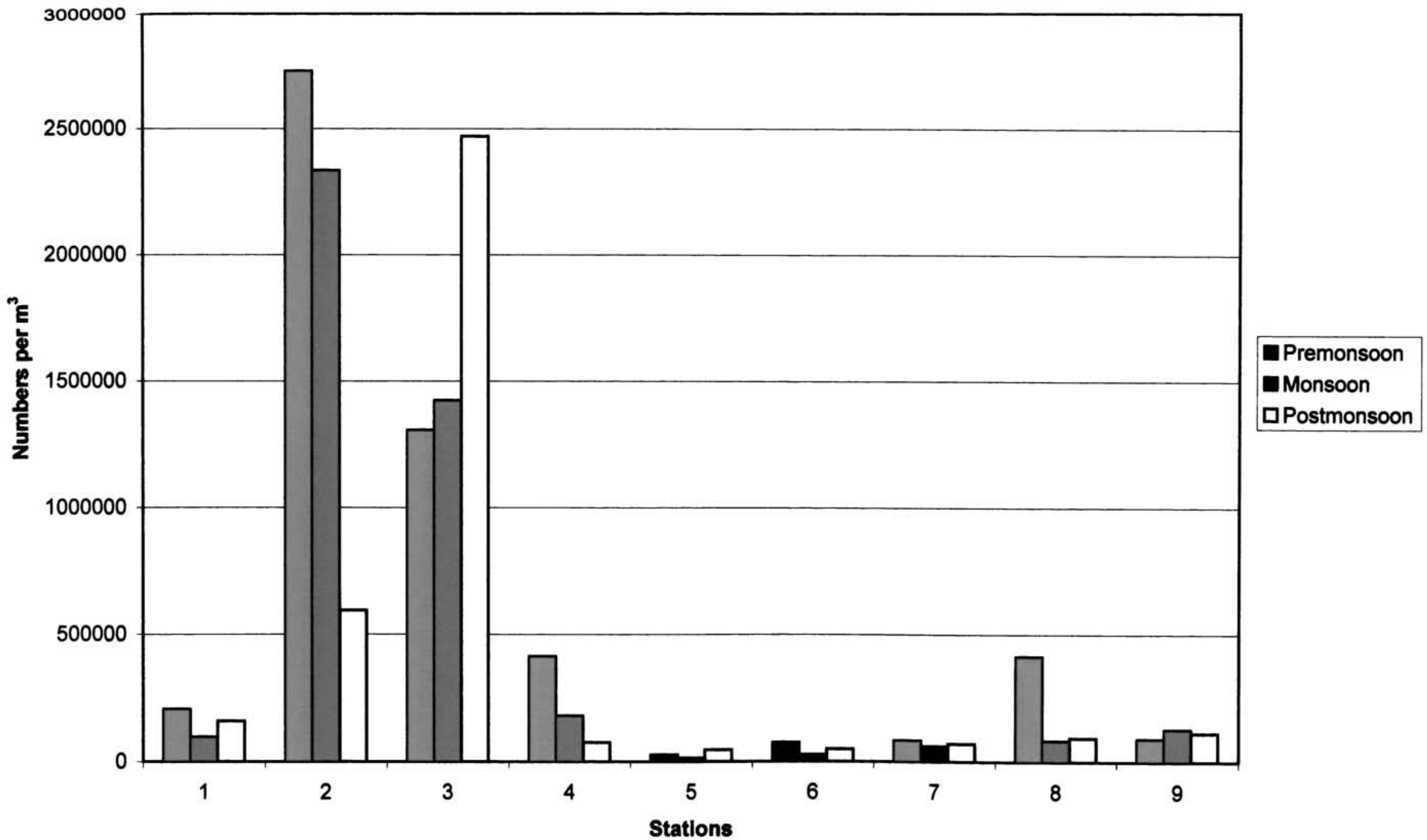


Fig.14. Seasonwise distribution of Zooplankton in the area



postmonsoon season. Two major peaks were noticed in the monthly variations, the primary peak was in March and the secondary one was in October. Zooplankton at this station varied from 50454 numbers per m^3 in August to 304354 numbers per m^3 in March.

At station II, the mean numbers of zooplanktons recorded were 1887866 per m^3 of water. Seasonally, 2734420 numbers/m^3 were noticed during premonsoon season, 2334351 numbers/m^3 during monsoon and 594827 numbers/m^3 were observed during the postmonsoon season. Monthwise distribution showed an increase in numbers from December to May and the maximum of 5846304 numbers per m^3 was recorded during May. A minimum of 411220 numbers per m^3 of water was observed in December.

At station III, an average of 1732844 numbers of zooplankton were recorded from m^3 of water. Seasonal distribution indicated, 1306212, 1423431 and 2468889 numbers/m^3 during premonsoon, monsoon and postmonsoon seasons respectively. The monthwise distribution of zooplankton varied from 200000 numbers per m^3 in June to 4798334 numbers per m^3 during November

An average density of 223205 numbers of zooplankton per m^3 of water were observed from station IV. Seasonally, 413223 numbers/m^3 were recorded during premonsoon, 180090 numbers/m^3 during monsoon and 76302 numbers/m^3 were observed during the postmonsoon season. Two peaks were noticed in the monthly distribution pattern. The major peak was in May and the minor one in September. Zooplankton at this station varied from 37560 numbers per m^3 in August to 1027207 numbers per m^3 in May.

At station V, the mean zooplankton numbers observed were 29195 numbers per m^3 of water. Seasonal distribution indicated, 26980, 14080 and 46526 numbers per m^3 during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise distribution showed the minimum in July and maximum in January, ranging between 11200 and 73465 numbers per m^3.

The mean density of zooplankton observed at station VI was 50424 numbers per m^3. Seasonally, 74693 numbers/m^3 were noticed during premonsoon, 27020 numbers/m^3 during monsoon and 49559 numbers/m^3 were recorded during the postmonsoon season. Monthwise variation showed a decline from February to May. The minimum of 5362 numbers per m^3 was noticed during October and a maximum of 156062 numbers per m^3 during February.

At station VII, an average of 71411 numbers per m^3 were recorded. Seasonally, 83262/m^3 were noticed during premonsoon season, 60165 numbers/m^3 were observed during monsoon and 70805 numbers per m^3 of water were recorded during the postmonsoon season. Two peaks were observed in the monthly distribution of zooplankton at this station, the primary peak was in April and the secondary one was in October. The variation was from 24840 numbers per m^3 in February to 221110 numbers per m^3 in April.

An average of 196831 numbers per m^3 were recorded at station VIII. Seasonal distribution showed, 413022, 83183 and 94288 numbers/m^3 during premonsoon, monsoon and postmonsoon seasons respectively. Monthwise distribution clearly showed a major peak in May. A minimum of 39804 numbers per m^3 was noticed during June and the maximum of 969510 numbers per m^3 was observed in May.

At station IX, the mean density of zooplankton observed was 110291 numbers per m^3. Seasonally, 89955 numbers/m^3 were noticed during premonsoon season, 127647 numbers/m^3 during monsoon and 113271 numbers/m^3 were recorded during the postmonsoon season. The monthwise variation was from 57260 numbers per m^3 in May to 194560 numbers per m^3 in July.

The maximum number of zooplankton recorded was in station II and the minimum in station V.

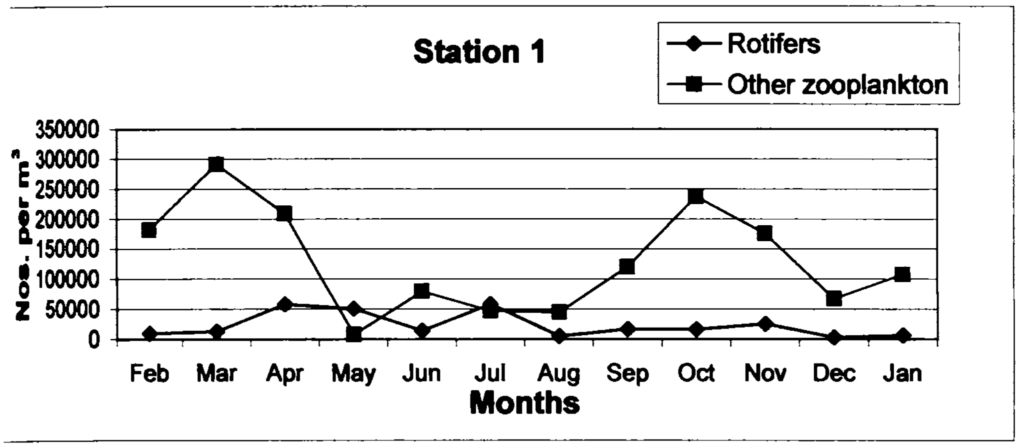
Interrelationship between zooplankton groups and rotifers in the area

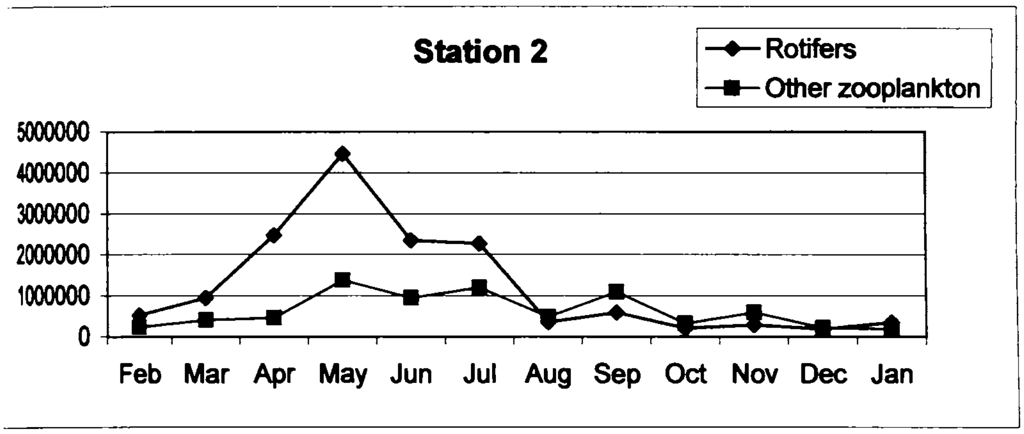
The rotifers formed a considerable portion of zooplankton in majority of stations covered under the present study. The numberwise as well as percentagewise composition of rotifers, out of zooplankton, in the study area are given in Table 6. To understand the variations of rotifers along with other zooplankton groups in the study area, monthwise studies were carried out. The monthwise distribution of rotifers and other zooplankton in each station are depicted in Fig.15.

Table 6. Distribution of Rotifers and Zooplankton in the area

Stations	Zooplankton Nos. per m^3	Rotifers Nos. per m^3	% of Rotifers out of Zooplankton
1	154334.25	23335.00	15.12
2	1887865.75	1255464.71	66.50
3	1732844.00	835603.75	48.22
4	223205.00	71593.83	32.08
5	29195.29	9449.54	32.37
6	50424.00	3354.17	6.65
7	71410.83	11340.42	15.88
8	196831.00	88915.42	45.17
9	110291.00	35083.33	31.81

Fig.15.Monthwise distribution of Rotifers and other zooplankton in the area





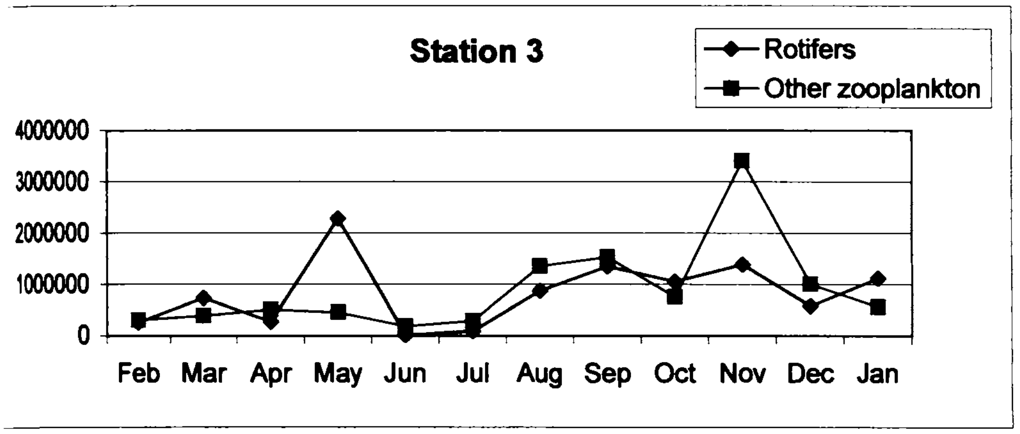
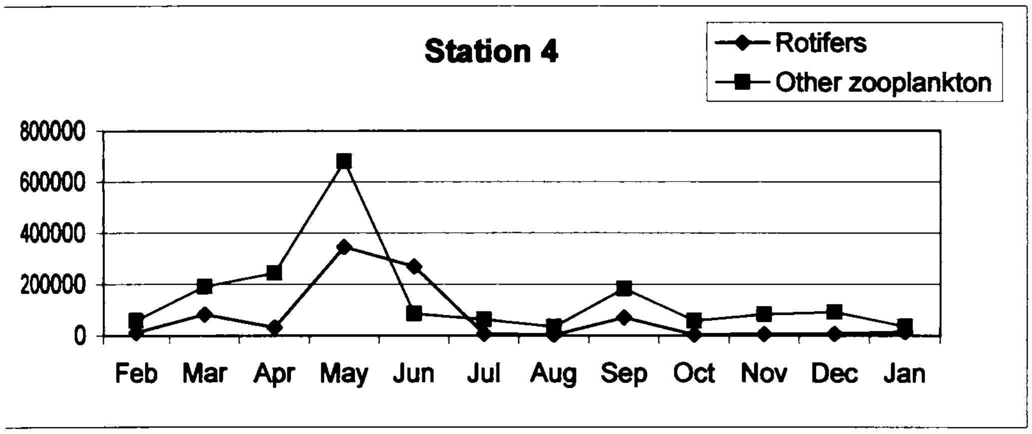
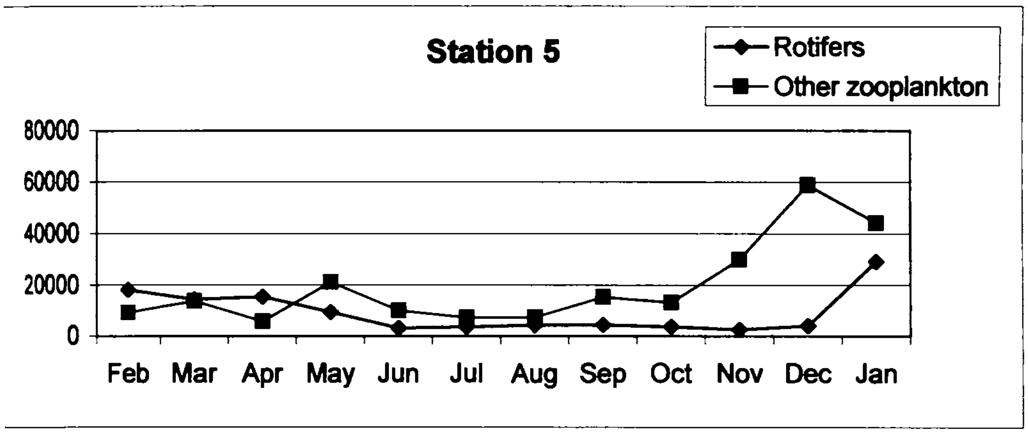


Fig.15 Continued





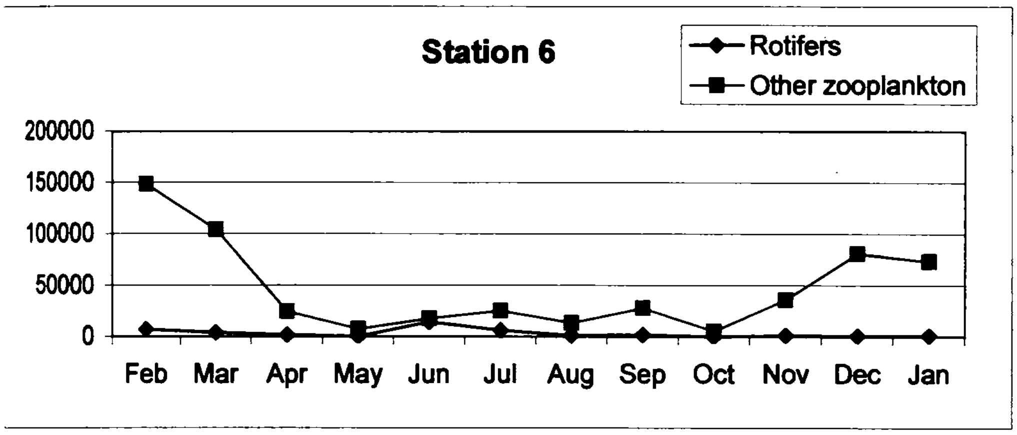
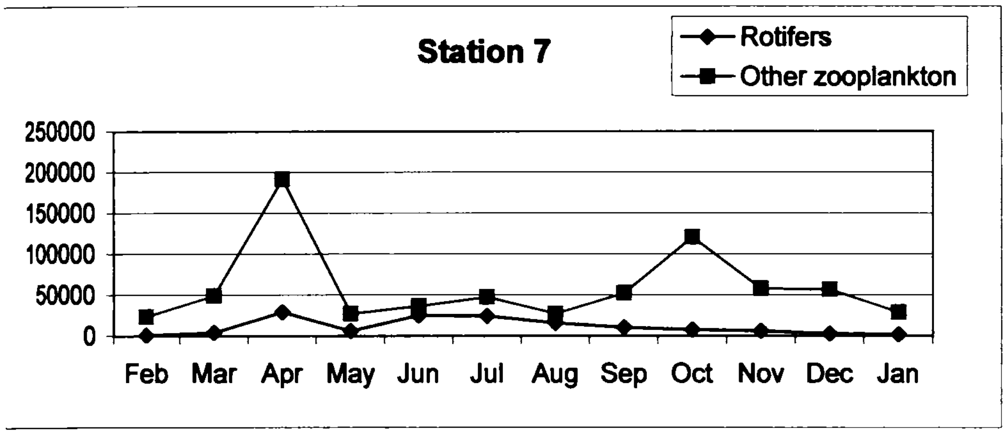
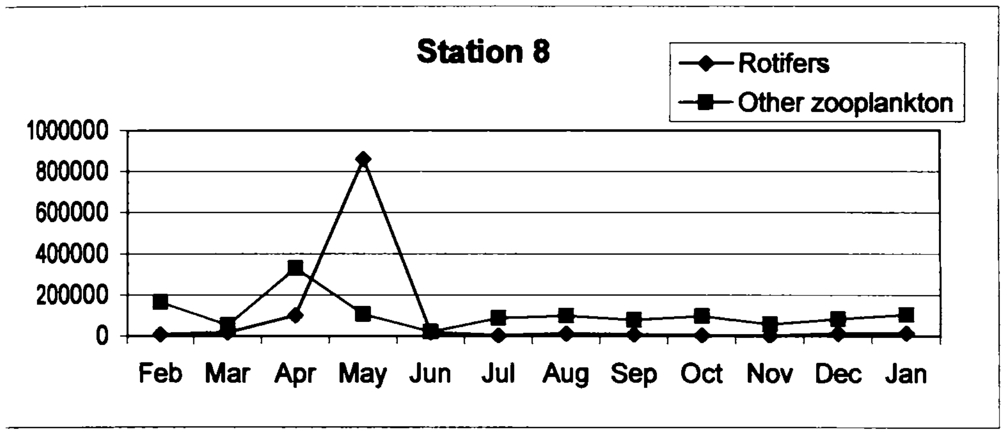
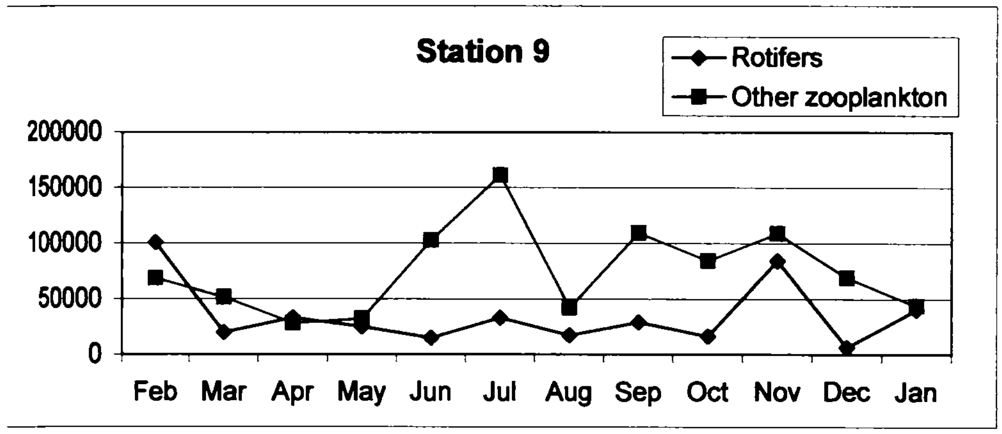


Fig.15 Continued







Out of the zooplankton, rotifers formed only 15.1% at station I. The trend in the variations of numerical abundance of zooplankton and rotifers at this station were similar in the monsoon season, while, during the premonsoon and postmonsoon seasons, the magnitude of monthwise variations were more for zooplankton, compared to monthwise variations of rotifers. This was mainly due to the abundance of copepod – nauplii and tintinnids during premonsoon and postmonsoon months, since this station was situated near barmouth.

Rotifers formed 66.5% of zooplankton available at station II. The pattern in the monthwise variations of zooplankton and rotifers at this station were the same. Here, rotifers dominated over all the other groups of zooplankton in all the months except during August, September, October, and November, where copepod-nauplii dominated.

At station III, 48.2% of zooplankton was contributed by rotifers. Here, the changing pattern of rotifers and zooplankton between months remained the same, but, during November, the magnitude of increase in the numerical abundance of zooplankton was much more than that of rotifers. This increase was attributed to the abundance of cyclopoid copepods and tintinnids during November.

Out of the zooplankton recorded at station IV, 32.1% were rotifers. At this station, two peaks were noticed, one in May and another in September, in the case of zooplankton as well as rotifers, and their monthwise variation followed the same pattern. In May, a sudden increase in tintinnids, rotifers and copepod-nauplii were observed.

Rotifers formed 32.4% of zooplankton at station V. During February-April, rotifers dominated over other zooplankton groups at this station. After April, rotifers showed a decline and other zooplankton, especially copepod-nauplii, showed an increase. From May to January, copepod-nauplii dominated over rotifers

At station VI, rotifers formed only 6.65% of the zooplankton. At this station, the numerical abundance of zooplankton was considerably more, than rotifers during premonsoon and postmonsoon seasons, which was mainly due to the abundance of copepod nauplii and tintinnids during these two seasons. Except for a small peak in June, rotifers were lesser in numbers than other zooplankton groups throughout the period of study at this station.

Out of the zooplankton, rotifers formed only 15.88% at station VII. At this station , other zooplankton groups altogether dominated over rotifers throughout the study period. In the case of zooplankton, two clear peaks – one in April and another in October were noticed, which coincided with abundance of copepod nauplii in these two months.

Rotifers formed 45.2% of zooplankton available at station VIII. At this station, the trend in the monthwise variations of zooplankton and rotifers were almost similar. In May, swarms of rotifers were observed and rotifers dominated well over other zooplanktonic groups. Other zooplankton groups showed a clear declining trend, when rotifers were abundant in May. The maximum number of other zooplankton groups was observed in April, while that of rotifers was in May.

At station IX, 31.8% of zooplankton was contributed by rotifers. The monthwise distribution pattern of other zooplankton and rotifers were almost the same at this station, but, the magnitude of variations differed. The maximum numbers of other zooplankton groups were observed in July, while, that of rotifers was in February at this station.

D. STUDIES ON BIODIVERSITY OF ROTIFERS

To understand the distribution of rotifers in the biodiversity point of view, the Richness index, Evenness index, Shannon index and Simpson index were calculated for rotifers and presented. These are mathematical expressions to measure the variability of distribution of different genera in different stations. Monthwise as well as seasonwise indices were computed for each station. The ANOVA test was conducted to study the variations of these indices between stations as well as between months.

The monthwise and stationwise values of Richness index, Evenness index, Shannon index and Simpson index are given in Tables 7.1 to 7.9. The seasonwise values of richness index, evenness index, Shannon index and Simpson index with Standard Deviations for all the stations are depicted in Fig. 16-19. ANOVA tests were carried out to understand the variations of different indices between stations as well as between months, and are given in Tables 8 and 9.

Table 7.1.Monthwise diversity indices of rotifers at station 1

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.1086	0.7211	0.4998	0.3196
Mar	0.2110	0.0378	0.0415	0.0122
Apr	0.1821	0.2586	0.2841	0.1229
May	0.1844	0.1108	0.1217	0.0459
Jun	0.2086	0.5020	0.5515	0.2868
Jul	0.7285	0.3048	0.6697	0.2509
Aug	0.5838	0.5093	0.9126	0.4409
Sep	0.1027	0.0072	0.0050	0.0012
Oct	0.7211	0.9375	1.9495	0.8449
Nov	0.8867	0.6067	1.3971	0.5796
Dec	0.3747	0.6876	0.9533	0.5068
Jan	0.1145	0.2056	0.1425	0.0624

Table 7.2.Monthwise diversity indices of rotifers at station 2

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.1517	0.1048	0.1151	0.0408
Mar	0.2179	0.0732	0.1015	0.0324
Apr	0.1358	0.0246	0.0271	0.0082
May	0.2612	0.0201	0.0323	0.0096
Jun	0.5452	0.2871	0.6307	0.2924
Jul	0.5465	0.2573	0.5653	0.2457
Aug	0.7816	0.2361	0.5661	0.2266
Sep	0.3008	0.1183	0.1904	0.0749
Oct	0.7342	0.2807	0.6464	0.2650
Nov	0.6358	0.3134	0.6886	0.2838
Dec	0.2467	0.1336	0.1852	0.0717
Jan	0.0783	0.1073	0.0744	0.0279

Table 7.3.Monthwise diversity indices of rotifers at station 3

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.3207	0.2116	0.3405	0.1483
Mar	0.0740	0.0761	0.0527	0.0184
Apr	0.0798	0.0619	0.0429	0.0144
May	0.1366	0.0596	0.0655	0.0209
Jun	0.4203	0.2583	0.4158	0.1665
Jul	0.6118	0.3402	0.7075	0.2905
Aug	0.3654	0.0654	0.1172	0.0385
Sep	0.4959	0.0343	0.0713	0.0204
Oct	0.6490	0.0468	0.1077	0.0321
Nov	0.2829	0.0189	0.0305	0.0078
Dec	0.1507	0.0143	0.0158	0.0041
Jan	0.2154	0.0597	0.0828	0.0272

Table 7.4.Monthwise diversity indices of rotifers at station 4

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.4242	0.2067	0.3326	0.1428
Mar	0.3527	0.1434	0.2309	0.0946
Apr	0.6747	0.4202	0.8737	0.3805
May	0.3136	0.1902	0.3062	0.1167
Jun	0.3198	0.2345	0.3774	0.1685
Jul	0.3333	0.7695	1.0668	0.6082
Aug	0.6497	0.9601	1.7202	0.8103
Sep	0.3580	0.4408	0.7094	0.4464
Oct	0.7406	0.7230	1.4068	0.6632
Nov	0.9106	0.8333	1.8310	0.7937
Dec	0.3333	0.6885	0.9545	0.5419
Jan	0.5189	0.5594	1.0023	0.5116

Table 7.5.Monthwise diversity indices of rotifers at station 5

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.5097	0.8208	1.4706	0.7149
Mar	1.1478	0.8405	2.0886	0.8373
Apr	0.5184	0.7122	1.2761	0.5952
May	0.8733	0.9455	2.0774	0.8664
Jun	0.3717	0.7579	1.0507	0.5989
Jul	0.7279	0.8748	1.7022	0.7938
Aug	0.9536	0.8179	1.7972	0.7956
Sep	0.5952	0.6502	1.1649	0.6282
Oct	0.9705	0.8073	1.7739	0.7939
Nov	0.7623	0.7389	1.4379	0.7106
Dec	0.2399	0.6626	0.7279	0.4971
Jan	0.4862	0.3549	0.6359	0.3018

Table 7.6.Monthwise diversity indices of rotifers at station 6

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.4504	0.7332	1.1800	0.6282
Mar	0.3617	0.9232	1.2799	0.7002
Apr	0.1332	0.7793	0.5402	0.3552
May	0.1643	0.4395	0.3046	0.1657
Jun	0.4182	0.8548	1.3757	0.7051
Jul	0.8016	0.8246	1.7147	0.7702
Aug	0.6902	0.3234	0.5795	0.2369
Sep	0.0000	0.0000	0.0000	0.0000
Oct	0.4178	1.0000	1.0986	0.6723
Nov	0.2821	1.0000	1.0986	0.6672
Dec	0.3118	0.6460	0.7097	0.4630
Jan	0.2887	0.8761	0.9624	0.5696

Table 7.7.Monthwise diversity indices of rotifers at station 7

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.1444	0.7522	0.5214	0.3387
Mar	0.7144	0.8508	1.6556	0.7891
Apr	0.2916	0.4026	0.5581	0.2919
May	0.3426	0.5888	0.8162	0.4925
Jun	0.6907	0.7850	1.6323	0.7676
Jul	0.6923	0.7901	1.6430	0.7656
Aug	0.6205	0.6147	1.1961	0.5638
Sep	0.5401	0.8584	1.5380	0.7684
Oct	0.7827	0.7956	1.6544	0.7737
Nov	0.4577	0.7163	1.1529	0.6395
Dec	0.5037	0.8516	1.3706	0.7368
Jan	0.3932	0.5180	0.7182	0.3738

Table 7.8.Monthwise diversity indices of rotifers at station 8

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.4402	0.7550	1.2152	0.6469
Mar	0.5064	0.6091	1.0914	0.5170
Apr	0.1734	0.0910	0.0999	0.0392
May	0.1463	0.0127	0.0139	0.0035
Jun	0.3055	0.6889	0.9551	0.5508
Jul	0.0000	0.0000	0.0000	0.0000
Aug	0.8452	0.3960	0.8701	0.3853
Sep	0.6711	0.6096	1.1862	0.6256
Oct	0.8233	0.6082	1.2647	0.6507
Nov	0.5162	0.5677	0.9138	0.5460
Dec	0.4259	0.8921	1.4357	0.7384
Jan	0.4189	0.4259	0.6854	0.3435

Table 7.9.Monthwise diversity indices of rotifers at station 9

Month	Richness index	Evenness index	Shannon index	Simpson index
Feb	0.6076	0.2676	0.5564	0.2516
Mar	0.5048	0.5481	0.9820	0.4611
Apr	0.5765	0.3517	0.6844	0.2806
May	0.5925	0.3930	0.7647	0.3468
Jun	0.7280	0.7839	1.6301	0.7343
Jul	1.3451	0.6066	1.6428	0.7290
Aug	1.0247	0.7777	1.8649	0.8123
Sep	0.7780	0.5039	1.1072	0.4904
Oct	1.2365	0.7298	1.8720	0.7609
Nov	0.6172	0.2402	0.4996	0.1851
Dec	0.6863	0.8557	1.6652	0.7755
Jan	0.5657	0.6319	1.2297	0.6095

Fig. 16 Seasonwise distribution along with SD of Richness Index of Rotifers in the study area

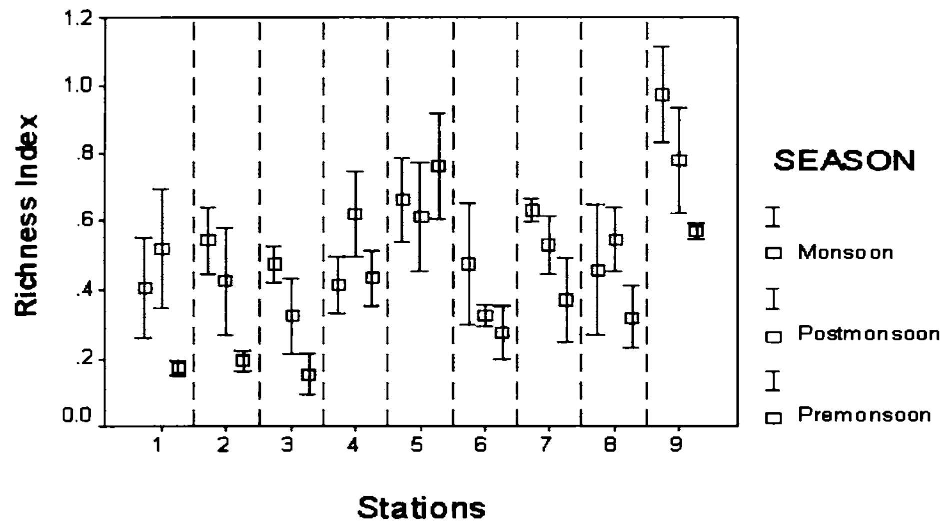


Fig. 17 Seasonwise distribution along with SD of Evenness Index of Rotifers in the study area

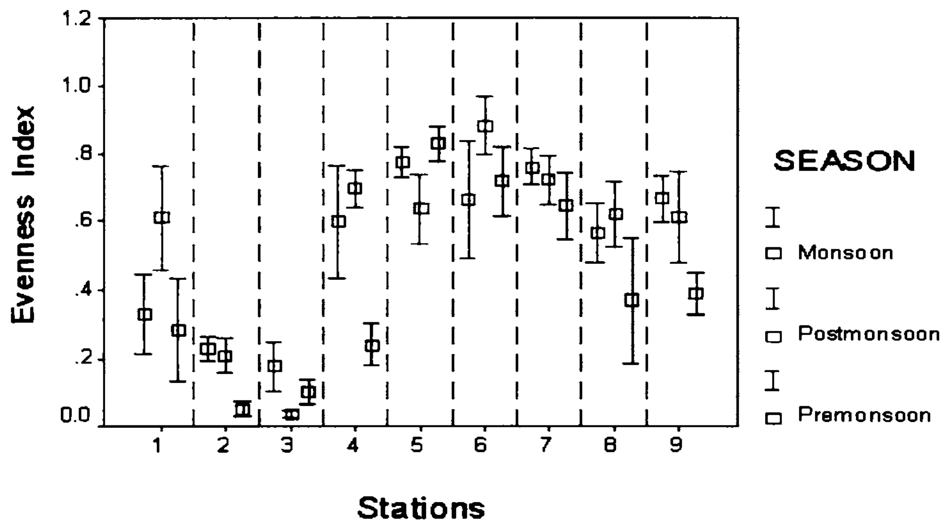


Fig.18 Seasonwise distribution along with SD of

Shannon Index of Rotifers in the study area

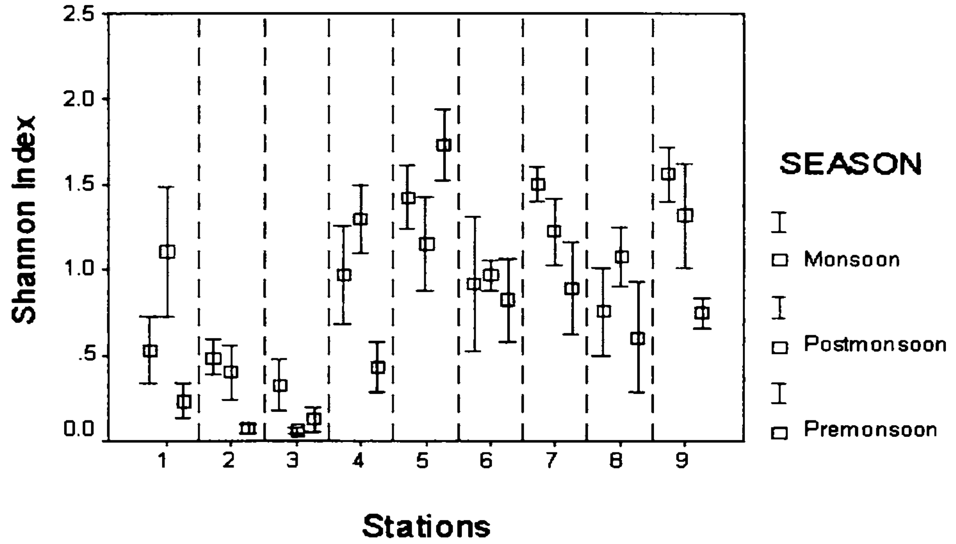


Fig.19 Seasonwise distribution along with SD of

Simpson Index of Rotifers in the study area

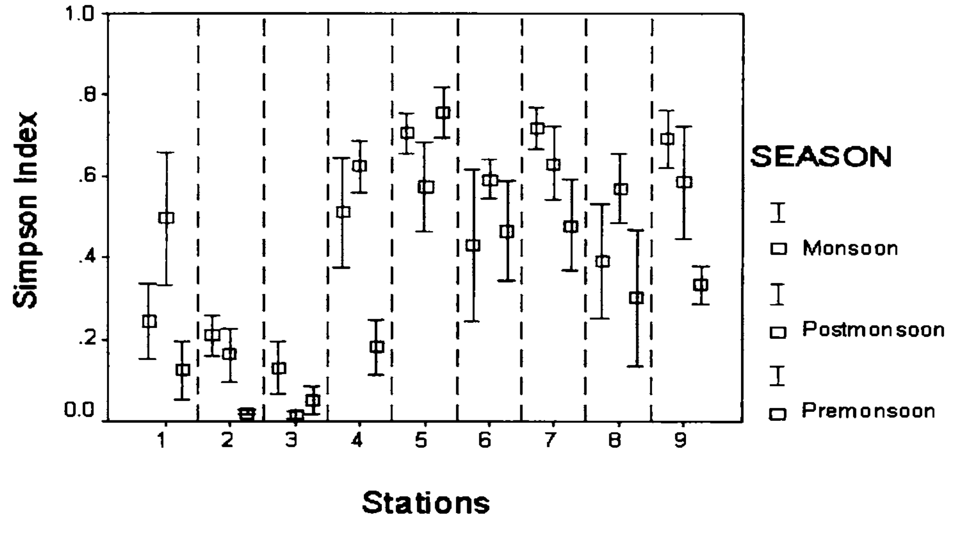


Table 8.Results of ANOVA of different diversity indices of rotifers between stations

	Sum of Squares	df	Mean Square	F	P
EVENNESS INDEX	5.42711836	8	0.678389796	15.47090	0.0000**
RICHNESS INDEX	2.28744768	8	0.285930961	4.85867	0.0000**
SHANNON INDEX	16.73291637	8	2.091614546	9.60335	0.0000**
SIMPSON INDEX	4.14822782	8	0.518528477	11.40853	0.0000**

** Highly Significant ($P< 0.01$)

Table 9.Results of ANOVA of different diversity indices of rotifers between months

	Sum of Squares	df	Mean Square	F	P
RICHNESS INDEX	2.678871852	11	0.243533805	4.301855	0.0000**
EVENNESS INDEX	1.190154566	11	0.108195870	1.197878	0.2993
SHANNON INDEX	6.445290818	11	0.585935529	1.766093	0.0707
SIMPSON INDEX	1.329468892	11	0.120860808	1.585406	0.1153

** Highly Significant ($P< 0.01$)

a).Richness index

The richness index at station I varied between 0.1027 and 0.8867 in September and November respectively. At station II, the range was from 0.0783 in January to 0.7861 in August. A minimum of 0.0740 in March and a maximum of 0.6490 in October were noticed at station III.

At station IV, the range was from 0.3136 in May to 0.9106 in November. The variations of richness index at station V were between 0.2399 in December and 1.1478 in March. At station VI, the range was from 0 to 0.8016, the minimum was in September and maximum in July.

The monthwise distribution of richness index at station VII revealed a minimum of 0.1444 in February and a maximum of 0.7827 in October. At station VIII, the variation was from 0-0.8452, the minimum was noticed in July and maximum in August.

Among all the stations, the richness index was the highest at station IX, in July, the lowest in March and the range was between 0.5048-1.3451.

The seasonal studies on richness(Fig.16) showed a gradual decrease from monsoon to premonsoon season at stations II, III, VI, VII and IX. The index was maximum during monsoon season at stations II, III, VI, VII and IX. At stations I, IV, and VIII, it was the highest during postmonsoon season. And only at station V, the richness index showed maximum during the premonsoon season.

b).Evenness index

The Evenness index at station I was the lowest in September and the highest in October. The range was between 0.0072 and 0.9375 at this station. At station II, the evenness index varied between 0.0201 in May and 0.3134 in November.

A minimum of 0.0143 was noticed in December and a maximum of 0.3402 in July at station III. At station IV, the evenness index varied between 0.1434 in March and 0.9601 in August. At station V, the evenness index was minimum during January and maximum during May, ranging between 0.3549 and 0.9455.

At station VI, the evenness index was 0 in September and a maximum of 1 was observed during October-November period. A minimum of 0.4026 was observed at station VII in April, the maximum of 0.8584 at this station was noticed in September.

The evenness index was minimum in July at station VIII and was maximum in December with a range between 0 and 0.8921. At station IX, the evenness index varied between 0.2402 in November and 0.8557 in December.

The evenness of distribution(Fig.17) were the highest at stations II, III, VII and IX during monsoon season. It was maximum at stations I, IV, VI and VIII during the postmonsoon season. At station V alone, the maximum evenness observed during the premonsoon season.

c).Shannon index

The diversity index or the Shannon-Weiner index was maximum at station V, than all the other stations studied.

The Shannon index at station I was minimum in September and maximum in October, ranging between 0.005 and 1.9495. At station II, the index varied from 0.0271 in April to 0.6886 in November. At station III, the variation was between 0.0158 in December and 0.7075 in July.

A minimum of 0.2309 was observed at station IV in March and a maximum of 1.8310 in November. At station V, Shannon index was minimum in January and maximum in March; except for December and January , all the values of Shannon index at this station were above 1.

At station VI, the variation in Shannon index was between 0 in September and 1.7147 in July. At station VII, a minimum of 0.5214 was noticed in February and a maximum of 1.6556 in March. The Shannon index ranged from 0 to 1.4357 during July and December respectively at station VIII. At station IX, Shannon index varied from 0.4996 in November to 1.8649 in August.

The Shannon diversity index(Fig.18) showed a gradual decrease from monsoon to premonsoon season at stations II, VII and IX. The index was maximum during monsoon season at stations II, III, VII and IX. At stations, I, IV, VI and VIII the index was maximum during the postmonsoon season. At station V alone, the index was maximum during the premonsoon season.

d). Simpson index

At station I, the index was the lowest in September and the highest in October, ranging from 0.0012 to 0.8449. A minimum of 0.0082 in April and a maximum of 0.2924 in June were noticed at station II.

The variations of Simpson index at station III was between 0.0041 in December and 0.2905 in July. The index ranged from 0.0946 in March to 0.8103 in August at station IV. A minimum of 0.3018 in January and a maximum of 0.8664 in May were observed in station V.

The index was the lowest in September and the highest in July at station VI. The range was 0-0.7702. At station VII, the index varied between 0.2919 in April and 0.7891 in March. At station VIII, the index was minimum in July and maximum in December.

The values were 0 and 0.7384. A minimum of 0.1851 was observed at station IX in November and a maximum of 0.8123 was noticed in August.

The seasonal studies on Simpson index of diversity(Fig.19) showed maximum during monsoon season at stations II, III, VII and IX. The diversity was the highest during postmonsoon season at stations I, IV, VI and VIII. Here also, at station V alone, the index was maximum during the premonsoon season.

The results of ANOVA(Tables 8&9) revealed that the variations between stations was significant with respect to all the four indices($P< 0.01$). But, between months, only the Richness index showed significant values($P<0.01$) and in other cases the variations were not significant.

PART II. ECOLOGY OF ROTIFERS IN THE STUDY AREA

The correlation between hydrography and rotifers were worked out using monthwise data, to understand the extend of influence of the various environmental characteristics on rotifers.

In the first section, the different environmental characteristics along with their correlations with the numerical abundance of Rotifers, family Brachionidae, genus *Brachionus* and different species of *Brachionus* in all the nine stations are discussed separately.

In the second section, in order to have an overall understanding about the study area, the data collected from all the nine stations were pooled together and correlation between rotifers and environmental characteristics were computed and described.

1. Hydrography, Rotifers and their interrelationships

Monthwise variations of rainfall, water temperature, pH, dissolved oxygen, salinity, alkalinity, phosphate-phosphorus, nitrite-nitrogen, ammonia, biochemical oxygen demand, hydrogen sulphide, chlorophyll a and total suspended solids in the study area are depicted in Figures 20-32.

The variations in distribution and abundance of rotifers, family Brachionidae, genus *Brachionus* and different species of *Brachionus* in the study area were explained in detail, in Part I. However a clear picture in toto will emerge only when the data on abundance of rotifers is correlated with environment and in order to highlight the issue, it is discussed under this Part. The numerical abundance of rotifers, family Brachionidae and genus *Brachionus* in different months pertaining to each station are given in Tables 5.1 to 5.9(Part I) and that of different species of *Brachionus* are given in Tables 10.1 to 10.9.

The correlation analysis between the environmental characteristics and numerical abundance of Rotifers, family Brachionidae and genus *Brachionus* of all the nine stations were carried out separately, and, the results are given in Tables 11.1 to 11.9. The numbers of different species of *Brachionus* available in each station were correlated with the environmental characteristics prevailed in the respective stations, correlation coefficients were calculated and given in Tables 12.1 to 12.9.

Fig.20. Monthwise distribution of Rainfall in the study area during the study period

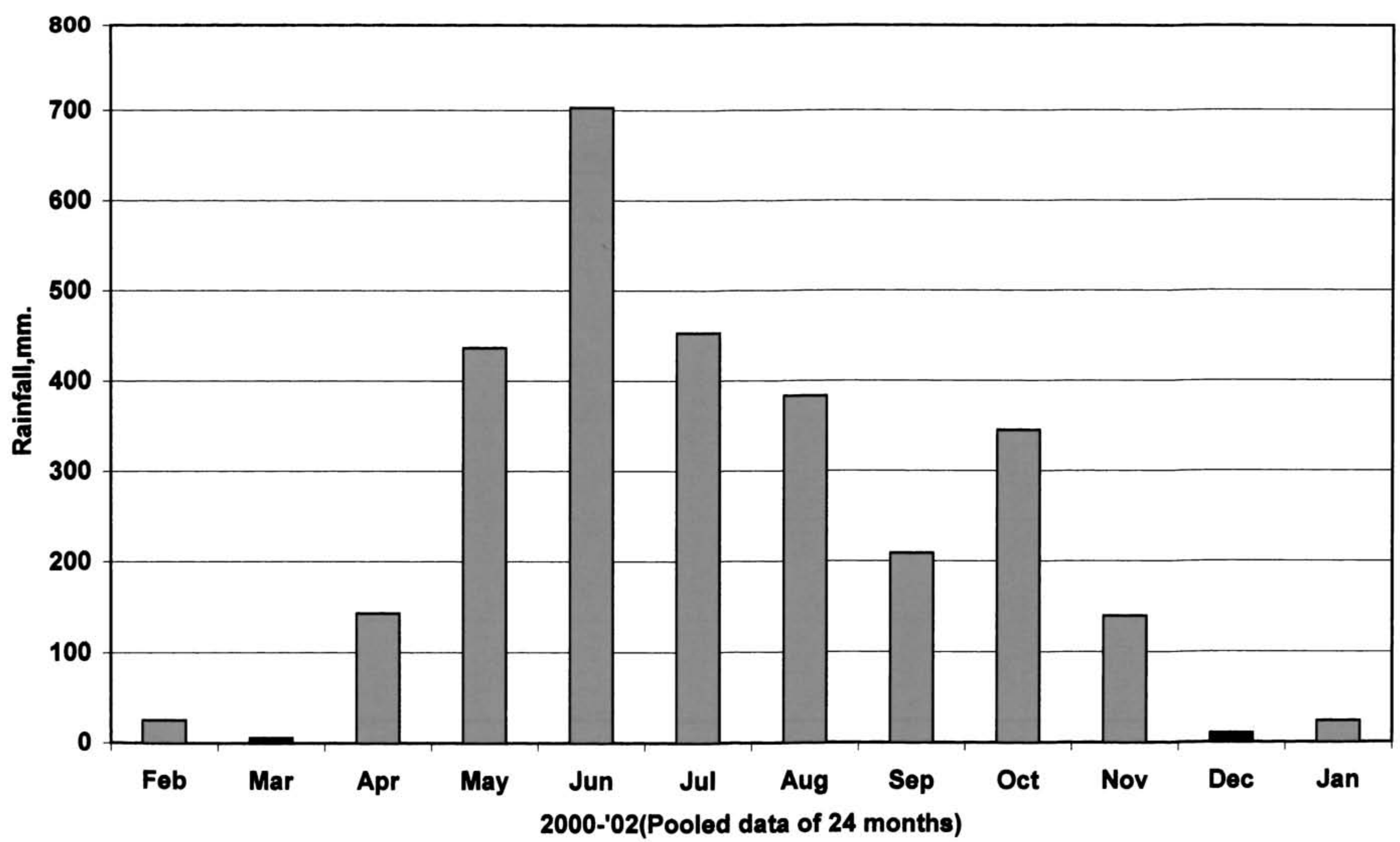


Fig.21. Spatial and monthly variations of Water Temperature during the study period

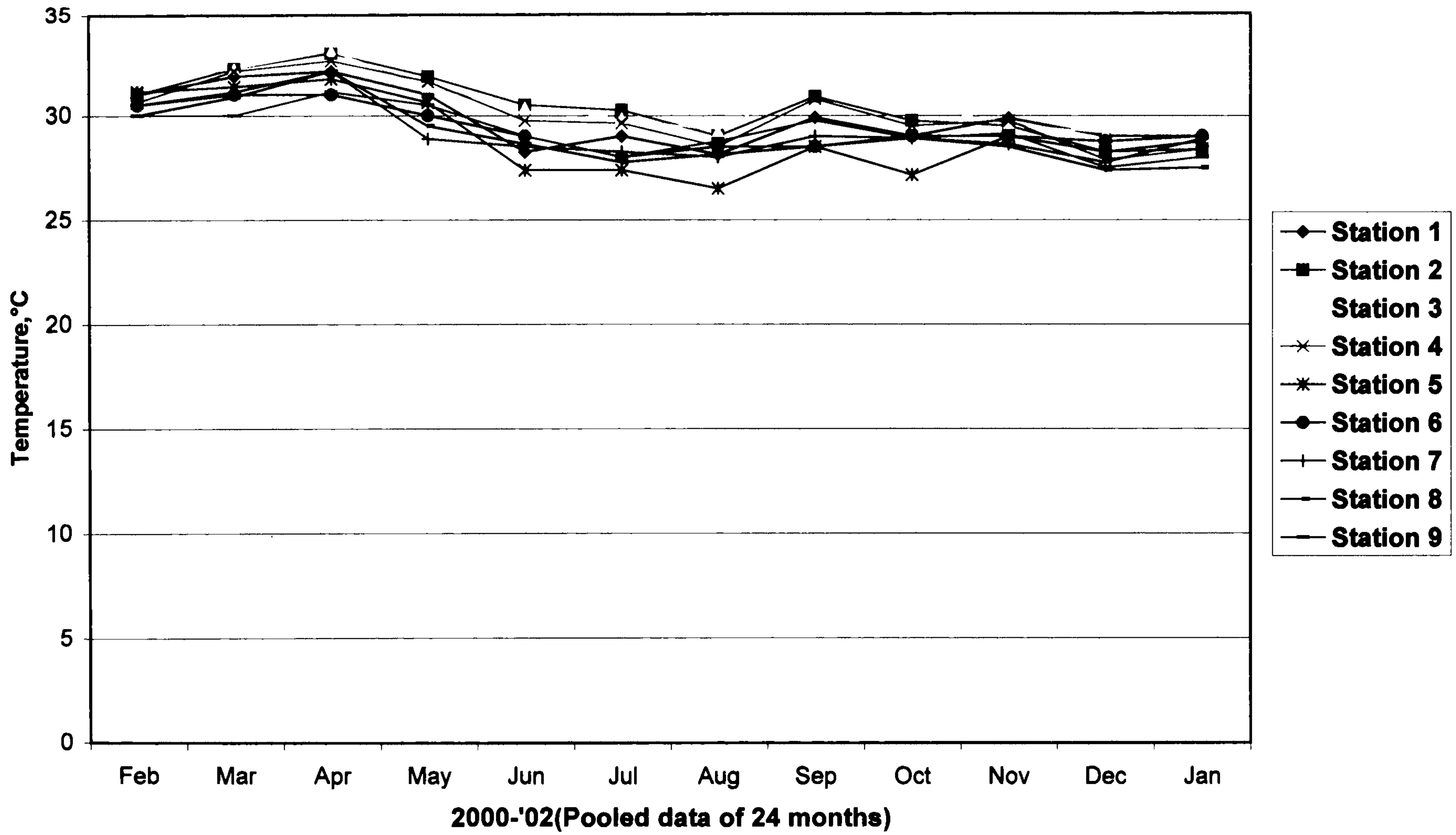


Fig.22. Spatial and monthly variations of pH during the study period

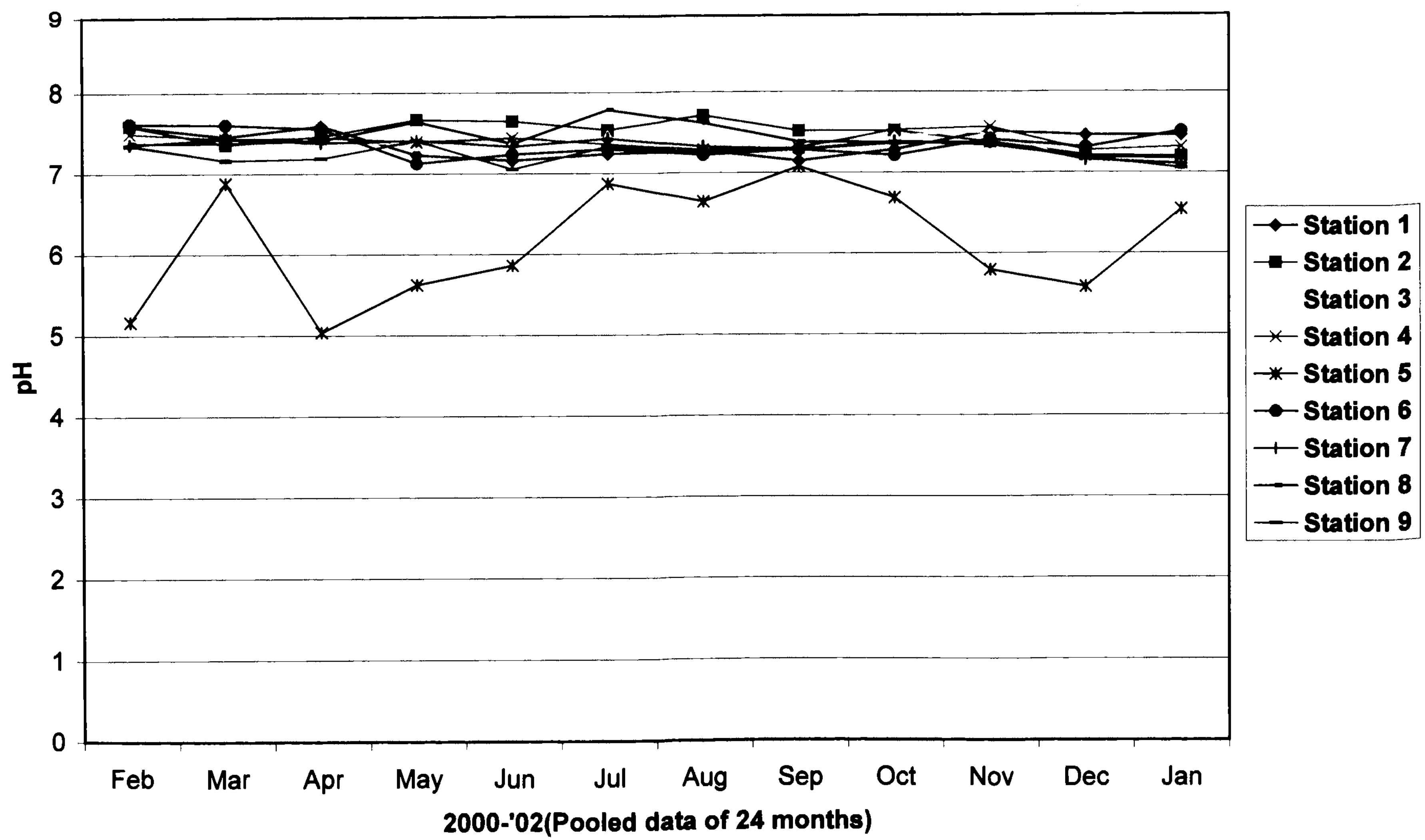
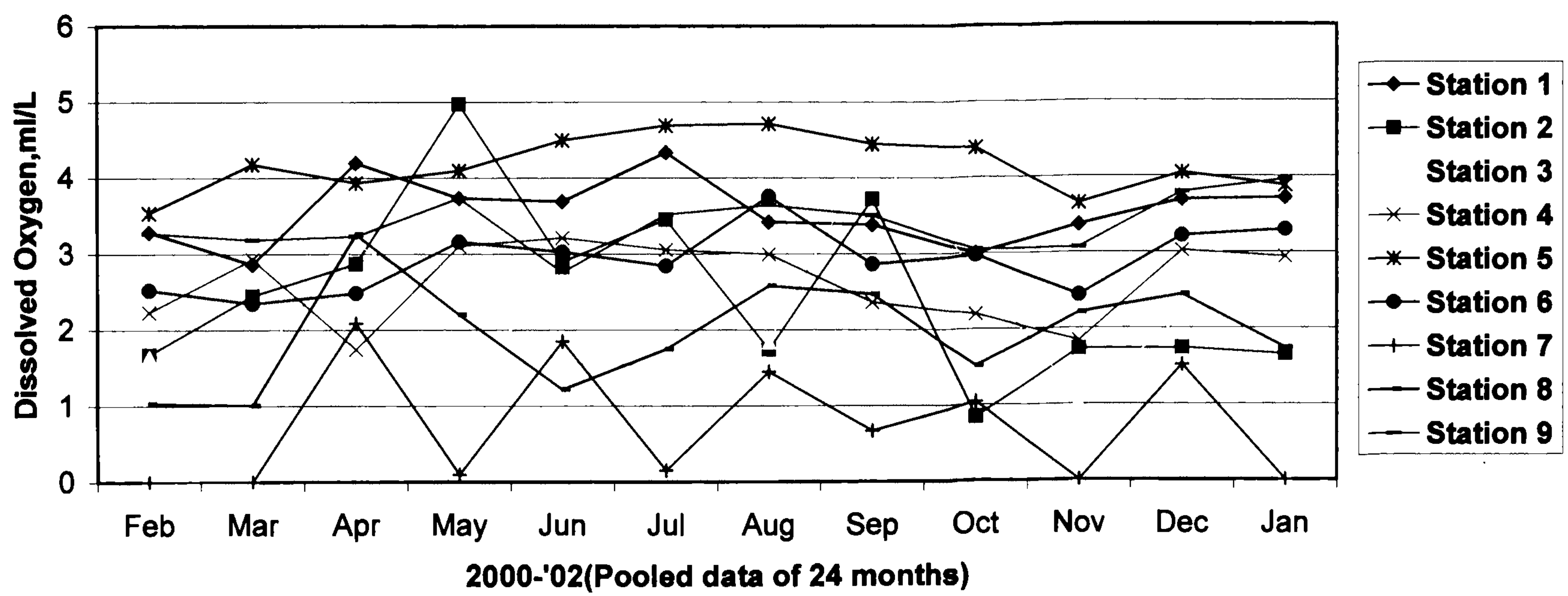
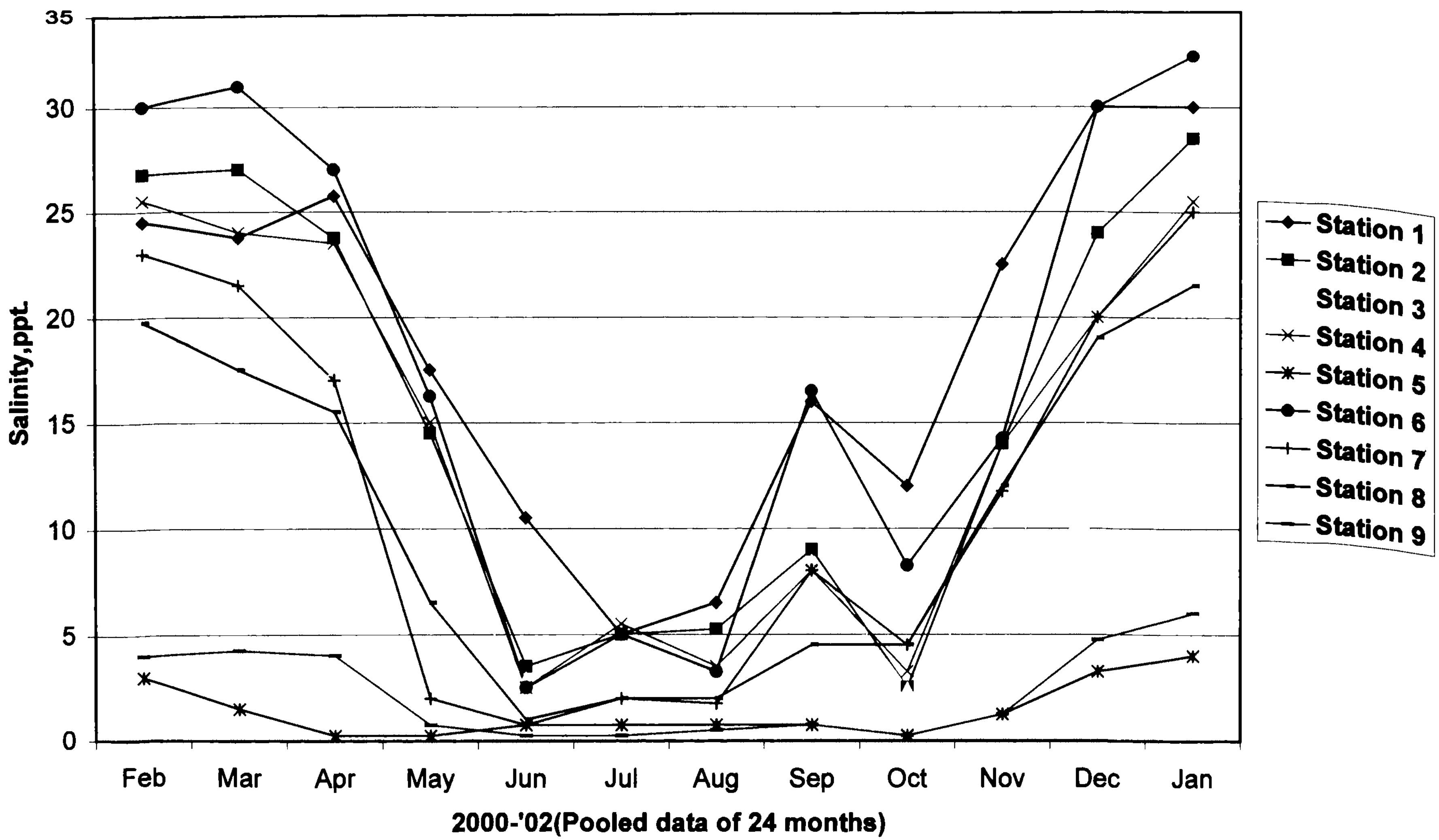


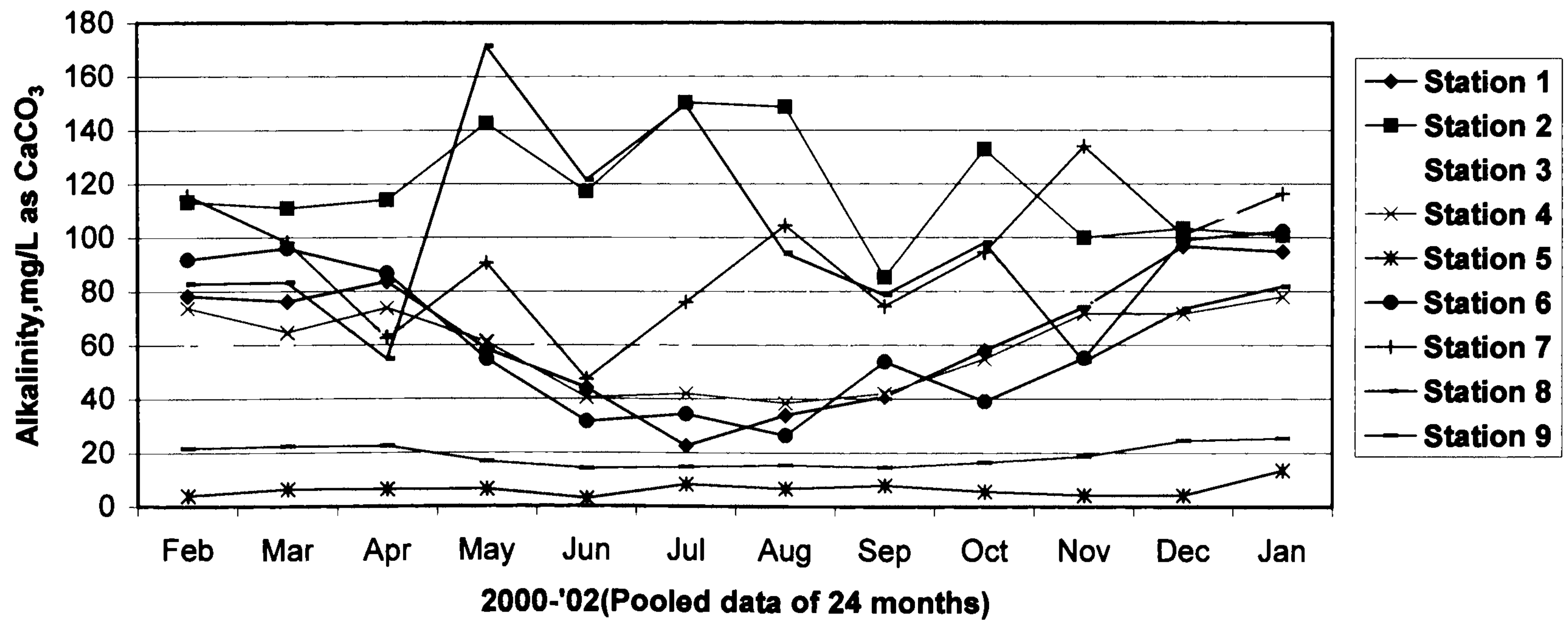
Fig.23. Spatial and monthly variations of Dissolved Oxygen during the study period





Salinity,ppt.
35
30
25
20
15
10
5
0
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2000-'02(Pooled data of 24 months)
Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7
Station 8
Station 9

Fig.25. Spatial and monthly variations of Alkalinity during the study period



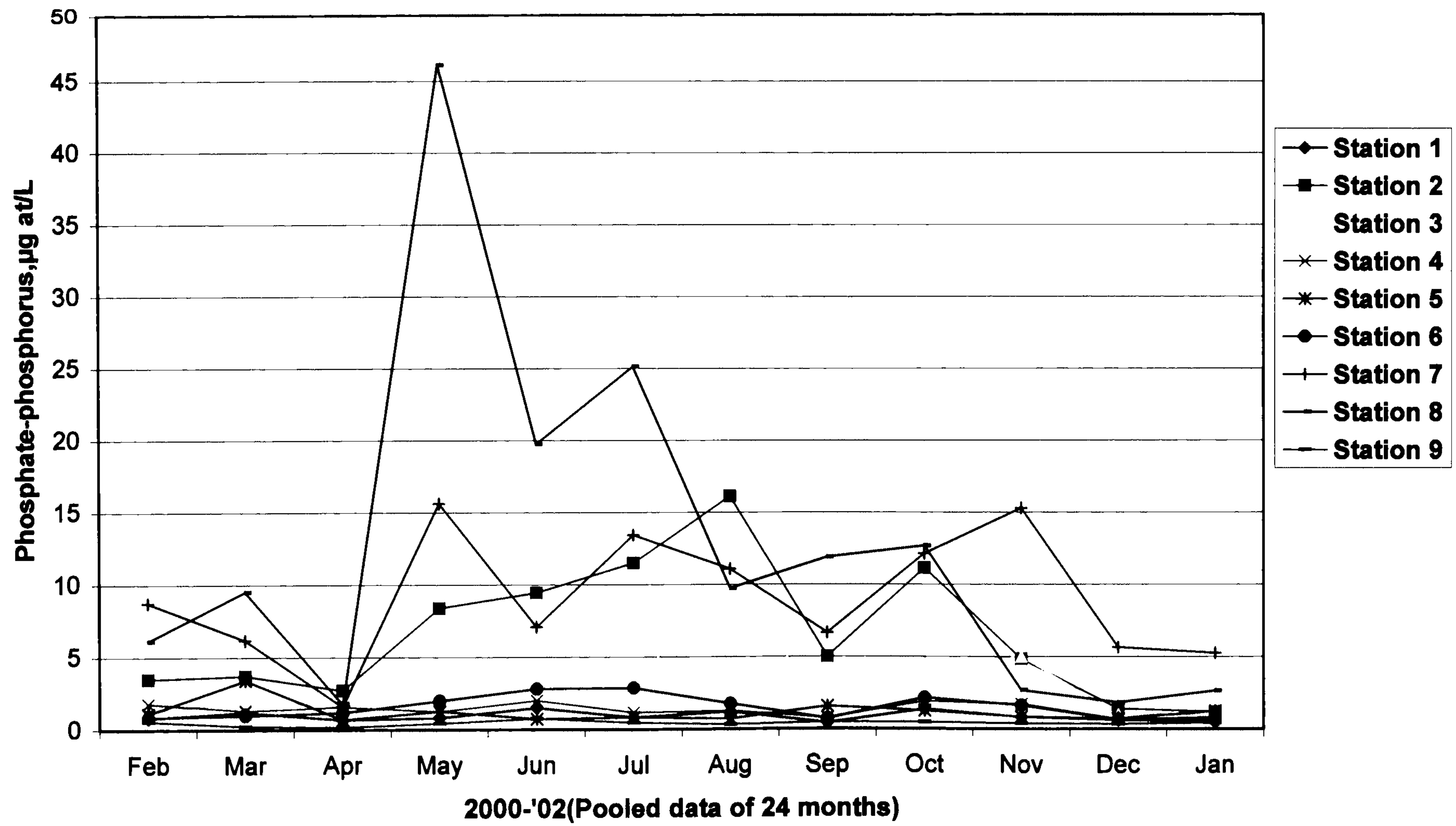

50
45
40
35
30
25
20
15
10
5
0
Phosphate-phosphorus,µg at/L
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2000-'02(Pooled data of 24 months)
Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7
Station 8
Station 9

Fig.27.Spatial and monthly variations of Nitrite-nitrogen during the study period

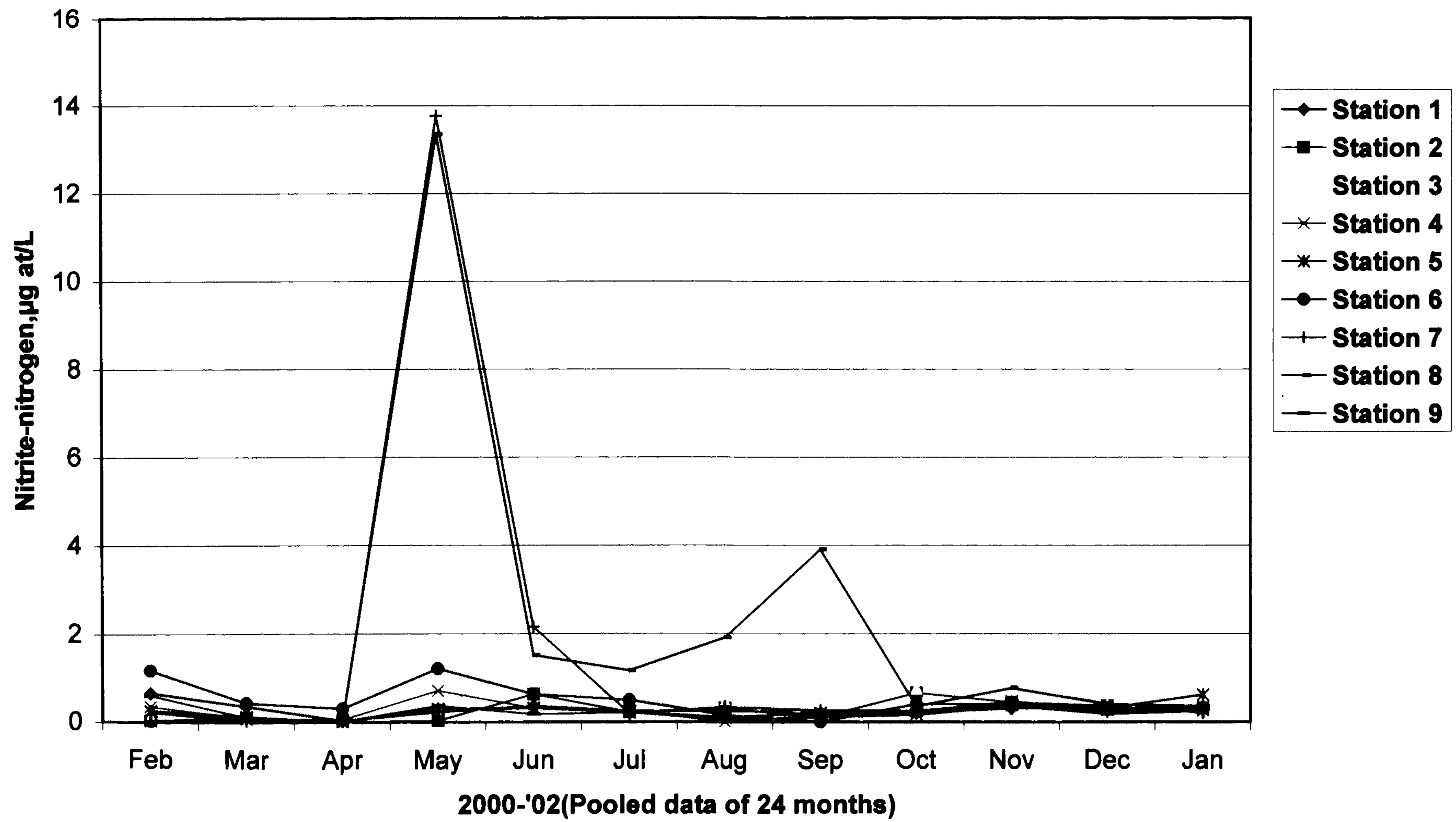


Fig.28. Spatial and monthly variations of Ammonia-nitrogen during the study period

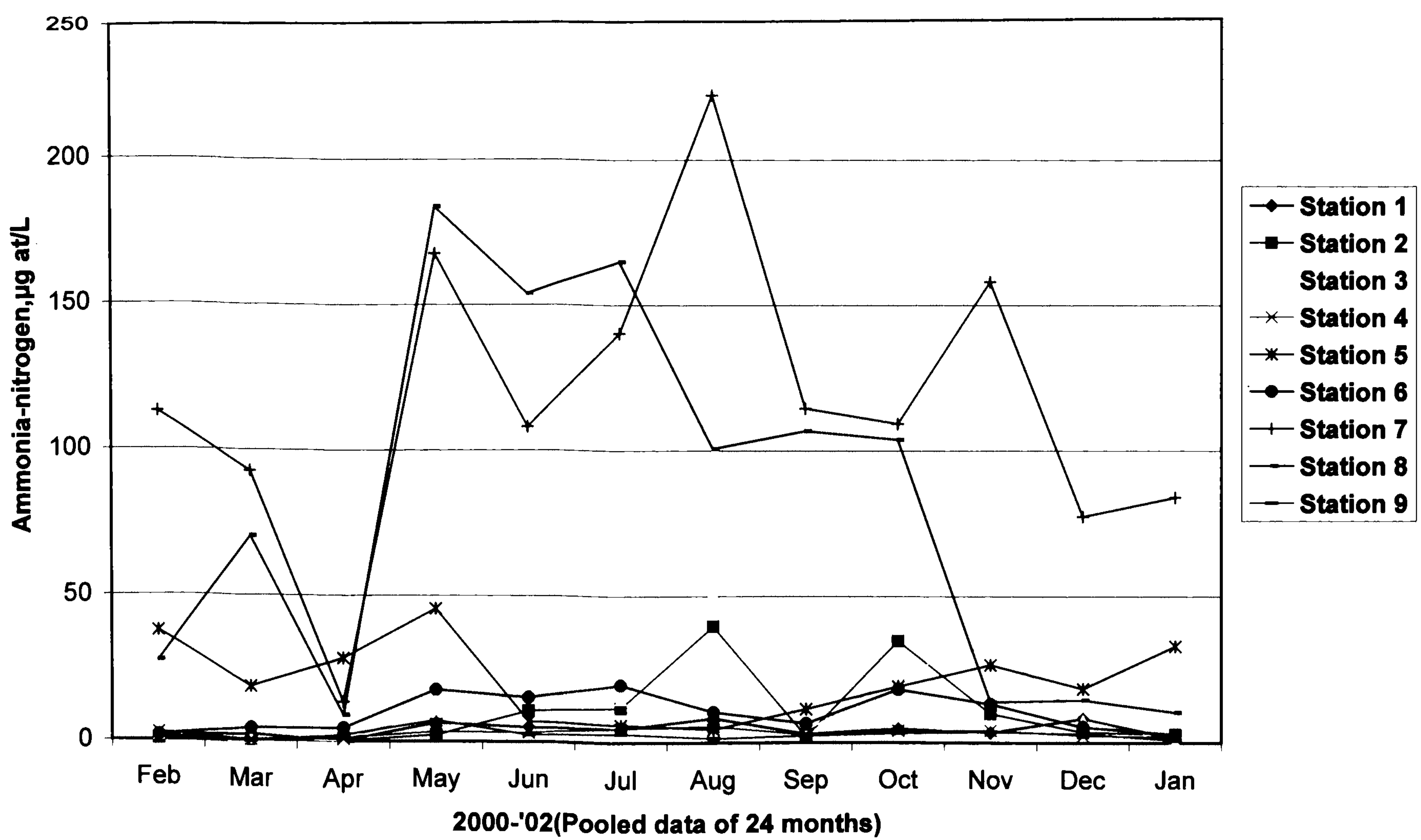


Fig.29. Spatial and monthly variations of BOD during the study period

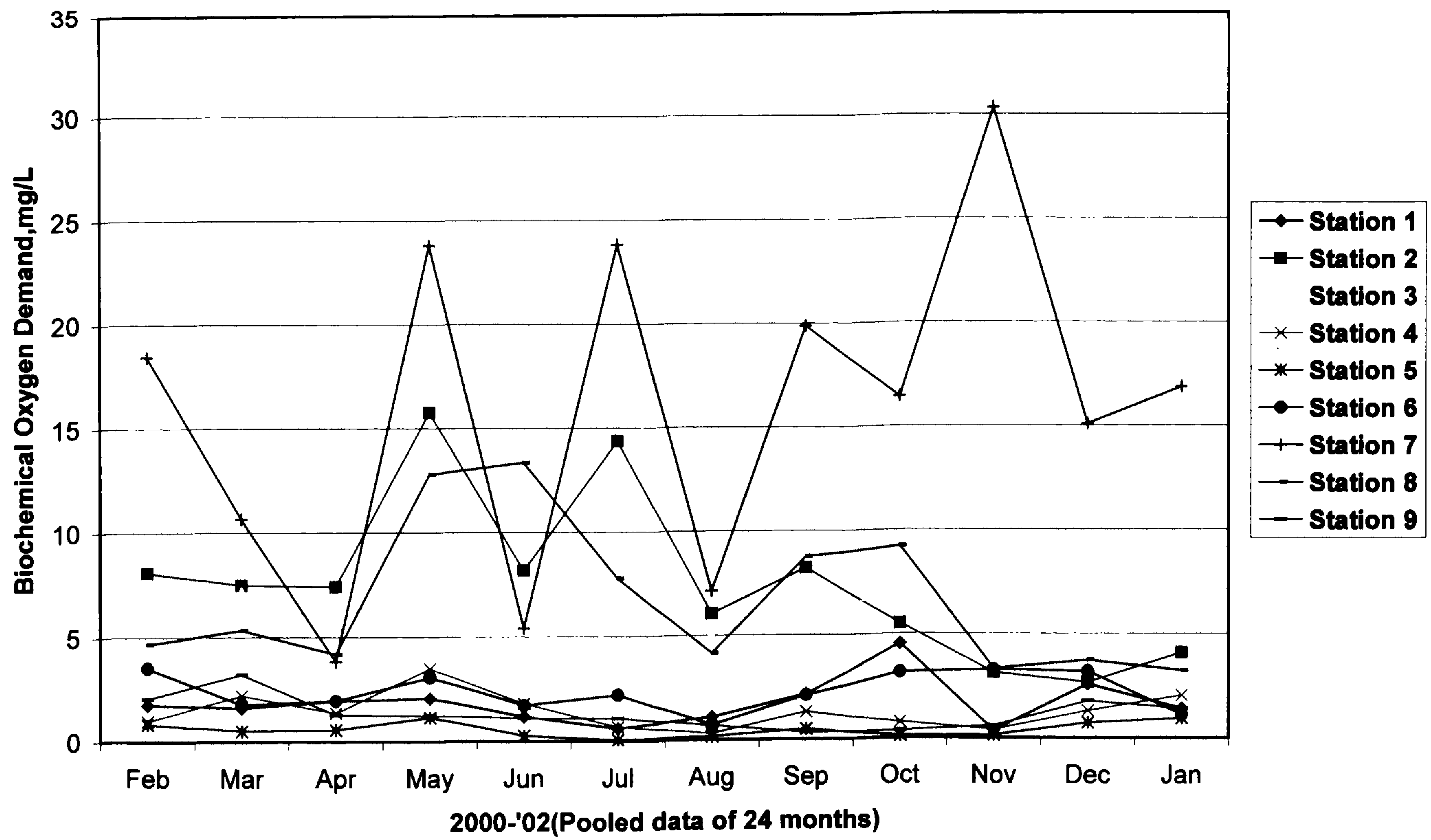
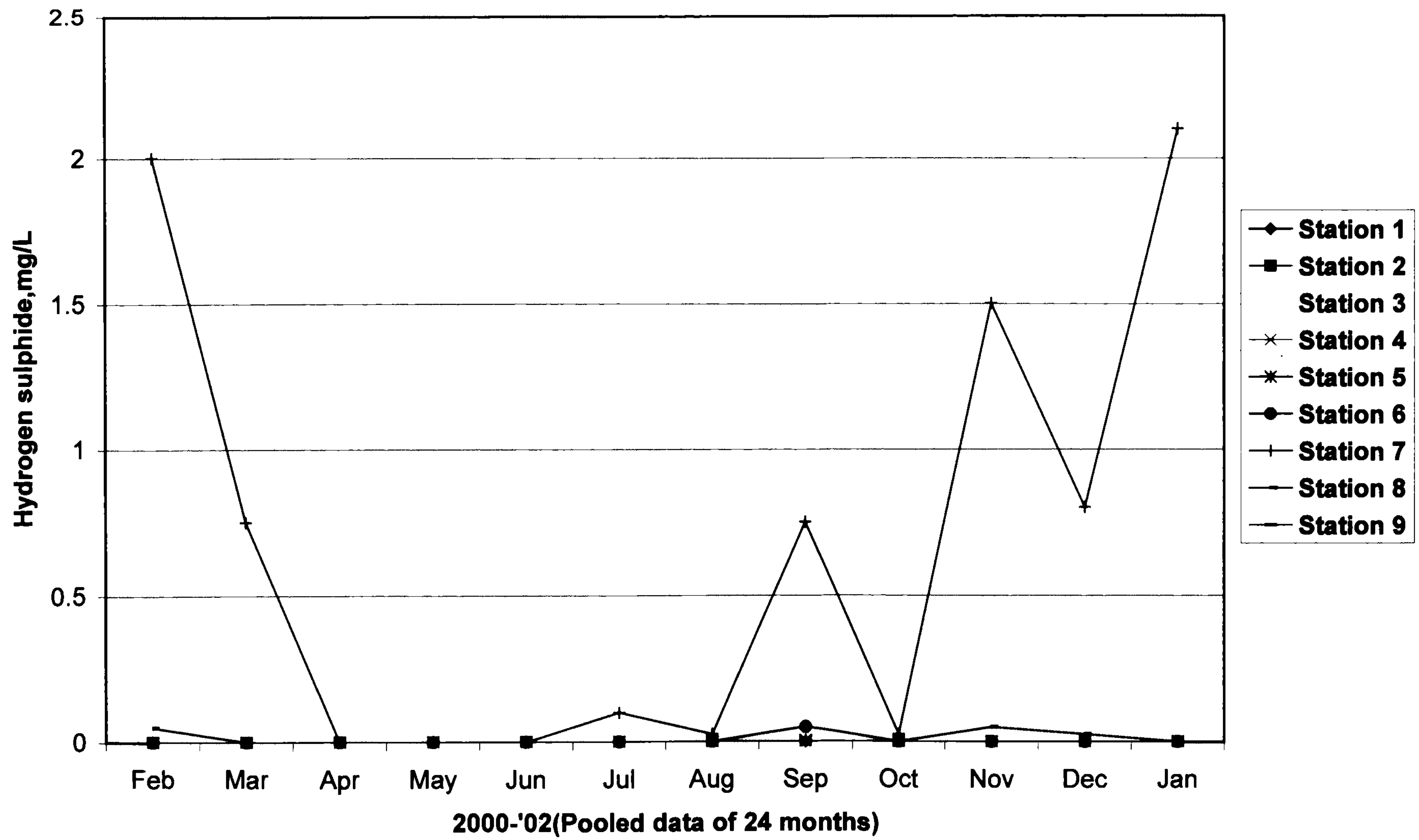
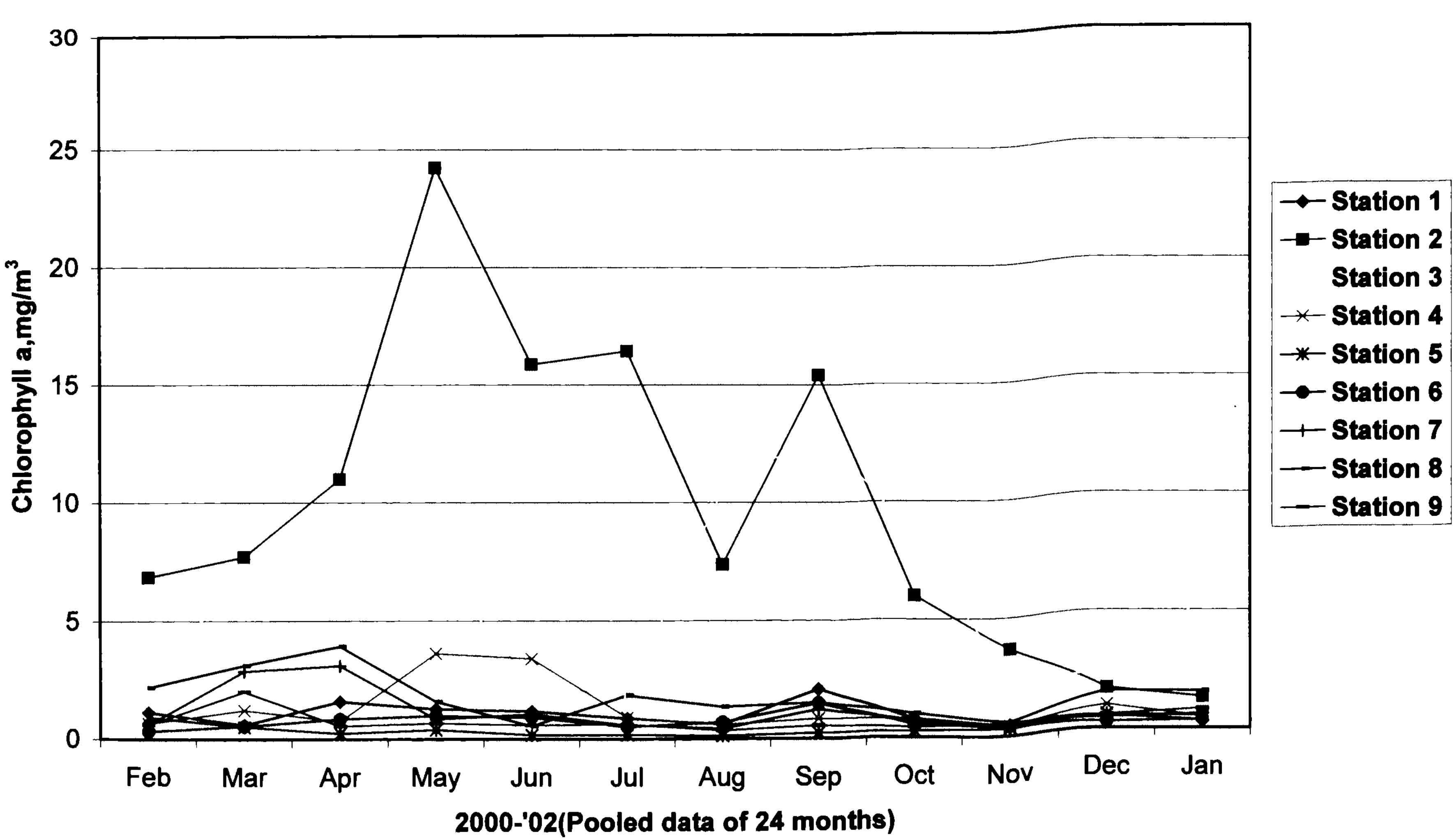


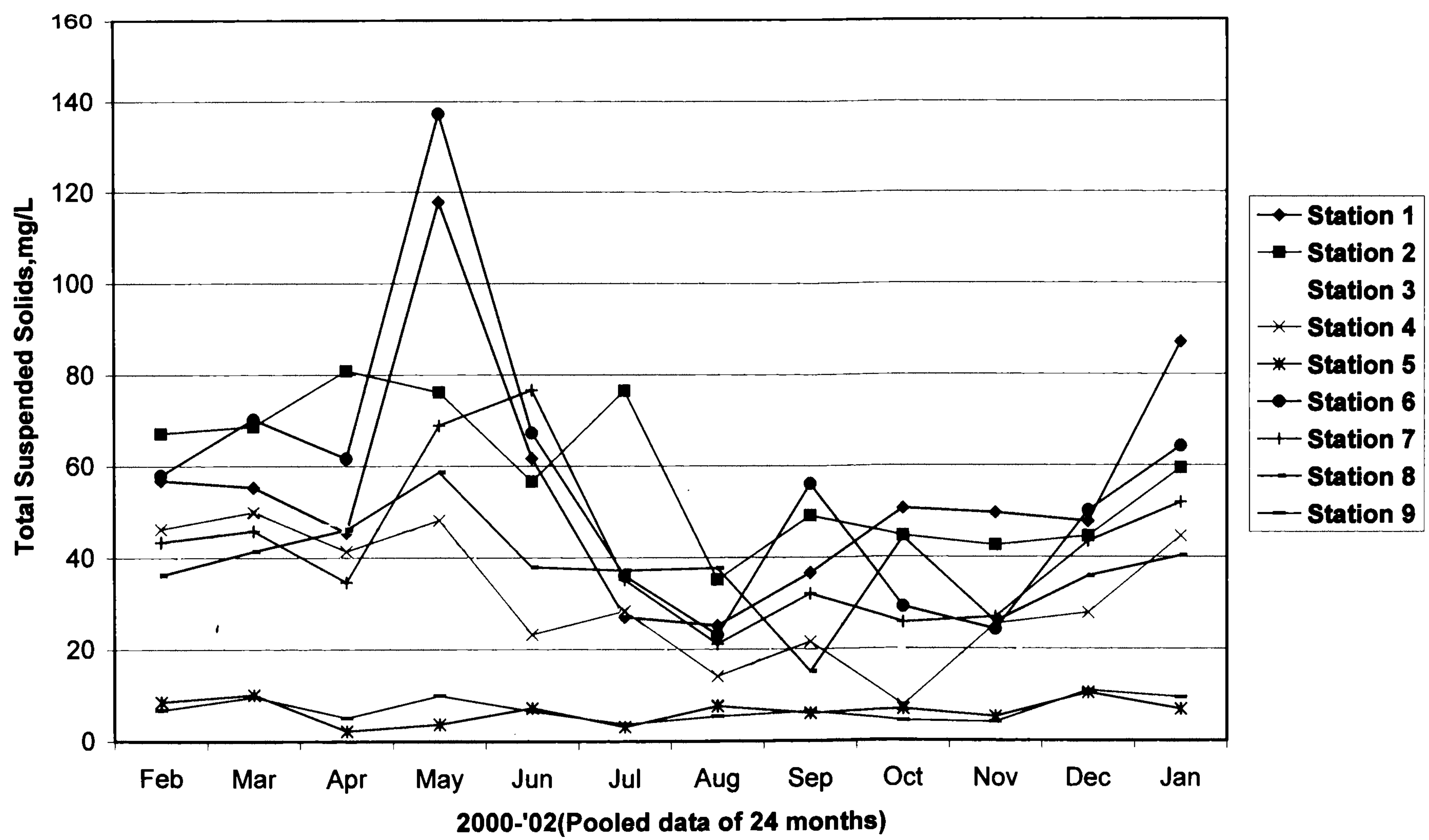
Fig.30. Spatial and monthly variations of H_2S during the study period





30
25
20
15
10
5
0
Chlorophyll a,mg/m^3
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2000-'02(Pooled data of 24 months)
Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7
Station 8
Station 9

Fig.32. Spatial and monthly variations of TSS during the study period



10.1. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 1

B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.rubens*	*B.forficula*
1000	7020	0	0	0	0
0	12800	0	0	0	200
240	54800	0	0	0	0
0	50000	0	0	0	0
0	7400	4800	0	0	0
13600	11600	25600	0	0	0
1200	1820	800	0	0	0
0	17000	0	0	0	0
0	20	2400	0	0	0
0	10400	5000	400	400	0
0	400	0	200	0	0
1200	4800	0	0	0	0

10.2. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 2

B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.rubens*	*B.forficula*
0	520000	0	0	0	0
0	937200	25	0	0	10
1400	2470200	0	0	0	0
62200	4380200	0	0	800	0
310400	800400	811400	20000	20400	0
225000	442500	1262500	2000	35000	0
39700	207500	56700	5000	7000	0
15000	502000	55000	500	250	0
18000	34000	112000	8000	8000	0
26667	186867	8000	12000	12000	0
0	182334	0	2134	0	0
5000	343000	0	0	0	0

10.3. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 3

B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.rubens*	*B.caudatus*	*B.forficula*
0	234000	0	0	0	0	6667
0	726867	0	0	2000	0	3334
2400	272000	0	0	0	0	0
40000	2218000	0	0	0	0	0
200	6200	6000	0	0	0	0
6000	6200	64000	0	2000	0	0
62500	757900	35000	2500	50	0	0
45000	1250200	30000	10200	0	0	0
240	1010200	22000	20	4000	0	0
20000	1353334	2000	2000	600	0	0
67	580000	0	0	0	0	0
0	1103800	0	0	0	50	0

10.4. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 4

B.plicatilis	B.rotundiformis	B.angularis	B.urceolaris	B.rubens	B.calyci-florus	B.forficula	B.biden-tata
0	2300	0	0	0	1200	8000	0
0	37000	0	0	0	7000	36000	0
1000	22500	0	0	0	0	1500	0
500	324100	0	0	100	0	0	0
24000	215500	6000	0	0	0	0	0
2000	1100	0	0	500	0	0	0
0	400	0	0	0	0	0	0
0	47346	0	1000	0	0	100	0
0	700	0	0	0	0	100	0
1600	0	400	0	400	0	0	0
3000	2000	0	0	0	20	0	0
1600	6000	0	0	0	0	2000	400

10.5. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 5

B.plicatilis	B.rotundiformis	B.angularis	B.urceolaris	B.rubens	B.forficula	B.quadri-dentatus	B.patu-lus	B.mira-bilis
500	2500	200	0	0	500	200	0	0
0	0	0	0	0	0	400	0	100
0	0	0	0	0	0	800	0	0
0	0	0	0	0	1000	220	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	100	0
0	0	0	0	0	0	0	0	0
0	0	0	0	2400	0	0	0	0
1100	21100	20	1000	1000	0	0	0	0

10.6. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 6

B.plicatilis	B.rotundiformis	B.angularis	B.urceolaris	B.falcatus	B.quadri-dentatus
0	600	0	0	0	0
0	1600	0	0	0	0
0	1400	0	0	0	0
0	0	0	0	0	0
0	0	2000	1000	200	1000
0	0	2400	0	0	0
0	0	40	0	0	0
0	2000	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
200	0	0	0	0	0
0	200	0	0	0	0

10.7. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 7

B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.rubens*	*B.forficula*	*B.quadri-dentatus*	*B.biden-tata*
0	0	0	0	0	0	0	0
0	1000	0	0	0	0	0	0
1000	21600	0	1600	200	0	0	0
0	250	0	0	0	0	0	0
0	0	0	0	0	0	0	1200
0	0	0	0	0	0	0	0
0	0	400	0	0	0	0	0
0	440	0	800	800	0	0	0
0	0	0	1200	0	0	0	0
0	0	0	0	0	0	200	0
0	0	0	0	0	0	0	0
0	0	0	0	0	20	0	0

10.8. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 8

B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.rubens*	*B.quadri-dentatus*
0	4600	0	0	0
0	13000	0	0	0
0	98000	0	2000	0
30000	830000	0	0	0
0	0	2000	0	0
0	0	3000	0	0
0	0	0	0	200
0	0	10	0	0
0	0	0	25	0
0	0	0	0	0
400	1200	200	400	0
0	11200	0	0	0

10.9. Monthwise distribution of *Brachionus* species(Nos./m^3) at station 9

B.plicatilis	*B.rotundiformis*	*B.urceolaris*	*B.rubens*	*B.falcatus*	*B.forficula*	*B.patulus*	*B.biden-tata*
400	86200	0	0	0	0	0	0
0	14400	0	0	0	0	0	0
0	28000	0	0	0	0	0	0
0	0	0	0	0	0	200	0
0	0	0	0	0	1000	1200	0
0	0	0	0	200	0	200	0
0	0	0	0	0	0	20	0
0	0	0	0	0	0	0	400
0	0	0	0	0	200	1000	0
0	0	0	0	0	0	0	0
0	0	400	1000	0	0	0	0
3200	18800	0	200	0	0	0	0

Table 11.1. Correlation coefficients of total Rotifers, family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 1

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.414	0.455	0.475
pH	-0.052	-0.073	-0.052
Dissolved Oxygen	0.670*	0.682*	0.699*
Salinity	-0.229	-0.199	-0.165
Alkalinity	-0.271	-0.260	-0.241
Phosphate	-0.167	-0.198	-0.242
Nitrite	-0.466	-0.464	-0.445
Ammonia	-0.210	-0.224	-0.228
BOD	-0.175	-0.201	-0.248
Chlorophyll a	0.370	0.433	0.441
TSS	0.103	0.159	0.165
Rainfall	0.308	0.304	0.270

* Significant at 5% level
** Significant at 1% level

Table 11.2. Correlation coefficients of total Rotifers ,family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 2

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.605*	0.625*	0.626*
pH	0.461	0.439	0.439
Dissolved Oxygen	0.838**	0.839**	0.839**
Salinity	-0.139	-0.087	-0.086
Alkalinity	0.451	0.432	0.432
Phosphate	0.175	0.137	0.136
Nitrite	-0.340	-0.392	-0.393
Ammonia	-0.293	-0.313	-0.314
BOD	0.828**	0.816**	0.816**
Chlorophyll a	0.863**	0.847**	0.847**
TSS	0.714**	0.720**	0.721**
Rainfall	0.539	0.479	0.479

* Significant at 5% level
** Significant at 1% level

Table 11.3. Correlation coefficients of total Rotifers ,family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 3

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	-0.032	-0.032	-0.032
pH	-0.090	-0.092	-0.092
Dissolved Oxygen	0.292	0.292	0.292
Salinity	-0.046	-0.045	-0.045
Alkalinity	0.142	0.141	0.141
Phosphate	0.099	0.098	0.098
Nitrite	-0.115	-0.111	-0.111
Ammonia	0.139	0.139	0.138
BOD	0.785**	0.786**	0.786**
H2S	0.247	0.247	0.247
Chlorophyll a	0.453	0.451	0.451
TSS	-0.007	-0.006	-0.006
Rainfall	-0.062	-0.063	-0.063

* Significant at 5% level
** Significant at 1% level

Table 11.4. Correlation coefficients of total Rotifers ,family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 4

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.362	0.362	0.362
pH	0.034	0.047	0.047
Dissolved Oxygen	0.444	0.451	0.452
Salinity	-0.167	-0.150	-0.150
Alkalinity	-0.229	-0.208	-0.209
Phosphate	0.160	0.172	0.173
Nitrite	0.581*	0.592*	0.590*
Ammonia	-0.094	-0.092	-0.093
BOD	0.784**	0.790**	0.790**
Chlorophyll a	0.976**	0.977**	0.978**
TSS	0.271	0.288	0.288
Rainfall	0.574	0.565	0.566

* Significant at 5% level
** Significant at 1% level

Table 11.5. Correlation coefficients of total Rotifers ,family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 5

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.550	0.042	0.046
pH	-0.166	0.095	0.062
Dissolved Oxygen	-0.537	-0.330	-0.351
Salinity	0.601*	0.727**	0.730**
Alkalinity	0.606*	0.773**	0.759**
Phosphate	0.268	0.038	0.004
Nitrite	0.325	0.713**	0.731**
Ammonia	0.588*	0.354	0.373
BOD	0.653*	0.494	0.501
Chlorophyll a	0.566	0.359	0.367
TSS	0.063	0.127	0.105
Rainfall	-0.552	-0.396	-0.388

* Significant at 5% level
** Significant at 1% level

Table 11.6. Correlation coefficients of total Rotifers ,family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 6

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.012	-0.204	-0.071
pH	0.070	-0.157	-0.022
Dissolved Oxygen	-0.179	-0.026	-0.221
Salinity	-0.296	-0.499	-0.324
Alkalinity	-0.240	-0.445	-0.280
Phosphate	0.465	0.576	0.428
Nitrite	0.303	-0.037	-0.065
Ammonia	0.113	0.267	0.148
BOD	-0.123	-0.375	-0.301
H2S	-0.104	0.094	0.227
Chlorophyll a	0.080	0.347	0.421
TSS	0.038	-0.025	0.056
Rainfall	0.496	0.664*	0.517

* Significant at 5% level
** Significant at 1% level

Table 11.7. Correlation coefficients of total Rotifers ,family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 7

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.135	0.698*	0.698*
pH	0.370	0.172	0.169
Dissolved Oxygen	0.609*	0.575	0.548
Salinity	-0.515	0.131	0.157
Alkalinity	-0.780**	-0.501	-0.436
Phosphate	-0.168	-0.583*	-0.551
Nitrite	-0.100	-0.136	-0.129
Ammonia	-0.137	-0.643*	-0.630*
BOD	-0.461	-0.529	-0.496
H2S	-0.674*	-0.315	-0.295
Chlorophyll a	0.354	0.742**	0.715**
TSS	0.015	-0.100	-0.142
Rainfall	0.616*	-0.071	-0.111

* Significant at 5% level
** Significant at 1% level

Table 11.8. Correlation coefficients of total Rotifers ,family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 8

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.194	0.198	0.198
pH	0.383	0.385	0.386
Dissolved Oxygen	0.172	0.173	0.173
Salinity	-0.133	-0.126	-0.127
Alkalinity	0.635*	0.633*	0.633*
Phosphate	0.797**	0.795**	0.795**
Nitrite	0.941**	0.939**	0.939**
Ammonia	0.467	0.461	0.461
BOD	0.510	0.502	0.502
H2S	-0.236	-0.234	-0.234
Chlorophyll a	0.031	0.039	0.038
TSS	0.650*	0.651*	0.651*
Rainfall	0.263	0.254	0.254

* Significant at 5% level
** Significant at 1% level

Table 11.9. Correlation coefficients of total Rotifers ,family Brachionidae and genus *Brachionus* with certain physico-chemical characteristics at station 9

	Total Rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.231	0.431	0.337
pH	0.356	0.126	0.029
Dissolved Oxygen	-0.169	-0.017	-0.068
Salinity	0.172	0.454	0.517
Alkalinity	0.189	0.405	0.459
Phosphate	0.165	0.133	0.105
Nitrite	0.772**	0.677*	0.602*
Ammonia	-0.092	-0.208	-0.389
BOD	0.051	0.435	0.449
Chlorophyll a	-0.094	0.071	0.088
TSS	-0.284	0.143	0.067
Rainfall	-0.367	-0.386	-0.461

* Significant at 5% level

** Significant at 1% level

Table 12.1. Correlation coefficients of selected species of *Brachionus* with certain physico-chemical characteristics at station 1

	B.plicatilis	B.rotundiformis	B.angularis	B.urceolaris	B.rubens	B.forficula
Temperature	-0.223	0.689*	-0.298	-0.085	0.007	0.470
pH	-0.211	0.098	-0.292	0.346	0.281	0.174
Dissolved Oxygen	0.570	0.447	0.522	-0.084	-0.139	-0.506
Salinity	-0.484	0.141	-0.565	0.319	0.138	0.184
Alkalinity	-0.518	0.070	-0.577*	0.329	0.138	0.164
Phosphate	-0.078	-0.281	0.079	-0.179	-0.069	0.284
Nitrite	-0.039	-0.465	-0.048	0.080	0.047	0.153
Ammonia	0.049	-0.297	0.088	0.162	-0.076	-0.204
BOD	-0.377	-0.034	-0.393	-0.271	-0.410	-0.050
Chlorophyll a	-0.093	0.562	-0.125	-0.447	-0.325	-0.234
TSS	-0.349	0.402	-0.364	-0.104	-0.067	0.003
Rainfall	0.271	0.078	0.420	-0.281	-0.141	-0.329

* Significant at 5% level **Significant at 1% level

Table 12.2.Correlation coefficients of selected species of *Brachionus* with certain physico-chemical characteristics at station 2

	B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.rubens*	*B.forficula*
Temperature	0.005	0.656*	-0.031	-0.240	-0.147	0.390
pH	0.432	0.320	0.292	0.257	0.298	-0.235
Dissolved Oxygen	0.342	0.749**	0.270	-0.205	0.126	-0.008
Salinity	-0.593*	0.143	-0.547	-0.581*	-0.646*	0.361
Alkalinity	0.378	0.269	0.437	0.031	0.484	-0.109
Phosphate	0.473	-0.050	0.451	0.366	0.556	-0.193
Nitrite	0.395	-0.532	0.275	0.812**	0.411	-0.241
Ammonia	0.110	-0.374	0.117	0.376	0.298	-0.225
BOD	0.447	0.646*	0.486	-0.224	0.364	-0.008
Chlorophyll a	0.517	0.694*	0.418	0.009	0.297	-0.095
TSS	0.170	0.647*	0.259	-0.425	0.077	0.209
Rainfall	0.833**	0.205	0.660*	0.615*	0.657*	-0.329

* Significant at 5% level **Significant at 1% level

Table 12.3.Correlation coefficients of selected species of *Brachionus* with certain physico-chemical characteristics at station 3

	B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.rubens*	*B.caudatus*	*B.forficula*
Temperature	-0.109	-0.022	-0.265	0.120	0.002	-0.314	0.382
pH	0.201	-0.113	0.419	0.063	0.281	-0.557	-0.113
Dissolved Oxygen	0.261	0.282	0.071	0.636*	-0.089	0.097	-0.284
Salinity	-0.422	-0.010	-0.641*	-0.212	-0.346	0.496	0.472
Alkalinity	0.113	0.138	0.071	-0.369	0.426	0.084	-0.237
Phosphate	0.623*	0.061	0.510	0.159	0.193	-0.314	-0.332
Nitrite	-0.082	-0.109	0.006	-0.135	0.121	-0.156	-0.343
Ammonia	0.562	0.109	0.377	0.061	0.128	-0.265	-0.345
BOD	0.197	0.801**	-0.424	0.102	0.043	0.469	-0.161
H_2S	0.431	0.223	0.257	0.955**	-0.177	-0.091	-0.127
Chlorophyll a	0.650*	0.426	0.169	0.644*	0.016	-0.038	-0.170
TSS	-0.408	0.023	-0.481	-0.292	-0.144	0.162	0.360
Rainfall	0.268	-0.086	0.448	-0.021	0.103	-0.304	-0.433

* Significant at 5% level **Significant at 1% level

Table 12.4.Correlation coefficients of selected species of *Brachionus* with certain physico-chemical characteristics at station 4

	B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.rubens*	*B.calyciflorus*	*B.forficula*	*B.bidentata*
Temperature	-0.143	0.331	-0.078	0.142	-0.076	0.443	0.454	-0.361
pH	0.082	0.024	0.159	-0.315	0.233	0.139	0.145	-0.283
Dissolved Oxygen	0.367	0.425	0.314	-0.164	-0.062	0.136	0.110	0.180
Salinity	-0.365	-0.177	-0.396	-0.209	-0.242	0.398	0.451	0.382
Alkalinity	-0.344	-0.211	-0.378	-0.362	-0.124	0.165	0.214	0.387
Phosphate	0.379	0.145	0.461	-0.407	0.056	0.021	0.023	-0.372
Nitrite	0.118	0.633*	0.111	-0.171	0.334	-0.267	-0.273	0.031
Ammonia	0.020	-0.025	0.034	-0.089	0.477	-0.593*	-0.627*	-0.238
BOD	0.131	0.774**	0.123	-0.025	-0.315	0.261	0.267	0.228
Chlorophyll a	0.607*	0.967**	0.615*	-0.112	-0.115	-0.028	-0.054	-0.212
TSS	-0.179	0.253	-0.195	-0.221	-0.088	0.466	0.508	0.290
Rainfall	0.623*	0.583*	0.645*	-0.043	0.200	-0.382	-0.421	-0.304

* Significant at 5% level **Significant at 1% level

	B.plicatilis	B.rotundiformis	B.angularis	B.urceolaris	B.rubens	B.forficula	B.quadridentatus	B.patulus	B.mirabilis
Temperature	0.122	0.004	0.370	-0.040	-0.137	0.438	0.805**	-0.318	0.416
pH	-0.020	0.124	-0.416	0.175	-0.168	-0.416	-0.468	0.239	0.323
Dissolved Oxygen	-0.450	-0.305	-0.543	-0.243	-0.196	-0.298	-0.315	0.178	0.006
Salinity	0.765**	0.682*	0.455	0.634*	0.682*	-0.078	-0.229	-0.279	0.025
Alkalinity	0.652*	0.784**	-0.186	0.813**	0.092	-0.124	-0.062	-0.084	0.0002
Phosphate	0.001	0.012	-0.033	0.016	-0.189	0.009	0.234	0.027	0.924**
Nitrite	0.684*	0.728**	0.074	0.725**	0.396	0.077	-0.593*	-0.009	-0.275
Ammonia	0.428	0.325	0.417	0.277	0.043	0.717**	0.371	-0.053	-0.063
BOD	0.499	0.431	0.335	0.395	0.350	0.662*	0.277	-0.345	0.019
Chlorophyll a	0.519	0.301	0.769**	0.212	0.371	0.367	0.101	-0.147	0.197
TSS	0.147	0.070	0.262	0.039	0.469	-0.193	-0.306	0.039	0.439
Rainfall	-0.416	-0.341	-0.334	-0.304	-0.429	0.117	-0.281	0.148	-0.329

* Significant at 5% level   **Significant at 1% level

Table 12.6.Correlation coefficients of selected species of *Brachionus* with certain physico-chemical characteristics at station 6

	B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.falcatus*	*B.quadridentatus*
Temperature	-0.188	0.462	-0.417	-0.110	-0.110	-0.110
pH	-0.102	0.482	-0.265	-0.243	-0.243	-0.243
Dissolved Oxygen	0.229	-0.509	0.024	0.086	0.086	0.086
Salinity	0.324	0.422	-0.573	-0.421	-0.421	-0.421
Alkalinity	0.377	0.360	-0.505	-0.354	-0.354	-0.354
Phosphate	-0.340	-0.521	0.759**	0.503	0.503	0.503
Nitrite	-0.165	-0.308	0.088	0.123	0.123	0.123
Ammonia	-0.227	-0.554	0.541	0.245	0.245	0.245
BOD	0.301	-0.174	-0.178	-0.205	-0.205	-0.205
H_2S	-0.091	0.641*	-0.136	-0.091	-0.091	-0.091
Chlorophyll a	-0.340	0.519	0.048	0.227	0.227	0.227
TSS	-0.065	0.124	-0.099	0.111	0.111	0.111
Rainfall	-0.323	-0.405	0.683*	0.652*	0.652*	0.652*

* Significant at 5% level   **Significant at 1% level

Table 12.7.Correlation coefficients of selected species of *Brachionus* with certain physico-chemical characteristics at station 7

	B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.urceolaris*	*B.rubens*	*B.forficula*	*B.quadridentatus*	*B.bidentata*
Temperature	0.688*	0.712**	-0.286	0.494	0.121	-0.079	-0.138	-0.168
pH	0.153	0.168	-0.015	0.168	-0.084	-0.705*	0.107	0.015
Dissolved Oxygen	0.525	0.511	0.277	0.487	0.103	-0.287	-0.287	0.433
Salinity	0.187	0.197	-0.325	-0.037	-0.068	0.455	0.010	-0.359
Alkalinity	-0.390	-0.394	0.149	-0.400	-0.332	0.301	0.528	-0.586*
Phosphate	-0.532	-0.543	0.144	-0.368	-0.303	-0.271	0.444	-0.141
Nitrite	-0.119	-0.116	-0.094	-0.198	-0.128	-0.101	-0.086	0.053
Ammonia	-0.622*	-0.629*	0.637*	-0.538	-0.167	-0.198	0.250	-0.052
BOD	-0.473	-0.479	-0.345	-0.311	0.034	0.035	0.559	-0.412
H_2S	-0.264	-0.267	-0.254	-0.357	-0.035	0.563	0.326	-0.264
Chlorophyll a	0.684*	0.717**	-0.205	0.509	0.230	-0.241	-0.248	-0.002
TSS	-0.140	-0.135	-0.390	-0.374	-0.219	0.181	-0.283	0.640
Rainfall	-0.136	-0.150	0.202	-0.038	-0.077	-0.304	-0.141	0.652*

* Significant at 5% level **Significant at 1% level

Table 12.8.Correlation coefficients of selected species of *Brachionus* with certain physico-chemical characteristics at station 8

	B.plicatilis	*B.rotundiformis*	*B.angularis*	*B.rubens*	*B.quadridentatus*
Temperature	0.110	0.201	-0.305	0.622*	-0.189
pH	0.385	0.383	0.491	-0.098	0.346
Dissolved Oxygen	0.116	0.175	-0.263	0.636*	0.286
Salinity	-0.155	-0.124	-0.500	0.267	-0.340
Alkalinity	0.670*	0.630*	0.542	-0.395	-0.009
Phosphate	0.821**	0.792**	0.359	-0.314	-0.067
Nitrite	0.955**	0.938**	-0.094	-0.193	-0.008
Ammonia	0.499	0.458	0.551	-0.405	0.100
BOD	0.526	0.500	0.404	-0.269	-0.222
H_2S	-0.202	-0.233	-0.288	-0.177	-0.204
Chlorophyll a	-0.051	0.041	-0.196	0.695*	-0.123
TSS	0.616*	0.651*	-0.031	0.229	-0.011
Rainfall	0.273	0.251	0.624*	-0.199	0.202

* Significant at 5% level **Significant at 1% level

Table 12.9.Correlation coefficients of selected species of *Brachionus* with certain physico-chemical characteristics at station 9

	B.plicatilis	*B.rotundiformis*	*B.urceolaris*	*B.rubens*	*B.falcatus*	*B.forficula*	*B.patulus*	*B.bidentata*
Temperature	-0.326	0.360	-0.497	-0.566	-0.353	-0.082	-0.116	0.153
pH	-0.487	0.056	-0.162	-0.265	0.221	-0.444	-0.122	0.089
Dissolved Oxygen	0.486	-0.076	0.356	0.455	0.113	-0.619*	-0.608*	0.099
Salinity	0.583*	0.502	0.366	0.474	-0.293	-0.350	-0.515	-0.219
Alkalinity	0.522	0.446	0.426	0.523	-0.319	-0.400	-0.501	-0.332
Phosphate	0.039	0.087	-0.177	-0.177	0.083	0.725**	0.658*	0.094
Nitrite	0.155	0.600*	-0.075	-0.062	0.002	-0.087	-0.095	-0.209
Ammonia	-0.320	-0.380	0.081	0.023	0.066	-0.022	0.161	-0.042
BOD	0.100	0.450	0.197	0.208	-0.069	-0.131	-0.304	-0.360
Chlorophyll a	0.088	0.091	-0.080	-0.061	-0.055	-0.120	-0.216	-0.105
TSS	0.321	0.053	0.508	0.571	-0.391	-0.105	-0.255	-0.050
Rainfall	-0.343	-0.462	-0.323	-0.383	0.300	0.680*	0.720**	-0.043

* Significant at 5% level
**Significant at 1% level

RAINFALL

Rainfall data is common for all the nine stations. The data related to rainfall was obtained from the Indian Meteorological department, Trivandrum. In the study area, rainfall was maximum during June and minimum during March. The values ranged from 5.5 to 702.5 mm. The data showed a gradual increase from March to June and then recorded a gradual decrease till September. A secondary peak was observed in October to the tune of 344.5 mm. coinciding with the north-east monsoon. Total annual rainfall was 2872 mm., of which 1746 mm was observed during the monsoon season, 609 mm. during the premonsoon season and 517 mm. during the post monsoon season.

STATION 1

Temperature:- The surface temperature ranged from 28.1°C in August to 32.1°C in April, with an average value of 29.8°C. During monsoon season, temperature recorded the lowest value of 28.8°C. It gradually increased to 29.2°C in post monsoon season and the highest value of 31.5°C was achieved in the premonsoon season.

pH :- pH values did not show much fluctuations. It varied from 7.14 in September to 7.59 in April, with an average of 7.36. A slight decrease in the monsoon season was noticed. The pH values during monsoon , postmonsoon and premonsoon seasons were 7.2, 7.42 and 7.46 respectively.

Dissolved Oxygen:- Dissolved oxygen varied from 2.86 ml/L in March to 4.33 ml/L in July, with an average value of 3.55 ml/L. The primary peak was in July and the secondary one was in April. Consequently, the values increased from 3.44 ml/L in the postmonsoon to 3.52 ml/L in the premonsoon and the highest of 3.7 ml/L in the monsoon season.

Salinity:- Wide fluctuations in the salinity were observed at this station. It varied from 5 ppt in July to 30 ppt in December and January. The average salinity at this station was 18.67 ppt. There was a sharp decline from premonsoon to monsoon and a sharp increase from monsoon to postmonsoon season, lowering of salinity upto 12 ppt was noticed during October.

Alkalinity:- Two peaks were registered; the primary one was during December with a value of 96.56 and a secondary peak in April with a value of 83.41mg/L as $CaCO_3$. Alkalinity ranged from 22.5 in July to 96.56 mg/L in December. Seasonally, an increasing trend was very clear from 35.25 mg/L during monsoon to 74.01mg/L during premonsoon and the highest was recorded during the postmonsoon season with a value of 80.76 mg/L as $CaCO_3$.

Phosphate:- It varied from 0.4 in September to 1.48µg at/L in June. Seasonally, the highest value of 0.97 µg at/L was observed in the monsoon season and the lowest of 0.81 µg at/L in the postmonsoon season.

Nitrite:- The nitrite content was low at this station with a range of 0.03µg at/L in April to 0.66µg at/L during February. A gradual increase was noticed from postmonsoon to monsoon and from monsoon to premonsoon.

Ammonia:- The ammonia nitrogen ranged from 0 to 8.13µg at/L, with an average value of 3.92µg at/L at this station. The lowest value of 2.49 was recorded during premonsoon and a maximum of 4.99µg at/L during the monsoon period.

BOD:- The Biochemical Oxygen Demand at this station showed a variation from 0.34mg/L in November to 4.49mg/L during October, with an average value of 1.74mg/L. There was a steady increase from monsoon to premonsoon to postmonsoon seasons and the values were 1.22, 1.81 and 2.19mg/L respectively.

H_2S:- Hydrogen sulphide was not observed at this station during the study period.

Chlorophyll a:- The chlorophyll content at this station varied from 0.43mg/m^3 in November to 2.06 mg/m^3 in September with an average of 0.95 mg/m^3. The value was low during the postmonsoon , increased during the premonsoon and the highest of 1.16 mg/m^3 was recorded during the monsoon period.

Total Suspended Solids:- A clear peak value of 117.7mg/L was observed during May and a minimum of 25mg/L was recorded in August. Subsequently, monsoon season registered a minimum of 37.5mg/L TSS content, it increased to 58.63mg/L during postmonsoon and the highest of 68.73mg/L was recorded during the premonsoon season.

The dissolved oxygen showed positive correlation with Rotifers, family Brachionidae and genus *Brachionus* which were significant at 5% level.

The temperature showed positive correlation with *B.rotundiformis*, whereas alkalinity showed negative correlation with *B.angularis*. These two correlations were significant at 5% level.

STATION 2

Temperature:- A minimum of 28.25°C was observed in December and the maximum of 33°C in April. There was a gradual decline from April to August upto the value of 29°C and then fluctuated. The highest value of 32.03°C was noticed in the premonsoon season, a decline in the monsoon season and the lowest value of 28.97°C was recorded during the postmonsoon period.

pH :- pH did not vary much between months at this station. The range was between 7.19 and 7.71, with an average value of 7.48.

Dissolved Oxygen:- The dissolved oxygen content at this station varied from 0.84ml/L in October to 4.97ml/L in May. There was a steady increase from January to May and after that the values fluctuated and a secondary peak was observed in September. Seasonwise data showed a decline from premonsoon to postmonsoon through monsoon, the lowest was 1.49ml/L in the postmonsoon.

Salinity:- There was a wide fluctuation in salinity at this station over the months. The variation was between 2.5ppt in October to 28.5ppt in January. A secondary peak of 9ppt was observed in September and a decline in October upto 2.5ppt. The lowest value of 5.69ppt was noticed in the monsoon season, the values increased to 17.25ppt in the postmonsoon and the highest of 23ppt was recorded during the premonsoon season. The average value of salinity at this station was 15.31ppt.

Alkalinity:- Throughout the study period, the total alkalinity at this station varied from 84.99mg/L in September to 150.17mg/L as $CaCO_3$ in July, a decrease in June and September and an increase in October were noticed. Seasonally, the lowest value of 109.09mg/L was recorded in the postmonsoon season.

Phosphate:- Phosphate content at this station ranged from 1.17μg at/L in January to 16.11μg at/L in August. A steady increase from April to August , a sharp decrease in September and a rise in October were recorded. The phosphate values were the same in both premonsoon and postmonsoon periods which amounted to 4.6μg at/L, while 10.5μg at/L was recorded during the monsoon season.

Nitrite:- The values showed a maximum of 0.65µg at/L in October and 0 in April, with an average of 0.26µg at/L. Seasonally, lower value of 0.04µg at/L was recorded during premonsoon when compared to monsoon and postmonsoon periods.

Ammonia:- It was not observed in March and April, but a value as high as 39.44µg at/L was noticed in August. A steady increase was noticed from April to August. A conspicuous decrease in September and a sharp increase in October were recorded. From October to March a steady decrease was noticed. An average of 9.63µg at/L was noticed at this station with the lowest of 0.54µg at/L during the premonsoon, 12.56µg at/L during the postmonsoon and the highest of 15.78µg at/L during the monsoon season.

BOD:- The Biochemical Oxygen Demand at this station showed a maximum of 15.73mg/L in May and a minimum of 2.64mg/L in December. Two major peaks were observed , one in May and another one in July. The data showed a lower value during postmonsoon when compared to monsoon and premonsoon seasons and an average of 7.54mg/L was recorded at this station.

H_2S:- Hydrogen sulphide was not recorded at this station.

Chlorophyll a:- The chlorophyll a content at this station was high during the study period with a range of 1.29mg/m^3 in January to 24.2mg/m^3 in May. There was a steady increase from February to May and then decreased till January with two peaks in between, one in July and another in September. A considerably lower value of 3.14 mg/m^3 was noticed during postmonsoon season when compared to premonsoon and monsoon periods. Compared to other stations, chlorophyll a concentration was higher at station II in most of the months.

TSS:- The total suspended solids at this station varied from 35mg/L in August to 80.7mg/L during April. Seasonally, the highest value of 73.05mg/L was recorded during the premonsoon season. The average for the station was 58.3mg/L.

At station II, the numerical abundance of Rotifers, family Brachionidae and genus *Brachionus* revealed highly significant positive correlations with dissolved oxygen, biochemical oxygen demand, total suspended solids and chlorophyll a. Also, significant positive correlation was noticed between water temperature and Rotifers, family Brachionidae and genus *Brachionus.*

The correlation coefficients of *B.rotundiformis* with temperature, BOD, chlorophyll a and TSS were significant at 5% level and that with dissolved oxygen was significant at 1% level. Salinity was found to be negatively correlated with *B.plicatilis, B.urceolaris* and *B.rubens* (significant at 5% level). The positive correlations between nitrite and *B.urceolaris* and that between rainfall and *B.plicatilis* were significant at 1% level. And, rainfall showed significant positive correlations with *B.angularis, B.urceolaris* and *B.rubens*.

STATION 3

Temperature:- There was not much variation in temperature between months at this station. An average of 30.69°C was observed, the maximum, during April and minimum during December. Seasonally, the values showed a gradual increase from 29.66°C during postmonsoon to 30.31°C during monsoon and the highest of 32.09°C during premonsoon season.

pH:- The values were almost constant throughout the study period with an average of 7.34.

Dissolved Oxygen:- The dissolved oxygen varied from 1.03ml/L during November to 4.38ml/L in September. Two major peaks were observed, the primary one was in September and the secondary one in April. Seasonally, not much change was noticed, the values were 2.3, 2.1 and 2.2ml/L during monsoon, postmonsoon and premonsoon seasons respectively.

Salinity:- The minimum was observed during October and the maximum in January. The values were between 2.5 and 22.5ppt. There was a steady downfall from January to June. A conspicuous rise in September and a decrease in October were noticed. Seasonally, the monsoon period recorded the lowest salinity of 4.56ppt with an increase upto 12.25ppt during postmonsoon and the highest value of 16.06ppt was observed during premonsoon season.

Alkalinity:- The average value at this station was 67.69mg/L as $CaCO_3$. The range was between 43.25mg/L in September and 93.13mg/L during October. Alkalinity was high during postmonsoon season while it was uniformly distributed during monsoon and premonsoon periods.

Phosphate:- The level of phosphate showed a conspicuous rise in August, coinciding with the maximum concentration at this station. The variation over the months were from 0.96µg at/L during January to 8.53µg at/L in August. Seasonally, the phosphate content was low during premonsoon, high during postmonsoon and the highest during the monsoon season, the range was between 1.87 and 4.64µg at/L.

Nitrite:- The maximum value of 1.44µg at/L was observed during June. In all the other months, the nitrite was less than 1µg at/L. Seasonally, lower value of 0.13µg at/L was recorded during premonsoon season, while it was 0.6µg at/L during both monsoon and postmonsoon periods.

Ammonia:- Two peaks were observed in the distribution pattern of ammonia-nitrogen over the months- the major one was in August and the minor one was in November. The average value for the station was 13.66µg at/L, varied from 0 in April to 51.18µg at/L in August. The highest was recorded during monsoon season, medium in postmonsoon and the lowest in premonsoon period.

BOD :- The variation in Biochemical Oxygen Demand was from 2.32mg/L in July to 8.51mg/L in January. A value of 8.43mg/L which was very close to the maximum was observed in May. BOD was low during monsoon season, and, almost the same in premonsoon and postmonsoon seasons, with an average of 5.54mg/L at this station.

H_2S :- Hydrogen sulphide was observed only in September, amounted to 0.025mg/L.

Chlorophyll a:- Two major rises were observed during the study period. The maximum of 12.94mg/m^3 during September and a secondary peak of 7.5mg/m^3 during April-May were recorded. The lowest value of 4.66mg/m^3 was noticed during postmonsoon and the values were almost the same during the premonsoon and monsoon periods. The average value of chlorophyll a at this station was 5.91mg/m^3.

TSS:- The total suspended solids at this station ranged from 9.5mg/L during August to 49.8mg/L in March. There was a steady decline from March to August. A decrease in August and an increase in September were obvious. Of the seasons, maximum TSS was recorded during premonsoon period.

Highly significant positive correlation was noticed between BOD and the distributions of Rotifers, family Brachionidae and genus *Brachionus* at this station.

Significant positive correlations of *B.plicatilis* with phosphate and chlorophyll a were noticed. BOD was closely related to the distribution of *B.rotundiformis*(significant at 1% level). Salinity was found to be negatively correlated with *B.angularis* at 5% level.

of significance. The distribution of *B.urceolaris* was found to be influenced by dissolved oxygen and chlorophyll a (significant at 5% level). Also, a positive correlation was observed between *B.urceolaris* and H_2S significant at 1% level.

STATION 4

Temperature:- The lowest temperature was recorded during December and the highest in April with an average value of 30.1°C at this station. Seasonally, there was a gradual increase from postmonsoon to premonsoon and during monsoon, the values were in between.

pH:- There was not much variation in pH between months. The average was 7.4.

Dissolved Oxygen:- The variation was from 1.74ml/L in April to 3.21ml/L in June. Seasonally, the highest of 2.9ml/L was recorded during monsoon.

Salinity:- The values decreased from February to June , and a steady increase from October to January. An increase in September and a decrease in October were noticed. The variation at this station was from 2.5ppt during June to 25.5ppt during January-February. The monsoon season showed the lowest value of 4.88ppt, in the postmonsoon the medium value of 15.69ppt and the highest of 22ppt were recorded during premonsoon period.

Alkalinity:- Alkalinity at this station ranged from 38.4mg/L in August to 77.81mg/L during January. Lower values were recorded during monsoon season and the values were the same in premonsoon and postmonsoon seasons. The average alkalinity at this station was 59.25mg/L as $CaCO_3$.

Phosphate:- The variation was from 0.65µg at/L in December to 1.97µg at/L in June with an average of 1.33µg at/L at the station. Seasonally, not much fluctuations were observed.

Nitrite:- The nitrite-nitrogen was less than 1µgat/L in all the months,the variation was from 0 in August to 0.71µg at/L during May. Seasonally also, there was not much variation, with an average value of 0.26µg at/L.

Ammonia:- The ammonia-nitrogen ranged from 0.08µg at/L in March to 5.32µg at/L during August with an average of 2.83µg at/L at this station. The values showed a gradual increase from premonsoon to monsoon through postmonsoon seasons.

BOD:- Two peaks were noticed- the primary one was in May and the secondary one in March. The values showed a gradual decrease from May to August. The lowest value of 0.27mg/L was recorded in August and the highest of 3.45mg/L was recorded in May. Seasonwise values showed the minimum during monsoon and maximum during premonsoon and the range was between 0.99 and 1.98mg/L.

H_2S:- Hydrogen sulphide was not recorded from this station during the study period.

Chlorophyll a:- The chlorophyll a varied from 0.40mg/m^3 during November to 3.58mg/m^3 in May. The highest value was observed during the premonsoon season,the lowest during postmonsoon and the values were in between these two values, during the monsoon period whereas the average value at this station was 1.20mg/m^3.

TSS:- The minimum was recorded during October and the maximum in March. Seasonally, the lowest value of 21.7mg/L was observed during monsoon, increased to 26.23mg/L during postmonsoon and the highest of 46.28mg/L during the premonsoon season.

The relationships of Rotifers, family Brachionidae and genus *Brachionus* with BOD as well as with chlorophyll a were found to be highly significant and, that with nitrite was significant.

The nitrite content showed positive correlation with *B.rotundiformis* at 5% level of significance. The ammonia content showed significant negative relation with *B.calyciflorus* and *B. forficula.* The positive correlations of chlorophyll a with *B.plicatilis* and *B.angularis* were significant at 5% level while with that of *B.rotundiformis* was significant at 1% level. The BOD showed highly significant positive correlation with *B.rotundiformis*. Significant positive correlations were observed between rainfall and *B.plicatilis, B.rotundiformis* and *B.angularis*.

STATION 5

Temperature:- The temperature varied from 26.5°C in August to 31.75°C in April at this station. A steady increase from December to April was noticed. Seasonally, the lowest temperature was observed during monsoon, the values were higher during postmonsoon and the highest temperature was recorded during the premonsoon period.

pH:- The average value of pH noticed at this station was 6.14. The lowest was 5.04 in April and the highest of 7.07 was in September. A gradual decrease from September to December and a steady increase from April to July were observed. Among the seasons, the lowest of 5.67 was recorded during the premonsoon season. Of all the nine stations studied, pH was lower at this station in all the months.

Dissolved Oxygen:- The dissolved oxygen content at this station ranged from 3.54ml/L during February to 4.71ml/L in August. Seasonally, the highest of 4.58ml/L was recorded during monsoon. Compared to other stations, dissolved oxygen content showed higher values at this station in most of the months.

Salinity:- The salinity was low at this station with an average of 1.40ppt. The lowest of 0.25ppt was recorded in April, May and October and the highest of 4ppt was observed during January. Among the seasons, the lowest was noticed during monsoon. Compared to other stations (except station IX), this station showed low salinity, where salinity never exceeded 4ppt.

Alkalinity:- An average alkalinity of 6.28 mg/L was recorded at this station. A minimum of 2.80mg/L was observed during June and a maximum of 13.4mg/L in January. Seasonwise, the maximum was noticed during the postmonsoon season. Compared to other stations, alkalinity was very low at this station throughout the study period.

Phosphate:- The monthwise variation at this station was between 0.68 and 3.38µg at/L, with an average of 1.18µg at/L. Seasonally, the highest phosphate content was observed during the premonsoon season.

Nitrite:-A maximum of 0.61µg at/L was observed during January and the nitrite-nitrogen was not recorded during April. Seasonwise analysis of data showed the highest value during the postmonsoon season.

Ammonia:- Two major peaks were observed, the primary one was during May and the secondary peak was in February. The monthwise variation was from 4.32µg at/L in August to 45.34µg at/L in May. Seasonally, lower values were recorded during monsoon, higher values in postmonsoon and the highest was observed during the premonsoon season.

BOD:- The monthwise variation of Biochemical Oxygen Demand was from 0.03mg/L during July to 1.11mg/L in May. Seasonally, the highest value was during the premonsoon season (0.73mg/L).

H$_2$S:- Hydrogen Sulphide was not noticed at this station during the study period.

Chlorophyll a:- The chlorophyll a concentration varied from 0.10mg/m^3 in August to 0.90mg/m^3 in February with an average of 0.35mg/m^3 at this station. Seasonally, the lowest was observed during the monsoon season.

TSS:- The minimum TSS was in April and the maximum in December, range was between 2.1 and 10.3mg/L. Among the seasons, the lowest was recorded during the monsoon season.

The interrelations of family Brachionidae and the genus *Brachionus* with salinity, alkalinity and nitrite were highly significant. The distribution of rotifers were positively correlated with salinity, alkalinity, ammonia and BOD, significant at 5% level at this station.

The temperature influenced the abundance of *B.quadridentatus,* the correlation coefficient of which was significant at 1% level. A highly significant positive correlation was noticed between salinity and *B.plicatilis*. The positive correlations of salinity with *B.rotundiformis*, *B.urceolaris* and *B.rubens* were significant at 5% levels. The relationships of alkalinity with *B.rotundiformis* and *B.urceolaris* were significant at 1% level. Alkalinity showed significant positive correlation with *B.plicatilis*. The abundance of *B.mirabilis* was found to be positively correlated with phosphate content which was significant at 1% level. The nitrite concentration was positively correlated with *B.plicatilis* and showed inverse relationship with *B.quadridentatus* and the correlations were significant at 5% levels. The distributions of *B.rotundiformis* and *B.urceolaris* were found to be positively correlated to the nitrite levels and their correlation coefficients were significant at 1% levels. *B.forficula* showed highly significant correlations with ammonia and significant correlation with BOD. The availability of *B.angularis* was found to be influenced by chlorophyll a and the correlation was significant at 1% level.

STATION 6

Temperature:- The monthwise variation was between 28 and 31°C. There was not much change between different seasons and the lowest was during monsoon period.

pH:- There was not much variation in pH over the months. The average at this station was 7.36.

Dissolved Oxygen:- The dissolved oxygen content at this station varied from 2.34ml/L during March to 3.76ml/L during August. An increase in August and a decrease in November were noticed. Seasonally, the highest was observed during monsoon, and the lowest during premonsoon season, and the average value at this station was 2.91ml/L.

Salinity:- The average salinity at this station was 18.04ppt. A sharp increase in September and a decrease in October were obvious. The monthwise variation was from 2.5 ppt in June to 32.5 ppt during January. Seasonwise variation showed the lowest during monsoon and the highest during the premonsoon period.

Alkalinity:- The alkalinity at this station varied from 26.24 mg/L in August to 102.24 mg/L during January. The values were low during monsoon season, high during postmonsoon and the highest was recorded during the premonsoon period. The average alkalinity at this station was 64.15 mg/L as $CaCO_3$.

Phosphate:- A minimum of 0.58 µg at/L was recorded during January and the maximum of 2.84 µg at/L was observed during July. Seasonally, the highest was noticed during the monsoon season.

Nitrite:- Two peaks were noticed – one during May and another during February and the values were 1.21 and 1.17 µg at/L respectively. During September, nitrite-nitrogen was not recorded. Seasonally, the highest was observed during the premonsoon period.

Ammonia:- The monthwise variation of ammonia–nitrogen was from 1.69 µg at/L during February to 19.44 µg at/L during July. The lowest value was recorded during premonsoon and the highest during monsoon and the average value observed for the station was 9.81 µg at/L.

BOD:- The Biochemical Oxygen Demand at this station ranged from 0.69 mg/L during August to 3.50 mg/L during February. When compared to premonsoon and postmonsoon, the values were lower during monsoon season.

H_2S:- Hydrogen Sulphide was recorded only during September, amounted to 0.05mg/L.

Chlorophyll a:- The monthwise variation was from 0.26mg/m^3 during December to 1.47 mg/m^3 during September. The average for the station was 0.64 mg/m^3. Seasonally, the lowest was noticed during postmonsoon season and the highest during monsoon .

Total Suspended Solids:- The TSS were minimum during August and maximum during May and the values were 23 and 137.1 mg/L respectively. Seasonwise distribution of TSS showed the lowest during postmonsoon and the highest during premonsoon season. The average for the station was 56.31 mg/L

A significant positive correlation was noticed between rainfall and the numerical abundance of family Brachionidae.

At this station, the amount of rainfall was positively correlated to the numerical abundance of *B.angularis, B.urceolaris, B.falcatus* and *B.quadridentatus* and their correlation coefficients were significant at 5% levels. *B.rotundiformis* showed significant positive correlation with H_2S. Highly significant correlation was also noticed between *B.angularis* and phosphate level.

STATION 7

Temperature:- Temperature ranged from 27.75°C in December to 32.13°C during April. Seasonally, the highest was recorded during premonsoon period when compared to monsoon and postmonsoon and an average value of 29.21°C was recorded at this station.

pH:- The pH varied between 7.10 and 7.43 and not much variation was noticed between months.

Dissolved Oxygen:- The dissolved oxygen was nil during January, March and November at this station. The maximum of 2.08 ml/L was recorded during April. Seasonwise, the minimum was recorded during premonsoon and the maximum during the monsoon season. The average value of dissolved oxygen at this station was as low as 0.74ml/L. In most of the months, the dissolved oxygen content was very low at this station when compared to other stations.

Salinity:- An average of 11.44 ppt was recorded at this station. The lowest salinity was observed during June and the highest during January. The monthwise variation was between 0.75 and 25 ppt; and seasonally, the salinity came down to 3.13ppt during monsoon season.

Alkalinity:- At this station, alkalinity varied from 47.27 mg/L during June to 133.83 mg/L during November. Throughout the study period, a fluctuating trend was observed between months. Seasonally, the lowest value of 75.47 mg/L was recorded during monsoon and the highest of 111.31 mg/L as $CaCO_3$ was observed during the postmonsoon season.

Phosphate-Phosphorus:- The phosphate was minimum in April and maximum in May. The range was between 1.59 and 15.62µg at/L. Seasonally, when compared to monsoon and postmonsoon, lower values were recorded during premonsoon season. The average for the station was 9.04 µg at/L.

Nitrite:- The highest value of 13.77 µg at/L was recorded during May, the lowest in April, which was as low as 0.01 µg at/L. Seasonwise values showed the minimum during postmonsoon and maximum during premonsoon season with an average of 1.49 µg at/L at this station. The nitrite content was very high during May at this station.

Ammonia:- The ammonia content was high at this station with a minimum of 13.37µg at/L during April and a maximum of 222.16 µg at/L during August. Seasonally, the lowest was recorded during premonsoon and the highest during monsoon. Compared to other stations ammonia levels were much higher at this station.

BOD:- The Biochemical Oxygen Demand was high at this station with a maximum of 30.30 mg/L during November and a minimum of 3.80 mg/L during April. A fluctuating trend was noticed between months throughout the study period. Higher values were noticed during postmonsoon when compared to monsoon and premonsoon seasons. Compared to other stations, BOD was much higher at this station

H_2S:- Hydrogen sulphide was not noticed during April, May and June and a maximum of 2.1 mg/L was recorded during January. During monsoon season, the value was low, increased during premonsoon and the maximum was during the postmonsoon season. Only at this station, Hydrogen sulphide was noticed in majority of months.

Chlorophyll a:- The chlorophyll a concentration varied from 0.29 mg/m^3 in November to 3.07 mg/m^3 during April. Seasonwise, the lowest was recorded during postmonsoon and the highest during premonsoon season.

TSS:- The monthwise variation showed the maximum of 76.5mg/L during June. From June, the values decreased upto August and the lowest value of 21 mg/L was recorded during August. Seasonally, the lowest was observed in postmonsoon season and the highest during the premonsoon period.

The distribution of rotifers were found to be positively correlated with dissolved oxygen and rainfall, significant at 5% level and showed negative relations with alkalinity and H_2S and their levels of significance were 1% and 5% respectively at this station. The family Brachionidae showed significant positive correlations with temperature, highly significant correlation with chlorophyll a and significant negative correlations with phosphate and ammonia. The distribution of the genus *Brachionus* was also positively correlated to temperature(5% level), and chlorophyll a(1% level) and negatively correlated to ammonia significant at 5% level.

At station VII, *B.plicatilis* showed significant positive correlation with temperature and chlorophyll a, and it showed significant negative correlation with ammonia. The distribution of *B.rotundiformis* was positively correlated with temperature and chlorophyll a, the correlation of which was significant at 1% level and it exhibited negative correlation with ammonia at 5% level of significance. *B.angularis* showed significant positive correlation with ammonia and *B.forficula* showed significant negative correlation with pH. The interrelations of *B.bidentata* with rainfall was positive and with alkalinity it was negatively correlated and both the correlations were significant at 5% level.

STATION 8

Temperature:- Temperature at this station varied from 27.38°C during December to 32.13°C during April. Seasonally, higher values were observed during premonsoon season and lower values during monsoon and postmonsoon periods.

pH:- The monthwise variation in pH was negligible. An average value of 7.41 was noticed at this station.

Dissolved Oxygen:- Seasonwise variation was negligible. But, the values fluctuated very much between months. The variation was from 1.01 ml/L in March to 3.26ml/L during April and the average for the station was 1.95 ml/L.

Salinity:- The maximum of 21.5 ppt was observed during January and a minimum of 1 ppt during June. Salinity was very low during monsoon, and, almost the same during premonsoon and postmonsoon seasons. The average salinity recorded at this station was 10.48 ppt.

Alkalinity:- The alkalinity was high at this station with an average of 95.16 mg/L as $CaCO_3$. The monthwise variation was from 53.85 mg/L in November to 171.32 mg/L during May. Seasonally, the lowest was recorded during postmonsoon season and the highest during monsoon period.

Phosphate-Phosphorus:- The phosphate content was very high and a maximum of 46.14 µg at/L was noticed during May at this station. It showed a sharp increase from 1.75 µg at/L in April, which was the minimum value recorded during the study period at this station. Among the seasons, phosphate was low during the postmonsoon season. Compared to other stations, phosphate content was very high at this station during May, June and July with a peak in May.

Nitrite:- Nitrite also showed a sharp increase in May upto 13.34 µg at/L which was the maximum recorded at this station and the minimum was in April amounted to 0.05 µg at/L. A secondary peak of 3.9 µg at/L was observed during September. Low value was recorded during postmonsoon season when compared to monsoon and premonsoon periods.

Ammonia:- Ammonia-nitrogen was high at this station with an average value of 79.72 µg at/L. The minimum was recorded during April and maximum in May. The values were 8.82 and 183.51 µg at/L during April and May respectively. Seasonally, the lowest was observed during postmonsoon season and the highest during monsoon.

BOD:- The variation was from 3.20mg/L in January to 13.31 mg/L during June. BOD was low during postmonsoon, increased during premonsoon and the highest was noticed during the monsoon period.

H_2S:- H_2S was recorded at this station during the months of February, September, November and December. The maximum value of 0.05mg/L was observed during February, September and November and the average for the station was 0.01mg/L.

Chlorophyll a:- The chlorophyll a concentration at this station ranged from 0.52 mg/m^3 during June to 3.89 mg/m^3 during April. Seasonally, the highest value was observed during the premonsoon season.

Total Suspended Solids:- Two major peaks were noticed, the primary one was in May and the secondary one was during October. The variation between months were from 15mg/L during September to 58.5 mg/L during May. Seasonally, the total suspended solids showed maximum during the premonsoon season.

The relationships of the numerical abundance of Rotifers, family Brachionidae and genus *Brachionus* with concentrations of nitrite and phosphate were highly significant, and with TSS and alkalinity the relations were significant.

The numerical abundance of *B.plicatilis* and *B.rotundiformis* at this station showed similar relationships with physico-chemical parameters prevailed at this station. They showed significant correlations with alkalinity and TSS and highly significant correlation with phosphate and nitrite. The rainfall influenced the distribution of *B.angularis,* the correlation of which was significant at 5% level. The correlation coefficients of *B.rubens* with temperature, dissolved oxygen and chlorophyll a were significant at 5% level.

STATION 9

Temperature:- Temperature at this station varied from 27.5°C during December to 31.13°C during April. Seasonally, the highest temperature recorded was during the premonsoon season.

pH:- pH didnot show much variation between months, the range was between 7.05 and 7.4.

Dissolved Oxygen:- The dissolved oxygen at this station varied from 2.76 ml/L in June to 3.95 ml/L during January. Seasonwise variation was negligible. The average dissolved oxygen content at this station was 3.39ml/L.

Salinity:- Salinity was low at this station, a maximum of 6 ppt was recorded during January. The minimum were observed during June, July and October equal to 0.25 ppt. Seasonally, the monsoon season showed the lower values, and, the values during premonsoon and postmonsoon were almost the same. The average salinity at this station was as low as 2.25 ppt.

Alkalinity:- Alkalinity at this station ranged from 14.04 mg/L in June to 25.26 mg/L during January. During monsoon season it was the lowest, and, the highest was recorded during postmonsoon season.

Phosphate-Phosphorus:- Phosphate concentration was low at this station with an average of 0.41 µg at/L.

Nitrite:- The nitrite concentration at this station ranged from 0.01 to 0.6 µg at/L. Seasonwise data showed lower values during monsoon season, when compared to premonsoon and postmonsoon periods.

Ammonia:- Ammonia concentration was low at this station and it was absent during March. A maximum of 7.02 µg at/L was noticed during May. Seasonally, slightly lower value was observed during monsoon when compared to premonsoon and postmonsoon seasons.

BOD:- The Biochemical Oxygen Demand at this station varied from 0.30 mg/L during September to 3.18 mg/L during March. When compared to monsoon and postmonsoon, the values were slightly higher during the premonsoon season.

H_2S:- Hydrogen sulphide was not recorded from this station during the study period.

Chlorophyll a:- A minimum of 0.32 mg/m^3 in August and a maximum of 1.97 mg/m^3 in March were observed. Seasonwise data showed a marginal increase during the premonsoon season. The average value of chlorophyll a recorded at this station was 0.67 mg/m^3.

Total Suspended Solids:- TSS at this station ranged from 3.6 mg/L in July to 10.8mg/L during December. TSS was low during monsoon season when compared to premonsoon and postmonsoon seasons. The average value recorded at this station was 6.73mg/L.

The correlation of nitrite with Rotifers was highly significant and with family Brachionidae and genus *Brachionus* the correlations were significant.

At station IX, the distribution of *B.plicatilis* was positively correlated to salinity and *B.rotundiformis* showed correlation with nitrite, and both the correlations were significant at 5% level. The correlations of *B.forficula* and *B.patulus* with environmental parameters at this station were the same, but levels of significance of correlation varied. Both the species showed significant negative correlation with dissolved oxygen. *B.forficula* exhibited positive correlation with phosphate(significant at 1% level) and rainfall(significant at 5% level) while *B.patulus* showed positive correlation with phosphate and rainfall at 5% and 1% levels of significance respectively.

2.Overall Correlation in the study area

The data collected from nine stations were pooled up and correlation coefficients between rotifers and environmental parameters were calculated to study the ecological implications in the study area. The numerical abundance of Rotifers, family Brachionidae and genus *Brachionus* are given in Table 13, the pooled up data on the different environmental characteristics in the study area are given in Table 14 and the calculated correlation coefficients between these are given in Table 15.

The significant correlations of the genus *Brachionus,* family Brachionidae and Rotifers with environmental parameters in the study area were similar. They showed highly significant correlations with nitrite, chlorophyll a and TSS, while they exhibited significant correlations with phosphate and BOD.

Table 13. Monthwise distribution(Nos./m^3) of Rotifers, family Brachionidae and genus *Brachionus* in the study area irrespective of stations

Months	Rotifers	Family Brachionidae	Genus *Brachionus*
Feb	105650.39	97365.17	97320.72
Mar	205724.61	199503.89	199215.00
Apr	336766.67	331182.22	331182.22
May	894056.67	884412.22	881952.22
Jun	303282.11	250060.00	249144.44
Jul	278671.11	234157.78	233933.33
Aug	143847.22	131977.78	130970.00
Sep	231899.06	220255.11	219782.89
Oct	146314.44	136923.33	135800.56
Nov	200385.17	183325.17	182474.06
Dec	89975.56	86261.50	86261.50
Jan	175613.89	169543.33	169521.11

Table 14. Monthwise distribution of environmental characteristics in the study area irrespective of stations

Months	Water temp. °C	pH	D.O. ml/L	Salinity ppt	Alkalinity mg/L as $CaCO_3$	PO_4-P µg at/L	NO_2-N µg at/L	NH_3-N µg at/L	BOD mg/L	H_2S mg/L	Chlorophyll a mg/m^3	TSS mg/L	Rainfall mm.
Feb	30.71	7.21	2.13	19.50	71.07	2.73	0.38	20.64	4.86	0.23	1.88	39.97	25.00
Mar	31.43	7.32	2.28	18.78	68.77	3.15	0.15	20.94	4.40	0.08	2.70	44.42	5.50
Apr	32.11	7.16	2.99	17.14	63.35	1.32	0.05	6.46	3.09	0.00	3.25	40.30	142.50
May	30.60	7.20	3.06	9.11	73.90	8.72	3.36	49.23	7.94	0.00	4.54	62.77	436.00
Jun	29.04	7.17	2.74	2.75	52.84	5.30	0.83	35.50	3.96	0.00	2.86	40.84	702.50
Jul	28.68	7.36	2.81	3.22	62.06	6.65	0.37	40.88	5.85	0.01	2.61	30.51	452.50
Aug	28.31	7.30	2.90	2.97	62.10	5.62	0.39	49.16	2.78	0.00	2.43	19.75	382.50
Sep	29.73	7.28	3.09	8.00	48.84	3.32	0.56	27.91	5.48	0.10	4.01	27.81	208.50
Oct	29.07	7.31	2.42	4.22	65.72	5.28	0.35	35.42	5.16	0.00	2.10	25.77	344.50
Nov	29.22	7.24	2.14	11.00	65.34	3.67	0.50	29.47	5.19	0.17	0.97	24.56	139.00
Dec	28.21	7.05	2.84	18.56	70.93	1.42	0.30	15.47	3.92	0.09	0.99	32.80	10.00
Jan	28.58	7.16	2.62	21.72	75.91	1.50	0.31	15.12	4.37	0.23	1.25	44.50	23.50

Table 15. Correlation coefficients of total Rotifers, Family Brachionidae and Genus *Brachionus* with certain physico-chemical characteristics in the study area irrespective of stations

	Total rotifers	Family Brachionidae	Genus *Brachionus*
Temperature	0.353	0.378	0.379
pH	-0.033	-0.050	-0.051
Dissolved Oxygen	0.462	0.457	0.457
Salinity	-0.195	-0.147	-0.146
Alkalinity	0.135	0.176	0.176
Phosphate	0.644*	0.612*	0.611*
Nitrite	0.919**	0.919**	0.919**
Ammonia	0.426	0.396	0.395
BOD	0.682*	0.679*	0.679*
H_2S	-0.412	-0.387	-0.387
Chlorophyll a	0.725**	0.718**	0.718**
TSS	0.727**	0.736**	0.737**
Rainfall	0.423	0.366	0.365

* Significant at 5% level
**Significant at 1% level

DISCUSSION

The results indicated the availability of 20 genera of rotifers distributed along the nine different habitats along Cochin backwater system. These 20 genera belonged to 13 families, whereas Sharma(1991) in an extensive work on rotifers has recorded 60 genera belonging to 24 families from India. As early as in 1971, Nair & Nayar reported 18 species of rotifers from freshwater habitats in Irijalakuda, Kerala. Later, Gopakumar(1998) reported 30 species of rotifers under 16 genera, belonging to 13 families from three brackishwater habitats of southern part of Kerala with varying salinity regimes. In a similar study, Anitha(2003) recorded 44 species of rotifers belonging to 16 genera under 12 families from two estuaries located in southern part of Kerala. The maximum numbers of genera recorded from brackishwater habitats of Kerala so far recorded was during the present study. Out of the 20 genera, a minimum of 13 and a maximum of 19 numbers of genera were distributed in varying numbers in different stations, in the present study.

The quantitative abundance of rotifers, family Brachionidae and genus *Brachionus* varied between stations significantly, except that of stations II and III. It is worthwhile to mention that maximum average density of 1255465 numbers per m^3 was noticed from Station II, which is a typical nursery area for finfishes and shellfishes. Station III stood second in rotifer abundance with an average density of 835604 numbers per m^3. The higher density of rotifers in these two ecosystems is associated with highly productive waters , which support fish and shrimp culture in these areas. Again, the minimum population density of just 3354 numbers per m^3 was noticed in station VI, which is a fisheries harbour site where several boats are being operated, everyday by fishermen, resulting in some extent of oil pollution, and, also repair work of boat/ship are carried out, including chipping of the hull. A small canal with polluted water having high content of organic matter also joins the area adjascent to station VI, which can also influence the rotifer fauna adversely. Unni & Fole(1997) observed a maximum rotifer count of 1489000 numbers per m^3 in summer, from Kanhargaov Reservoir, Madhya Pradesh, which they suggested as the maximum count ever reported from Indian reservoirs. But, during the present study, a maximum of 2107609 numbers per m^3 was recorded during the summer season at station II, which is even higher than the highest density reported by Unni & Fole(1997). This shows the tremendous capacity of this organism to exist in very high densities in a particular biotope, that too in a tropical brackishwater habitat.

The variability in the distribution of rotifers in different stations can also be explained in terms of diversity indices. In the present study, the indices of richness, evenness and diversity are found to follow a similar pattern, eventhough the magnitude is different. While studying the diversity of rotifer communities in lakes of southern Chile, Schmid-Araya(1993) also observed that diversity was significantly related to richness and evenness in all the stations studied. In the present study, although the changing trend in different seasons are same, the values differed considerably from station to station. The results of ANOVA also indicated that all the four indices (Richness, Evenness, Shannon and Simpson) show significant variations between stations. Thus the assemblages of rotifers in different stations are not identical. The maximum species richness of rotifers was noticed at station IX, where 19 genera of rotifers were recorded out of 20 reported from the study area. The evenness of distribution was maximum at station VI, where the abundance was minimum. Since, the diversity is a function of both richness and evenness combined together, maximum diversity index was noticed at station V. Eventhough station V is influenced by the industrial pollutants from factories, the higher dissolved oxygen content and perhaps the weeds floating in a portion of the collection site might have been the reason for higher rotifer diversity at this station. The associations of other zooplankton group like amphipods with floating weeds is well known. This may be true in the case of rotifers also. It is worthwhile to mention here that Duggan *et al.*(1998) found high diversity of rotifers with respect to macrophyte distribution - with emergent and submerged vegetation.

Among the 13 families reported in the present account, the family Brachionidae formed the major portion and constituted 94% of total rotifers in the study area with a range of 25.83 – 98.61 % in different stations. The dominance of this family was observed in 7 out of 9 stations studied. Gopakumar(1998) and Anitha(2003) also noticed maximum number of species under the family Brachionidae among the total number of rotifer species; from the brackishwater habitats of southern coast of Kerala. This shows that the family Brachionidae is highly resistant and has been well adapted to live in varying ecological biotopes.

According to Koste(1978) the family Brachionidae is composed of seven genera, namely, *Brachionus, Keratella, Platyias, Anuraeopsis, Notholca, Kellicottia* and *Paranuraeopsis*. Sharma and Michael(1980) opined that the first five out of the seven mentioned by Koste(1978), are represented in India. It is worthwhile to mention that the first four genera out of the five, are reported during the present study, which was carried out from such a small area, showing the high magnitude of their distribution. The fifth genus, *Notholca* is not observed during the present work as this is noticed mainly from cold water regions such as Kashmir, Yamuna river etc.(Edmondaon & Hutchinson, 1934; Qadri & Yousuf,1982; Balkhi *et al.*, 1984; Sarma, 1988). Also, Green(1972) and Chengalath *et al.*(1974) pointed out the absence of the genus Notholca as characteristic of many tropical waters.

The genus *Brachionus* dominated in eight out of the nine stations in relation to rotifers and it formed the major portion of the family Brachionidae in all the nine stations studied in the present account. An overall dominance of *Brachionus* by 94% out of rotifers and 99.75% out of the family Brachionidae in the study area are recorded. This is in agreement with the findings of Green(1972), Chengalath *et al.*(1974), Pejler(1977), Fernando(1980), Sharma & Michael(1980) and Sharma(1983), who also noticed the abundance of *Brachionus* spp. in tropical regions. Sharma(1987) pointed out that various species of the genus *Brachionus* dominate plankton samples in warmer parts of peninsular India. He again emphasized that a majority of the reported Indian species of *Brachionus* are cosmopolitan and show a wide distribution. In the present study also, the genus *Brachionus* were observed from all the nine stations studied in varying concentrations. Apart from the genus *Brachionus*, other 7 genera – *Anuraeopsis, Lecane, Monostyla, Trichocerca, Polyarthra, Encentrum* and *Testudinella* were also recorded from all the nine stations studied; but, out of total rotifers, these contributed only 0.05%, 0.17%, 0.27%, 0.24%, 0.21%, 0.93% and 0.92% respectively. In *Brachionus*, the population density is widely attributed as a stimulus for mictic female production(Gilbert, 1977 ; Pourriot and Snell, 1983 ; Snell and Boyer, 1988 ; Carmona *et al.*, 1994), which is proved true in the present investigation also. Several resting eggs of *Brachionus* were noticed in the samples collected from stations II and III in the course of this study and this also coincides with the maximum density of rotifers especially *Brachionus* in these two sites. However, the actual counts of these cysts were not taken during the study period.

According to Sharma(1983), *B.angularis, B.calyciflorus, B.quadridentatus* and *B.caudatus* are widely distributed in India and this is proved true in the present study also. Among the 13 species of *Brachionus* recorded, *B.plicatilis* and *B.rotundiformis* were recorded in all the nine stations. As far as the distribution pattern of *Brachionus* species is concerned, the number of species ranged between 5 and 9 in different stations. It is worthwhile to mention here that, in all the stations, *B.rotundiformis* dominated and contributed 85.76% among the 13 species of *Brachionus* in the study area with a range of 45-96 % in different stations. Next in abundance was *B.angularis* followed by *B.plicatilis, B.rubens, B.urceolaris* and *B.forficula,* contributing 9.6% and 3.68%, 0.39%, 0.27% and 0.23% respectively. Other species contributed only less than 0.05%.

The present study is more concentrated on the genus *Brachionus,* and, 13 species are observed under this genus from the study area. According to Sharma(1987) this genus includes about 46 species globally. Very recently Segers(2002) pointed out the availability of 55 species of *Brachionus;* from India, Sharma(1983) reported 20 species , which he commented as the highest number from south east Asia. It is interesting to note that, out of 20, as many as 13 species are recorded from such a small region of India, in the present account. Anitha(2003) reported 14 species of *Brachionus* from southern part of Kerala while Gopakumar(1998) documented 12 species. According to Pennak(1957) and Jyoti and Sehgal(1979), not more than two species of a rotifer genus will be recorded simultaneously, per sample from a water body. Later, George(1961) recorded simultaneous appearance of 3 species of *Brachionus* from the ponds in Delhi. In this context, it is worthwhile to note the presence of 5 species of *Brachionus* simultaneously from stations 1, 2, 3 & 5 during the present study.

The seasonal abundance of rotifers in the present work showed maximum during the premonsoon season, in majority of the stations. A very similar observation has been noticed by Ramesh and Jayapaul(1987) while studying the rotifer biomass in Adayar estuarine area. They recorded a peak in rotifers between March and June. Also, Unni and Fole(1997) observed a peak of rotifers in summer season, while studying the distribution and diversity of rotifers in Kanhargaov Reservoir, Madhya Pradesh. In the present study, when data from all the nine stations are pooled together, maximum rotifer abundance recorded was during the premonsoon season and the least during the postmonsoon season. A similar trend was observed by Gopakumar(1998) from Kadinamkulam lake located in southern part of Kerala. Also, a leading worker in rotifer research, Sharma(1983, 1987) also stated that, in tropical regions, *Brachionus* spp. dominate in total rotifers and the *Brachionus* spp. shows abundance in warmer parts of peninsular India. This statement is in agreement with the present study also, wherein *Brachionus* spp. form 94% of total rotifers and *Brachionus* spp. dominated in 89% of the area studied. Thus, the higher temperature and associated environmental characteristics in the study area might have favoured the abundance of rotifers during the premonsoon season.

It is interesting to note that 9 species of *Brachionus* viz. *B.angularis, B.bidentata, B.calyciflorus, B.caudatus, B.forficula, B.falcatus, B.patulus, B.quadridentatus* and *B.rubens*, which are recorded during the present study conducted in a typical brackishwater area in Cochin backwater system are also available from freshwater tanks/ponds in and around Sambalpur, Orissa in Eastern India(Sharma,1980). This indicates high salinity tolerance of these species as well as their wide distribution. It is also noteworthy to mention that the numerical abundance of eight species of *Brachionus*, viz. *B.plicatilis, B.rotundiformis, B.angularis, B.urceolaris, B.rubens, B.forficula, B.quadridentatus* and *B.patulus* varied between different stations studied, which in turn indicates the variability of all the nine stations selected for the present study.

Similar to the distribution of rotifers, the maximum abundance of zooplankton in terms of quantity was also noticed at station II. Among the 17 groups of organisms in the zooplankton observed during the present study, rotifers and copepods dominated. The share of rotifers in total zooplankton varied from 6.65% to 66.5% in different stations. An interesting observation recorded by Alois Herzig(1987) in his work on the analysis of planktonic rotifer populations seems to be pertinent here. He reported that in freshwater zooplankton, in terms of biomass, rotifers can account for 10 – 44% of total zooplankton production, which is almost similar to the present observation. Unni(1993) observed that rotifers form the most dominant group among zooplankton in the reservoirs of Madhya Pradesh, in central India. It is very interesting to note that this is true in the brackishwater habitats selected for the present study; in the central part of Kerala, rotifers contributed maximum(52%) of the total zooplankton production. Eventhough, the present study did not analyse the interactions of other zooplankton members with rotifers, one major observation was that copepods and rotifers dominated in the zooplankton samples in all the nine stations studied. From the various observations, Alois Herzig(1987) observed that *Polyarthra, Pompholyx, Brachionus, Asplanchna, Synchaeta, Filinia* and *Keratella quadrata* are a substantial component of the diet of cyclopoid copepods. This observation points out that a good copepod population thrive well, if only a rich population of rotifers exist. Copepods being an important food item of fish larvae, this finding points out that the areas of rotifer abundance are productive areas for rich fishery wealth.

The environmental parameters influence the distribution and abundance of rotifer community of a particular aquatic ecosystem. In the present study, the different stations were so selected that, they are ecologically different and with varied environmental parameters.

The magnitude of salinity tolerance differs in different species of *Brachionus*. Among the 13 species of *Brachionus* recorded during the present study, *Brachionus rotundiformis and B.plicatilis* were observed from all the nine stations with varying salinity regimes which indicate the euryhaline nature of these two species. Sharma(1991) reported *B.plicatilis* as euryhaline. In a similar study conducted in the Mediterranean wetlands of Spain, Miracle *et al.*(1987) observed *B.plicatilis* from a salinity range of 0.5-88 ppt. It is worthwhile to note the observation of Carmona *et al.*(1995) that *B.rotundiformis* was reported from a salinity range of 5-64 ppt.

Sarma(1991) noticed that majority of *Brachionus* spp. inhabit freshwater bodies, but *B.plicatilis* is euryhaline. In the present study, other than *B.rotundiformis* and *B.plicatilis*, all the 11 species of *Brachionus* are not recorded from all the stations, which indicate their restricted distribution, probably in relation to salinity. These species found to prefer lower salinities. It is worthwhile to point out here that; of the nine stations studied, the lowest salinity was noticed at station V, where salinity never exceeded 4 ppt and the maximum numbers of *Brachionus* species(9 species) were recorded from this station which indicate the preference of *Brachionus* species to lower salinities. And, the numbers of species of *Brachionus* recorded showed gradual increase, from station I to station V. This number was the maximum at station 5. The first station is located at the mouth of the estuary and other stations are situated subsequently upstream. Of the stations studied, station V and station IX are low saline areas where salinity never exceeds 4 ppt and 6 ppt respectively. Out of the 20 genera of rotifers recorded from the study area, a maximum of 19 genera were observed from station IX, followed by 18 genera at station V. In other stations, the numbers of genera observed were less. This observation indicate that, not only *Brachionus* species, but also rotifers in general prefer lower salinities. Ruttner Kolisko(1974) also stated that, rotifers are at home in freshwater and she also pointed out that, some genera which inhabit not only in freshwater, but also in inland seas of low salinity, are derived from fresh-water ancestors. Shiel(1979), while studying rotifers of the River Murray in south Australia, also observed that no single factor can be described as limiting, but increasing salinity had the most marked influence on the rotifer plankton, when a decrease in species diversity was recorded. From Kerala also, Nair *et al.*(1984), Nair and Aziz(1987) and Gopakumar(1998) too emphasized a similar role of salinity in the distribution and occurrence of rotifers which was true for the present study also.

In the study area, irrespective of stations, rotifers showed highly significant positive correlation with chlorophyll a. The chlorophyll a concentration is a direct measure of primary productivity of a water body. Of all the stations studied, chlorophyll a concentration was the highest at station II, followed by station III in almost all the months studied. This indicates the highly productive nature in terms of primary productivity in these two stations, when compared to other stations. It was interesting to note that the rotifer density also was maximum at station II followed by station III, among all the stations studied. In general, station II(Puthuvypu) is considered as a good nursery ground for finfishes and shell fishes which can be due to the high primary productivity as well as secondary productivity which is evidenced by the high chlorophyll content and high rotifer density. Station III(Narakkal) is a well known site wherein traditional aquaculture methods are being practiced. The collection spot gets a good inflow of water coming from culture ponds of varying types and sizes. This can be the reason for high chlorophyll a and, subsequently high rotifer density, at this station. A positive correlation between the population density of rotifers and chlorophyll a was also reported by van Dijk and van Zanten (1995) in the river Rhine. In river Thames(England), May and Bass(1998) also reported that in general, an increase in rotifer abundance seemed to parallel a similar increase in chlorophyll a concentration in the river water.

During the present study period, the numerical abundance of rotifers, family Brachionidae and genus *Brachionus* were the maximum in the premonsoon season, in the study area. Similarly, temperature also showed the highest values during the premonsoon season, ranging between 30-32°C which clearly indicates a positive relationship between temperature and rotifers in the study area. Modenutti(1998) reported that most of the *Brachionus* species were found in spring and summer, at water temperatures ranging from 20 to 28°C in Samborombon river basin, Argentina. Ruttner-Kolisko(1974) too opines that these species are thermophilic. Herzig(1987) suggested that temperature is an important factor in restricting the occurrence of rotifers in temperate waters. While studying the rotifers in Kanhargaov Reservoir, Unni and Fole(1997) stated that high water temperature favoured development of rotifers in summer. A very similar observation was also reported by Sinha(1992).

In the study area, significant positive correlations were observed between Biochemical Oxygen Demand(BOD) and rotifers. Stationwise analysis indicate significant positive correlations between rotifers and BOD at stations II, III, IV and V. Compared to all the other stations, BOD values were higher at station VII(3.8–30.3 mg/L), in almost all the months, during the study period. Station VII is located nearer to the Ernakulam market, and all the wastes and decayed materials are discharged into this canal, resulting in organic pollution at this station. It is interesting to note a negative correlation between rotifers and BOD at this station. Probably, high BOD resulting from high organic pollution may not be favourable for the growth and multiplication of rotifers. The above observations point out that eventhough BOD is positively correlated to the abundance of rotifers, very high values of BOD are not favourable for rotifer production.

It is worthwhile to mention here that *B.rotundiformis* dominated over other species of *Brachionus* in all the stations studied and this species showed significant correlation with BOD at stations II, III and IV. Pandit and Kaul(1981) also designated

Brachionus sp. as an indicator of eutrophic pollution in the wetlands of Kashmir. A close correlation between BOD and *B.plicatilis* has been observed by Rao and Chandra Mohan(1976b) in Visakhapatnam backwaters and they consider *B.plicatilis* as an indicator of pollution. It is worthwhile to mention here that the species, *B.rotundiformis* was considered as *B.plicatilis* in 1976, when Rao and Mohan studied, and only during 1990's *B.rotundiformis* is taxonomically accepted as a separate species. Thus, what the authors described as *B.plicatilis* in 1976 can really be *B.rotundiformis*.

The abundance of rotifers showed highly significant positive correlations with total suspended solids(TSS) in the study area. Stationwise analysis showed significant positive correlations between rotifers and TSS at stations II and VIII, of which the correlations were highly significant at station II. The TSS at station II varied between 35 and 80.7 mg/l, while at station VIII, range of TSS was from 15 to 58.5 mg/l. Konnur and Azariah(1987) in their work on the distribution of rotifer biomass in the estuarine region of Adyar river also found a correlation between the biomass of rotifer and the total suspended particulate matter. But, they observed that very high and very low suspended particulate matter cause a reduction in the biomass of rotifers. In other words, when the particulate matter amounted less than 200 mg/l and above 450 mg/l, a suppression of rotifer population, was noticed by the authors. The range of TSS in the present study is not in agreement with the ranges observed by Konnur and Azariah(1987) in Adyar river. In an another study, Holland *et al.*(1983) stated that variations in suspended solids, often significantly associated with variations in rotifer numbers in Atchafalaya river basin, Louisiana; which is in agreement with the present study.

Phosphate content showed significant positive relationship with the abundance of rotifers in the present study area. Compared to other stations, phosphate concentration was higher at station VIII, with a peak in May. Station VIII(Mangalavanam) is located in a mangrove forest with a bird sanctuary, the decayed mangrove leaves and guano add a lot of nutrients, especially phosphate to this site. It is interesting to note a highly significant positive correlation between the abundance of rotifers and phosphate content at this station. This is in agreement with Kobayashi *et al.*(1998) who noticed a positive correlation between total phosphorus and zooplankton density in Hawkesbury Nepean river in Australia where, 64% of total zooplankton taxa was composed of rotifers. In the present study, the share of rotifers in total zooplankton was also upto 66.5%.

The nitrite concentration showed highly significant positive correlation with rotifers in the study area. Stationwise analysis showed significant correlation between rotifers and nitrite at stations VIII, IX and IV. Compared to other stations, nitrite showed higher values at stations VII and VIII. At station VIII, the high nitrite content may be due to the decayed mangrove vegetation and the guano present. Station VII is situated near the Ernakulam market and all the wastes and decayed matter are discharged into this canal which may cause the increased nitrite content at this station. In spite of the higher values of nitrite at stations VII and VIII, significant positive correlation with rotifer abundance was observed only at station VIII and not so at station VII. This can be due to some negative impacts of other factors like high H_2S, low dissolved oxygen content and very high BOD levels on the abundance of rotifers at station VII.

Nandan and Azis(1994) mentioned that *Brachionus* sp. along with *Acartia tropica,* copepod nauplii, *Chironomus calligaster* and *Pentaneura* sp. were indicators of sulphide pollution in retting zones of the Kadinamkulam estuary, Kerala. However, in the present study area, a negative correlation between H_2S and total rotifers was recorded at station 7, where H_2S was significantly high. In some other stations, H_2S was present only in negligible quantities and in others, H_2S was absent. During the study period, *Brachionus* spp. as well as other rotifers were recorded, not only from the stations where H_2S was present, but also from stations where H_2S was not observed.

Station VII is located in a place where lot of organic matter is discharged from the adjoining market. In other words, it is affected by organic pollution, which is characterized by very high BOD, high phosphates and nitrites, high levels of H_2S, ammonia and low dissolved oxygen content. Here, phosphates, nitrites and certain levels of BOD are favourable for rotifer population, but, other parameters like high H_2S, high ammonia and low dissolved oxygen, showed negative impact on rotifer population. So, the distribution of rotifers at this station may be governed by a combination of these positive and negative aspects. Thus, correlation of single parameters in such stations may not give reliable conclusions. Unlike other stations, the genus *Encentrum* dominated over other genera at this station, which indicate high tolerance of this genus to adverse conditions prevailing in this station. The genus *Encentrum* comes under the family Dicranophoridae, and a domination of this family of rotifers, was also noticed at this station.

Station V is affected by industrial pollution and is characterized by very low pH, as low as 5 in certain months, due to the discharges from factories situated in nearby areas. But, due to mixing of water from small rivulets, the dissolved oxygen content is high in this station, which can favour rotifer population. So, here also, favourable as well as unfavourable factors together act on the distribution and abundance of rotifers. At this station alone, family Lecanidae dominated over other families of rotifers, while the family Brachionidae dominated over other families in 7 out of 9 stations. Thus, the different stations are having their own physico-chemical characteristics and act as different ecosystems. The rotifer assemblages as well as the interrelationships or combined interactions of environmental characteristics on the distribution and abundance of rotifers can also be different for different ecosystems.

The foregoing discussions reveal the influence of different environmental characteristics on the distribution and abundance of rotifer populations in varying habitats. It is also interesting to note the absence of correlations of certain parameters with rotifer community, in certain stations. This can be due to the combined interactions of different variables acting on the distribution and abundance of rotifers, rather than the influence of a single variable, on rotifer population. Such a view is also expressed by Gopakumar(1998) and Anitha(2003), while studying the impact of environmental parameters on the distribution of rotifers in brackishwater habitats of southern Kerala.

Thus, different species/genera were found to prefer specific environments. Such information can advantageously be applied not only to select a particular strain/species of rotifer, but also to understand the interactions of various environmental factors on the culture conditions of rotifers. Since rotifers are considered to be an excellent and indispensable live feed organism in aquaculture practices, detailed and long term investigation in this line is necessary to arrive at more reliable conclusions.

CHAPTER 3

REPRODUCTIVE POTENTIAL OF THE SPECIES, *BRACHIONUS ROTUNDIFORMIS* TSCHUGUNOFF IN RELATION TO SALINITY, FEED TYPE AND FEED CONCENTRATION

INTRODUCTION

The reproductive potential is a measure of the inherent ability of an organism to reproduce, which is symbolized by **r**. When the environmental resources are unlimited and favorable, **r** will be maximum and constant for a particular organism. The rate of reproduction along with environmental characteristics such as availability of food, density of population, predation, physico-chemical and biological characteristics of the ecosystem, climate of the region, etc. govern the population structure of a species in the natural habitat. **r** denotes the difference between natality and mortality rates. In effect, **r** summarizes all life table parameters, as it combines survival, fecundity, timing of development and reproduction (Gopakumar,1998).

The above generalization also holds good for rotifers. Any deviation from the maximum reproductive rate of a species is a function of environmental resistance. The environmental stress which acts upon the reproductive potential of a species/strain can be assessed by experimental studies. Several researchers have worked on the influence of physico-chemical factors, feed type and feed concentration on reproduction, growth and culture of rotifers. A review of these works are given below:

As early as in 1957, Ito studied the relations between the growth of *B.plicatilis* and the quantity of phytoplankton. Erman(1962a, 1962b) described the feeding of planktonic Rotifera as well as the quantitative aspects of feeding selectivity of food in the planktonic rotifer, *B.calyciflorus*. Hirayama and Kusano(1972) studied the influence of water temperature on the growth of population of the filter feeding rotifer, as a part of the fundamental studies on physiology of rotifer, for its mass culture. Halbach(1973b) described the life table and population dynamics of the rotifer *Brachionus calyciflorus* Pallas, as influenced by periodically oscillating temperatures. Hirayama and Watanabe(1973) dealt with the nutritional effect of yeast, while Hirayama *et al.*(1973) analyzed the influence of phytoplankton density on population growth of rotifer. The survival and fecundity of *B.calyciflorus* in waters of different salinities were studied by Aranovich and Spektorova (1974). Ruttner-Kolisko(1974) states "nearly all plankton rotifers are herbivores feeding on algae less than 20μ in size; in the food chain they consequently form an important link between the nannoplankton and the carnivorous zooplankton. The fry of many fishes depend at some stage on food of the size of rotifers(c. 200-500μ). In addition to the autotrophic nannoplankton, rotifers undoubtedly consume organic detritus and bacteria."

Hirayama and Nakamura(1976) tried dry *Chlorella* powder as food for rotifers. The genetics of reproduction, variation and adaptation in rotifers were studied by King(1977). Pilarska(1977) dealt with the food selectivity and feeding rate in *B.rubens,* while Scott and Baynes(1978) studied the effect of algal diet and temperature on the biochemical composition of the rotifer, *B.plicatilis*. The food selectivity of *B.plicatilis* feeding on phytoplankton was described by Chotiyaputta and Hirayama(1978). Kabay and Gilbert(1978) analysed the intensity of the body wall outgrowth responses to temperature , food density , pH and osmo-regularity differences in *Asplanchna sieboldi* . The nutritional effect of eight species of marine phytoplankton on population growth of *B.plicatilis* was studied by Hirayama *et al.*(1979). The induction of sexual reproduction and resting egg production in *B.plicatilis* reared in seawater were explained by Lubzens *et al.*(1980). Hino and Hirano(1980) studied the relationship between body size of *B.plicatilis* and the maximum size of particles ingested.

Ito *et al.*(1981) described the morphological characters and studied the suitable temperature for the growth of several strains of *B.plicatilis*. Schluter and Joost(1981) studied the influence of some environmental factors on population growth of *B.rubens*, when the rotifers were mass cultured on liquid wastes. Again, Joost and Schluter(1981) tried mass production of *B.rubens* in the effluent of high-rate algal ponds used for the treatment of piggery waste. Gatesoupe and Luquet(1981) worked out the practical diet for mass culture of *B.plicatilis* to the application of larval rearing of Sea bass *Dicentrarchus labrax*. Fukusho and Okauchi(1982) explained the strain and size of *B.plicatilis* cultured in Southeast Asian countries. Fukusho and Iwamoto(1982) discussed the polymorphism in size of the rotifer, *B.plicatilis* being cultured with various feeds. Lindstroem(1983) studied the changes in growth and size of *Keratella cochlearis* in relation to some environmental factors in cultures. Hirata *et al.*(1983) discussed the continuous culture of the rotifer *B.plicatilis* fed recycled algal diets. The temperature acclimation in an experimental population of *B.calyciflorus* was explained by Galkovskaya(1983). Trotta(1983) described an indoor solution for mass production of the marine rotifer,*B.plicatilis*, fed on the marine micro alga *Tetraselmis sueciea*. Herzig(1983) made comparative studies on the relationship between temperature and duration of embryonic development of rotifers. Hirayama and Funamoto(1983) described the supplementary effect of several nutrients on nutritive deficiency of baker's yeast on population growth of *B.plicatilis*. The food value of *Tetraselmis tetrathele* for the culture of *B.plicatilis* was studied by Okauchi and Fukusho(1984). Yamasaki *et* *al.*(1984) studied the influence of marine *Chlorella* density on food consumption and growth rate of *B.plicatilis*. Rothhaupt(1985) made a model approach to the population dynamics of *B.rubens* in two-stage chemostat culture. Lubzens *et al.*(1985) studied the salinity dependence of sexual and asexual reproduction in *B.plicatilis*. Fukusho *et al.*(1985) analyzed the food value of *B.plicatilis* cultures with *Tetraselmis tetrathele* for the larvae of a flounder *Paralichthys olivaceus*. The production and nutritional quality of *B.plicatilis* in relation to different cell densities of marine *Chlorella* sp. were studied by Rezeq and James(1985) while Yufera and Pascual(1985) described the effects of algal food concentration on feeding and ingestion rates of *B.plicatilis* in mass culture. The influence on size, growth and reproduction of the long term acclimation of a parthenogenetic strain of *B.plicatilis* to subnormal temperatures was analysed by Nagata(1985).

Abdul *et al.*(1986) tried mass production of *B.plicatilis* by using marine yeast in outdoor conditions. The effect of temperature, salinity and food level on sexual and asexual reproduction in *B.plicatilis* were studied by Snell(1986). Yufera(1987) studied the effect of algal diet and temperature on the embryonic development time of the rotifer *B.plicatilis* in culture. Rezeq and James(1987) dealt with the production and nutritional quality of *B.plicatilis* fed by marine *Chlorella* sp. at different cell densities. Starkweather(1987) gave an account on rotifer energetic while Galkovskaya(1987) studied the planktonic rotifers and temperature. The relationship between water chlorinity and bisexual reproduction rate in *B.plicatilis* was described by Hino and Hirano(1988). The influence of salinity on population growth of *B.plicatilis* was discussed by Joshi(1988). James and Rezeq(1988) studied the effect of different cell densities of *Chlorella capsulate* and marine *Chlorella* sp. for feeding *B.plicatilis.* Castellanos Paez *et al.*(1988) described the embryonic development of amictic eggs of *Brachionus plicatilis.* Miracle and Serra(1989) dealt with the salinity and temperature influence in rotifer life-history characteristics. Hirata(1989) dealt with feed types and method of feeding *B.plicatilis* as live feed. Korstad *et al.*(1989a, 1989b) discussed the feeding kinetics of *B.plicatilis* fed with *Isochrysis galbana* as well as the life history characteristics of *B.plicatilis* fed by different algae. Rothhaupt(1990a, 1990b) described the differences in particle size- dependent feeding efficiencies of closely related rotifer species as well as the changes of the functional responses of the rotifers *B.rubens* and *B.calyciflorus* with particle size. Stemberger(1990) studied food limitation, spination, and reproduction in *Brachionus calyciflorus* .

The environmental management for mass culture of the rotifer, *B.plicatilis,* was dealt by Maeda and Hino(1991). Kirk(1991) studied the role of selective feeding as inorganic particles alter competition in grazing plankton. Hur(1991) dealt with the selection of optimum phytoplankton species for rotifer culture during cold and warm seasons and their nutritional value for marine fish larvae. The salinity adaptability of five different strains of the rotifer, *B.plicatilis* was explained by Yamasaki and Hirata(1991). Guisande and Mazuelos(1991) studied the reproductive pattern of *B.calyciflorus* at different food concentrations. Roa(1992) made biological observations in a stock of *B.plicatilis,* isolated from the solar pans of Araya, Venezuela. A model to evaluate the contribution of environmental factors to the production of resting eggs in the rotifer *B.plicatilis* was explained by Lubzens *et al.*(1993). Vadstein *et al.*(1993) studied the particle size dependent feeding by *B.plicatilis.* Galindo *et al.*(1993) analysed the reproductive investment of several rotifer species. Arndt(1993) made a review on rotifers as predators on components of the microbial web- bacteria, ciliates and heterotrophic flagellates. The fecundity patterns of S and L type rotifers of *B.plicatilis* were discussed by Hirayama and Rumengan(1993). Hlawa and Heerkloss(1994) conducted experimental studies in the feeding biology of rotifers in brackish water. Walz(1995) studied the energetics and life history strategies of rotifer populations in plankton communities. Lubzens *et al.*(1995) observed the physiological adaptations in the survival of rotifers, at low temperatures. Vallejo *et al.*(1995) determined the optimal algal density and efficiency of diet in the production of the rotifer *B.plicatilis*. The feeding rate of *B.plicatilis* on two types of food, depending on ambient temperature and salinity, was discussed by Lebedeva and Orienko(1995). The male discrimination of female *B.plicatilis* and *B.rotundiformis* was studied by Rico-Martinez and Snell(1995). Hagiwara *et al.*(1995b) dealt with the morphology, reproduction, genetics and mating behavior of small tropical marine *Brachionus* strains. Carmona *et al.*(1995) described the mictic patterns of the rotifer, *Brachionus plicatilis,* in small ponds. Dahril *et al.*(1995) studied the effect of human excreta on the growth of a freshwater green alga, *Chlorella* sp. and a rotifer, *B.calyciflorus*. Dumont *et al.*(1995) made laboratory studies on the population dynamics of *Anuraeopsis fissa* in relation to food density. The population structure and the effect of pH on growth characteristics of *Brachionus calyciflorus amphiceros* growth on freshwater *Chlorella* sp. was discussed by Hettiarachchi *et al.*(1995). Walz *et al.*(1995) correlates egg size to body size in rotifers which is an indication of reproductive strategy. The population growth dynamics of the rotifer, *B.plicatilis,* cultured in non-limiting food condition was described by Yufera and

Navarro(1995). Wang(1995) studied the effect of temperature and food density on *B.calyciflorus* population dynamics. The feeding behavior of *B.plicatilis* related to temperature and micro algal concentration was studied by Acosta and Perez(1995). The feeding biology of *B.quadridentatus* and *B.plicatilis* were dealt by Heerkloss and Hlawa(1995).

The nutritional effect of three micro algae and one cyano bacteria on the culture of *B.plicatilis* were studied by Ruedajasso(1996). Aparici *et al.*(1996) described a simulation approach using a rotifer growth model. The reproduction rates, in relation to food concentration and temperature, in three species of the genus *Brachionus,* was discussed by Pourriot and Rougier(1997). Wang and Li(1997) made comparative studies on principal parameters of population growth of five freshwater rotifers. Yufera *et al.*(1997) discussed the energy content of rotifers, *B.plicatilis* and *B.rotundiformis,* in relation to temperature. The particle grazing efficiency and specific growth efficiency of *B.plicatilis* were described by Hansen *et al.*(1997). Oltra and Todoli(1997) discussed the effects of temperature, salinity and food level, on the life history traits of the marine rotifer *Synchaeta Cecilia,* while Kirk(1997) studied the starvation and reproduction in planktonic rotifers. Maruyama *et al.*(1997) explained the application of unicellular alga, *Chlorella vulgaris,* for the mass culture of marine rotifer *Brachionus.* The effect of temperature and food concentration in two species of littoral rotifers were dealt by Ignacio and Martinez(1998). Green(1998) discussed the strategic variation of egg size in *Keratella cochlearis*. Conde-Porcuna(1998) conducted a life table experiment to find out the chemical interference by *Daphnia* on *Keratella.* Ronneberger(1998) examined the uptake of latex beads as size-model for food of planktonic rotifers. The effect of algae on the reproduction of *B.calyciflorus* was observed by Jiakin and Xiangfei(1998). The influence of dilution rate on the population dynamics of rotifers, *B.plicatilis* and *B.rotundiformis* in semi-continuous culture fed freeze-dried micro algae was studied by Navarro and Yufera(1998). Rumengan *et al.*(1998) observed the morphology and resting egg production of the tropical ultra-minute rotifer, *B.rotundiformis,* fed by different algae.

The resource limitation and reproductive effort in a planktonic rotifer were discussed by Stelzer(2001). King *et al.*(2002) examined the nutritional properties of the marine rotifer, *B.plicatilis* fed by the freshwater micro algae *Selenastrum capricomutum.* The effect of temperature on resting egg formation of the tropical 'ss' type rotifer *B.rotundiformis* was studied by Assavaarsee *et al.*(2003).

In India, Sarma(1985) studied the effect of food density on the growth of *B.patulus*. The experimental studies on the ecology of *B.patulus* in relation to food, temperature and predation was made by Sarma(1987). Rao and Sarma(1988) discussed the effect of food and temperature on the reproduction in *B.patulus* while Sarma(1989) observed the effect of *Chlorella* density and temperature on somatic growth and age at maturity of the rotifer *B.patulus* and Sarma and Rao(1990) studied the population dynamics of *B.patulus* in relation to food and temperature. Rafiuddin and Neelakantan(1990) tried the production of rotifer *B.plicatilis* fed with different cell densities of microalgae, *Chlorogibba trochisciaeformis,* while Sharma and Saini(1991) attempted rotifer production through NPK fertilization. Iyer and Rao(1995) dealt with the epizoic mode of life in *B.rubens* as a deterrent against predation by *Asplanchna intermedia.* Iyer and Rao(1996) conducted laboratory and field studies regarding the responses of the predatory rotifer, *Asplanchna intermedia* to prey species differing in vulnerability. The importance of food concentration and initial population density in the case of competitive interactions between herbivorous rotifers were dealt by Sarma *et al.*(1996). The feeding preference and population growth of *Asplanchna brightwelli* offered two non-evasive prey rotifers, as well as the effect of methyl parathion-treated prey, *B.calyciflorus* on the population growth of the predator *Asplanchna sieboldi* were studied by Sarma *et al.*(1998a, 1998b). Nandini and Rao(1998) analysed the somatic and population growth in selected rotifer species offered the cyanobacterium *Microcystis aeruginosa* as food. Sarma *et al.*(1999) studied the competition between *B.calyciflorus* and *B.patulus* in relation to algal food concentration and initial population density. Rajamani *et al.*(1999) tried the mass production of rotifer with different combinations of fertilizers. Boby *et al.*(2001) described the use of rotifer as larval feed for the tropical clown fish *Amphiprion sebae,* under captive condition. The reproduction in selected species of rotifers as well as the effect of salinity on competition between the rotifer *B.rotundiformis* and *Hexarthra jenkinae,* were investigated by Sarma *et al.*(2002a, 2002b). Sarma *et al.*(2003) studied the comparative population growth and life table demography of the rotifer, *Asplanchna girodi,* at different prey(*B.calyciflorus* and *B.havanaensis*) densities.

In Kerala, Jothy and Easterson(1984) assessed the food value of rotifer to post larvae of *Penaeus indicus* reared in the laboratory. Gopakumar(1998) studied the brackishwater rotifers of Kerala with special reference to *B.plicatilis* as live feed for aquaculture. Gopakumar and Jayaprakas(2001) published a research review on rotifer as live feed for larviculture of marine fishes. Anitha(2003) studied certain live feed organisms used in aquaculture with special reference to rotifers of the family Brachionidae. Gopakumar(2004) dealt with the influence of enriched rotifers on the survival of *Amphiprion* sp. and *P.monodon.* Again, Gopakumar and Jayaprakas(2004) discussed the life table parameters of *B.plicatilis* and *B.rotundiformis* in relation to salinity and temperature.

The above review gives an insight into the major factors such as temperature, salinity and food that influence the reproductive potential and thereby the population size of rotifers. According to Miracle and Serra (1989), in cold water species net reproduction is highly variable with temperature and has a high effect on **r**; but in warm water, net reproduction varies little within a certain temperature range. According to Gopakumar(1998), the influence of temperature on **r** was not conspicuous, as it is with salinity, feed type and feed concentrations, while studying **r** values of rotifers of southern part of Kerala. From the same region, Anitha(2003) also reported that the maximum **r** values for *B.rotundiformis* was at room temperature. So, in tropical countries like India, the influence of temperature on **r** values is not very significant.

Salinity is one of the most important aspect influencing the reproductive rate of rotifers. Although, certain species of *Brachionus* can tolerate wide ranges of salinities, there can be an optimum salinity at which maximum **r** values exhibit, and that can be characteristic for a particular strain. Any deviation from this optimum salinity will result a decrease in **r** values. The influence of salinity and reproductive potential of S and SS strains of *B.rotundiformis* were studied by Hagiwara *et al.*(1995a)

The feed type and feed concentration play a vital role in influencing the reproductive rate of rotifers. For culture of rotifers, the commonly used micro algae belong to *Chlorella, Nannochloropsis, Isochrysis* and *Tetraselmis*. While some studies have suggested that, algal diet has little effect on reproductive rates(Ito,1960; Theilacker & McMaster,1971; Scott & Baynes,1978), others(Hirayama *et al.*,1979; Okauchi & Fukusho,1984) pointed out that different species of algae resulted in substantially different reproductive rates. The reproductive rates of rotifers do have direct influence on the quantity of food supplied. The studies conducted by Korstad *et al.*(1989a) also emphasized this statement while examining the reproductive potential of *B.rotundiformis.*

The reproductive potential of a particular species is different from another species, so also for different strains. In India, Sarma(1985, 1987) and Sarma and Rao(1990) investigated the population dynamics and the influence of environmental factors on the reproduction of *B.patulus*. In an another work, Gopakumar(1998) studied the reproductive potential of five strains of *B.plicatilis* collected from the brackishwater habitats of southern Kerala. Another work on reproductive potential was carried out recently by Anitha(2003) in which she studied the **r** values of *B.angularis, B.caudatus, B.calyciflorus, B.plicatilis, B.murray* and *B.rotundiformis* on the samples collected from southern part of Kerala. The above discussions reveals that Indian work on this subject are scarce and there is no previous report on the reproductive potential of rotifers from the central part of Kerala. Hence the impact of salinity, feed type and feed concentrations on reproductive potential of *B.rotundiformis* collected from Cochin backwater is presented in this account. Studies were also conducted to see whether any variation in **r** values, when rotifers with and without eggs are initially employed for the experiments.

MATERIALS AND METHODS

The rotifer, *Brachionus rotundiformis* was isolated from Vypeen and experiments were conducted to find out the reproductive potential at different salinities, different feed types and different feed concentrations. Salinities selected were 35, 21, 14 & 7 ppt. Feed types were *Nannochloropsis oculata, Chlorella marina, Isochrysis galbana* and baker's yeast, *Saccharomyces cerevisiae*. The microalgal cultures maintained in the laboratory of Central Marine Fisheries Research Institute, Kochi were used for the experiments. Before starting experiments, the rotifer cultures were acclimatized to the particular feed types, and salinities for one month. Feed concentrations selected were 8, 4, 2 & 1 million cells per ml in the case of *Nannochloropsis oculata* and *Chlorella marina*. With regard to *Isochrysis galbana* and *Saccharomyces cerevisiae*, 4, 2, 1 & 0.5 million cells per ml were selected. The feed concentrations were prepared by centrifuging the feeds of the particular salinity at 3000 rpm and serial dilutions were prepared by adding water of that particular salinity. The counts of feed were estimated using a haemocytometer.

The experimental design was as follows. 1ml of each of the feed concentrations were taken in 5 ml glass tubes; 10 tubes for each concentration and a total of 40 tubes (for the 4 concentrations of feed) were taken for a single salinity of a feed type. Like this, 40 tubes each for four salinities were set, as described earlier. So, in total 40 x 4 ie. 160 tubes were set for one feed type. Totally, 4 feed types were taken, so, 160x4 = 640 tubes. The experiments were conducted in two sets of 320 tubes each. In set I, rotifers without egg were used for the experiment and in set II, rotifers with 1 egg were used. To each tube containing 1 ml of feed, one rotifer each was transferred with the help of a micropipette. All the tubes were plugged with cotton and kept under illumination for 9 hours a day and after 3 days, all the tubes were taken out and fixed using 4% formaldehyde solution. The rotifer counts in each tube was taken and recorded. The reproductive potential was calculated using the formula, $\mathbf{r} = \ln Nt - \ln No/t$ where,

Nt = Number of rotifers after time t ; No = Number of rotifers initially present and t = time taken in days.

Three-way ANOVA was done using SYSTAT version 7.0.1, SPSS INC, to compare the influence of salinity, set of experiment and feed concentration separately as well as their interactions in different combinations on reproductive potential values of each feed type. ANOVA test was also performed to study the influence of these variables at different levels on the **r** values, with respect to the four feed types separately.

RESULTS

The reproductive potential in relation to salinity and feed concentration in two sets of experiments using the four feed types – *Nannochloropsis oculata, Chlorella marina, Isochrysis galbana* and baker's yeast, are presented.

A. FEED TYPE – *Nannochloropsis oculata*

The mean numbers, mean reproductive potentials along with their standard deviations when rotifers without as well as with 1 egg was used for the experiments, are given in Tables 16.a and 16.b.

When the experiments were conducted at a salinity of 35 ppt., the reproductive potentials were higher when rotifers with 1 egg was used in the 4 feed concentrations viz. 1,2,4 and 8 million cells per ml. The lowest of 0.79 was observed, at a feed concentration of 2 million cells per ml when rotifers without egg was used for the study, and a maximum of 1.09 was noticed at a feed concentration of 8 million cells per ml, when rotifers with 1 egg was used.

At 21 ppt. salinity, the **r** value showed slight increase in all the 4 feed concentrations, when rotifers with 1egg was used for the experiment. The **r** value varied from 1.09 to 1.51 at feed concentrations of 1 million and 8 million cells per ml respectively.

When the salinity used for the experiment was 14 ppt., the minimum as well as maximum values of **r** were noticed when rotifers without egg was used for the experiment. The range was from 1.21 at 1 million cells per ml feed concentration to 1.76

at a feed concentration of 8 million cells per ml. However, the values were higher when rotifers with 1 egg was used for the study at feed concentrations of 1, 2 and 4 million cells per ml.

At 7 ppt salinity, eventhough, a slight decline in **r** value was noticed at feed concentrations of 1 million and 8 million cells per ml, when rotifers with 1 egg was used, an increase was recorded at feed concentrations of 2 million and 4 million cells per ml; when rotifers with 1 egg was used for the experiment. And, the magnitude of increase was more, when rotifers with 1 egg was used. The reproductive potential at this salinity varied between 1.04 and 1.31 at feed concentration of 1 million and 4 million cells per ml respectively.

In majority of cases, in all the feed concentrations selected, as well as in the 4 salinities adopted for the study, the **r** values were slightly higher when rotifers with 1 egg was used for the experiment, compared to that with rotifers without egg. Also, the reproductive potential was found to increase with feed concentrations, and maximum was noticed at the highest feed concentration of 8 million cells per ml. Among the 4 salinities adopted for the experiments, the lowest **r** value of 0.792 was noticed at 35 ppt salinity and the highest of 1.756 was observed at 14 ppt salinity.

The results of 3-way ANOVA comparing the **r** values in relation to salinity and feed concentrations in two sets of experiments are given in Table 16.c. The analysis showed that the influence of salinity and feed concentration on reproductive potential in two sets of experiments were significant. Indepth studies showed that the variations between salinities at 4 levels viz. 35 ppt., 21 ppt., 14 ppt. and 7 ppt. in all combinations were found to influence the **r** values. In the case of feed concentrations, the variations in r values of $1x10^6$ cells per ml with those of $2x10^6$ cells per ml, $4x10^6$ cells per ml and $8x10^6$ cells per ml, were significant. The variations between 2 million and 4 million cells per ml with that of 8 million cells per ml were also found to influence the **r** values, significantly.

The salinity and feed concentration in two sets of experiments independently, influence the **r** values significantly. The interactions of feed concentration + salinity on **r** value were found to be significant($P<0.01$). But, the interactions of the set of experiment + feed concentration, set of experiment + salinity and set + feed concentration + salinity on **r** values were not significant.

Table 16. Reproductive potential of *Brachionus rotundiformis* in different salinities and feed concentrations of *Nannochloropsis oculata*

a) When rotifer without egg was used for the experiment

SALINITY								
	7ppt		14ppt		21ppt		35ppt	
Conc.of feed Cells /ml	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD
$1x10^6$	26±4	1.08±0.05	38±4	1.21±0.04	26±3	1.09±0.03	16±3	0.92±0.07
$2 x10^6$	31±16	1.08±0.24	63±4	1.38±0.03	49±6	1.29±0.04	12±5	0.79±0.16
$4 x10^6$	37±21	1.10±0.31	96±9	1.52±0.03	75±14	1.44±0.06	16±7	0.88±0.18
$8 x10^6$	53±20	1.28±0.17	196±31	1.76±0.05	86±21	1.48±0.07	24±11	0.99±0.27

b) When rotifer with 1egg was used for the experiment

	SALINITY							
	7ppt		14ppt		21ppt		35ppt	
Conc.of feed Cells /ml	Mean Nos. ± SD	Mean r ± SD	Mean Nos. ± SD	Mean r ± SD	Mean Nos. ± SD	Mean r ± SD	Mean Nos. ± SD	Mean r ± SD
1x10^6	26 ± 12	1.04±0.19	42±3	1.24±0.03	30±2	1.13±0.03	17±1	0.94±0.03
2x10^6	39 ± 10	1.21±0.09	68±8	1.40±0.04	50±4	1.30±0.03	25±5	1.06±0.08
4x10^6	55 ± 20	1.31±0.13	106±9	1.56±0.03	80±13	1.45±0.06	21±6	1.00±0.09
8x10^6	43 ± 12	1.23± 0.12	181±16	1.73±0.03	100±37	1.51±0.14	28±9	1.09±0.14

Table 16.c. Results of three-way ANOVA comparing the reproductive potential of *B.rotundiformis* in relation to salinity, set of experiment and feed concentration

Sources	Sum of Squares	df	Mean Square	F-ratio	P
Set of expt.	0.13	1	0.13	7.05	0.01*
Feed concentration	1.96	3	0.65	34.80	0.00**
Salinity	5.77	3	1.92	102.64	0.00**
Set + Feed concentration	0.08	3	0.03	1.35	0.26
Set + Salinity	0.08	3	0.03	1.40	0.25
Feed concentration + Salinity	0.64	9	0.07	3.80	0.00**
Set + Feed concentration + Salinity	0.13	9	0.01	0.80	0.62
Error	2.31	123	0.02		

* Significant at 5% level

** Significant at 1% level

B. FEED TYPE – *Chlorella marina*

The mean numbers, mean reproductive potentials along with their standard deviations, when rotifers without as well as with 1 egg used for the experiment, are given in Tables 17.a and 17.b.

The **r** values were higher, when rotifers with 1 egg was used for the experiment, at feed concentrations of 1 million, 2 million and 4 million cells per ml, at a salinity of 35 ppt, a minimum of 0.86 was noticed at a feed concentration of 1 million cells per ml and a maximum of 1.28 at feed concentration of 4 million cells per ml.

At 21 ppt salinity also, the **r** values were higher, when rotifers with 1 egg was used for the study at feed concentrations of 1 million, 2 million and 4 million cells per ml. The variation was between 0.912 at 1 million cells per ml and 1.57 at 8 million cells per ml.

When rotifer with 1 egg was used for experiment, the reproductive potentials were found to be higher, at a salinity of 14 ppt and a feed concentration of 4 million cells per ml. In other feed concentrations, the **r** values were slightly higher, when rotifers without egg was used for the study. The range was from 0.906 at 1 million cells per ml to 1.563 at a feed concentration of 8 million cells per ml.

When rotifers with 1 egg was used for the experiment at feed concentrations of 1 million and 8 million cells per ml, at 7 ppt salinity, the reproductive potentials were higher. The **r** values were higher when rotifers without egg was used for the study at feed concentrations of 2 million and 4 million cells per ml. At this salinity, the **r** value varied between 0.896 at 1 million cells per ml and 1.52 at 8 million cells per ml.

The reproductive potentials showed a gradual increase, along with the increase in feed concentrations, in all the salinities used for this experiment, except at feed concentration of 8 million cells per ml at 35 ppt salinity. This observation was true when rotifers without and with 1 egg were used for the study. During the experiment, the overall variation in reproductive potential was between 0.858 at 35 ppt salinity and 1.573 at 21 ppt salinity. At 14 ppt, the **r** value observed was 1.563, which was only slightly lower than the maximum. The minimum was noticed at feed concentration of 1 million cells per ml and maximum at 8 million cells per ml.

The results of 3-way ANOVA comparing the variations of influence/interactions of salinity, set of experiment and feed concentration on **r** values are given in Table 17.c. The influence of salinity and feed concentration on **r** values were found to be significant($P<0.01$). Detailed studies indicated that, in the case of salinity, the variations of **r** values between that of 35 ppt with other 3 levels of salinities viz. 21 ppt, 14 ppt and 7 ppt were found to be significant and other variations were not significant. The variations of **r** values between all the levels of feed concentrations, viz. 1 million, 2 million, 4 million and 8 million cells per ml were found to be significant and the **r** values were not influenced by sets of the experimentals, viz. rotifers without egg or with 1 egg.

The interactions of salinity + feed concentration on r values were significant ($P<0.01$). The interactions of set + feed concentration, set + salinity and set + feed concentration + salinity on **r** values were not significant.

Table 17. Reproductive potential of *Brachionus rotundiformis* in different salinities and feed concentrations of *Chlorella marina*

a) When rotifer without egg was used for the experiment

SALINITY								
	7ppt		14ppt		21ppt		35ppt	
Conc.of feed Cells /ml	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD
$1x10^6$	15±2	0.90±0.05	21±5	1.01±0.07	16±4	0.91±0.09	15±8	0.86±0.17
$2 x10^6$	25±9	1.04±0.15	35±5	1.18±0.06	28±9	1.09±0.12	25±15	1.02±0.18
$4 x10^6$	50±4	1.30±0.03	64±4	1.38±0.02	52±7	1.31±0.05	42±5	1.25±0.04
$8 x10^6$	93±16	1.50±0.06	109±2	1.56±0.00	112±13	1.57±0.03	31±16	1.10±0.16

b) When rotifer with 1egg was used for the experiment

SALINITY								
	7ppt		14ppt		21ppt		35ppt	
Conc. of feed Cells /ml	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD
$1x10^6$	23±2	1.04±0.03	15±2	0.91±0.04	16±5	0.92±0.09	25±8	1.05±0.11
$2 x10^6$	24±9	1.04±0.11	29±3	1.13±0.03	29±6	1.12±0.06	34±13	1.15±0.12
$4 x10^6$	41±4	1.24±0.03	67±6	1.40±0.03	56±9	1.34±0.05	56±32	1.28±0.21
$8 x10^6$	96±9	1.52±0.03	108±4	1.56±0.01	95±10	1.52±0.04	24±11	1.03±0.13

Table 17.c. Results of three-way ANOVA comparing the reproductive potential of *B.rotundiformis* in relation to salinity, set of experiment and feed concentration

Sources	Sum of Squares	df	Mean Square	F-ratio	P
Set of expt.	0.01	1	0.01	0.78	0.38
Feed concentration	4.89	3	1.63	144.50	0.00**
Salinity	0.59	3	0.20	17.56	0.00**
Set +Feed concentration	0.04	3	0.01	1.13	0.34
Set +Salinity	0.06	3	0.02	1.64	0.18
Feed concentration +Salinity	1.18	9	0.13	11.63	0.00**
Set + Feed concentration + Salinity	0.13	9	0.01	1.30	0.24
Error	1.32	117	0.01		

* Significant at 5% level ** Significant at 1% level

C. FEED TYPE – *Isochrysis galbana*

The mean numbers, mean reproductive potentials along with their standard deviations, when rotifers without as well as with 1 egg was used for the study are given in Table 18.a and 18.b.

At 35 ppt salinity, the **r** values were higher, when rotifers with 1 egg was used for the experiment at feed concentrations of 0.5 million, 1 million and 4 million cells per ml. The range was between 0.82 at feed concentration of 1 million cells per ml and 1.22 at 0.5 million feed concentration.

When rotifer with 1 egg was introduced for the experiment at a feed concentration of 0.5 million cells per ml, the **r** value was higher at a salinity of 21 ppt. In other feed concentrations, the **r** values were higher when the experiments were conducted with rotifers without egg. A minimum of 1.11 and a maximum of 1.4 were noticed at feed concentrations of 2 million cells per ml.

At 14 ppt salinity, the **r** values showed higher values, when rotifers with 1 egg was used for the study at feed concentrations of 0.5 million, 2 million and 4 million cells per ml. The variation was between 0.942 at feed concentration of 0.5 million cells per ml and 1.412 at 4 million cells per ml feed concentration.

At 7 ppt salinity, the **r** values were higher when rotifers with 1 egg was used for the study in all the 4 feed concentrations selected. The **r** values ranged from 1.16 to 1.52 at feed concentrations of 0.5 million and 4 million cells per ml respectively.

The increase in reproductive potential values were associated with increase in feed concentrations at salinities 14 ppt and 7 ppt. But, the **r** values were found to fluctuate at salinities of 35 ppt and 21 ppt. The overall variation of reproductive potential was between 0.82 at feed concentration of 1 million cells per ml and 1.518 at feed concentration of 4 million cells per ml. The minimum was observed at 35 ppt and maximum at 7 ppt salinity.

The results of 3-way ANOVA showing the influence/interactions of salinity, set of experiment and feed concentrations on **r** values are given in Table 18.c. The influence of salinity on **r** values were found to be significant($P<0.01$). Between salinities, the variations were significant in all combinations, except that between 21 ppt and 7 ppt.

The combined interactions of feed concentration + salinity on **r** values were found to be significant($P<0.05$). In this feed, the influence of feed concentration, set, set + feed concentration, set + salinity and set + feed concentration + salinity on **r** values were not significant.

Table 18. Reproductive potential of *Brachionus rotundiformis* in different salinities and feed concentrations of *Isochrysis galbana*

a) When rotifer without egg was used for the experiment

SALINITY								
	7ppt		14ppt		21ppt		35ppt	
Conc.of feed Cells /ml	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD
$0.5x10^6$	36±13	1.16±0.17	24±16	0.94±0.31	51±13	1.30±0.09	26±2	1.08±0.02
$1 x10^6$	50±16	1.28±0.12	39±17	1.20±0.12	70±25	1.39±0.16	15±9	0.82±0.25
$2 x10^6$	63±29	1.34±0.18	44±25	1.19±0.26	71±23	1.40±0.12	24±12	1.01±0.18
$4 x10^6$	73±24	1.41±0.11	33±2	1.16±0.02	46±26	1.20±0.24	22±10	0.96±0.24

b) When rotifer with 1egg was used for the experiment

SALINITY								
	7ppt		14ppt		21ppt		35ppt	
Conc. of feed Cells /ml	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD
$0.5x10^6$	38±8	1.21±0.07	26±21	1.00±0.24	57±10	1.35±0.06	40±10	1.22±0.08
$1 x10^6$	48±8	1.29±0.06	29±15	1.05±0.24	41±30	1.14±0.26	30±11	1.12±0.10
$2 x10^6$	75±28	1.42±0.11	49±28	1.23±0.22	42±40	1.11±0.28	16±3	0.91±0.06
$4 x10^6$	105±46	1.52±0.15	99±72	1.41±0.30	42±33	1.14±0.25	37±18	1.13±0.28

Table 18.c. Results of three-way ANOVA comparing the reproductive potential of *B.rotundiformis* in relation to salinity, set of experiment and feed concentration

Sources	Sum of Squares	df	Mean Square	F-ratio	P
Set of expt.	0.02	1	0.02	0.48	0.49
Feed concentration	0.17	3	0.06	1.27	0.29
Salinity	1.81	3	0.60	13.24	0.00**
Set + Feed concentration	0.19	3	0.06	1.36	0.26
Set + Salinity	0.34	3	0.11	2.51	0.06
Feed concentration + Salinity	1.08	9	0.12	2.63	0.01*
Set + Feed concentration + Salinity	0.36	9	0.04	0.88	0.54
Error	5.24	115	0.05		

* Significant at 5% level

** Significant at 1% level

D. FEED TYPE – Baker's yeast

The mean numbers, mean reproductive potentials along with their standard deviations when rotifers without as well as with 1 egg used for the experiments, are given in Table 19.a and 19.b.

At 35 ppt salinity, the **r** values were higher when rotifers with 1 egg was introduced for the experiment at feed concentrations of 1 million and 4 million cells per ml. But, in feed concentrations of 0.5 million and 2 million cells per ml, the reproductive potential values were higher when rotifers without egg was used for the experiment. At this salinity, the minimum as well as maximum **r** values were observed at feed concentration of 4 million cells per ml, in the range of 0.35 to 0.86.

At 21 ppt salinity, the **r** values were higher when rotifers with 1 egg was introduced for the experiment at feed concentrations of 2 million and 4 million cells per ml. But, in other two feed concentrations, the **r** values were higher when rotifers without egg was used for the study. At this salinity, the minimum **r** value of 0.265 was observed at 0.5 million as well as at 1 million cells per ml feed concentrations and the maximum of 0.628 was noticed at feed concentration of 2 million cells per ml.

At 14 ppt salinity, the reproductive potential values were higher when the experimental rotifers were with 1 egg at feed concentrations of 1 million, 2 million and 4 million cells per ml. At this salinity, the variation in **r** values was between 0.478 at feed concentration of 0.5 million cells per ml and 0.78 at feed concentration of 4 million cells per ml.

At 7 ppt salinity, the **r** values were higher when rotifers without egg was used for the study at feed concentrations of 1 million, 2 million and 4 million cells per ml. The range was from 0.44 to 0.978 at feed concentrations of 0.5 million and 4 million cells per ml respectively.

In brief, there was no considerable variation between **r** values when rotifers without as well as with 1 egg was taken for the study. In majority of cases, the **r** values were found to increase along with the increase in feed concentrations. During the experiment with baker's yeast, the overall variation in reproductive potential was from 0.265 at 21 ppt salinity to 0.978 at 7 ppt salinity.

The results of 3-way ANOVA showing the influence/interactions of salinity, set and feed concentrations on **r** values are given in Table 19.c. The **r** values were significantly influenced by feed concentrations and salinity($P<0.01$). Indepth studies showed that the variations of **r** values between salinities were significant except that between 35 ppt and 14 ppt. In the case of feed concentrations, the variations of **r** values between feed concentrations were significant except in two instances viz. (1) between that of 1 million and 2 million cells per ml and (2) between that of 4 million and 8 million cells per ml. The interactions of set of the experiment, set + feed concentration, set + salinity, feed concentration + salinity and set + feed concentration + salinity on **r** values were not significant.

Table 19. Reproductive potential of *Brachionus rotundiformis* in different salinities and feed concentrations of Baker's yeast

a) When rotifer without egg was used for the experiment

SALINITY								
	7ppt		14ppt		21ppt		35ppt	
Conc.of feed Cells /ml	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD
0.5×10^6	4±2	0.44±0.17	5±2	0.48±0.17	3±1	0.32±0.19	5±2	0.52±0.18
1×10^6	11±7	0.67±0.31	6±4	0.52±0.21	4±2	0.41±0.22	5±2	0.51±0.14
2×10^6	15±7	0.87±0.18	8±5	0.59±0.25	6±5	0.47±0.29	7±2	0.66±0.08
4×10^6	21±8	0.98±0.18	11±8	0.71±0.23	8±8	0.58±0.26	3±1	0.35±0.09

b) When rotifer with 1egg was used for the experiment

SALINITY								
	7ppt		14ppt		21ppt		35ppt	
Conc. of feed Cells /ml	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD	Mean Nos. ± SD	Mean **r** ± SD
0.5×10^6	5±2	0.53±0.13	5±2	0.48±0.16	2±0	0.27±0.06	4±1	0.49±0.08
1×10^6	7±5	0.55±0.23	7±4	0.59±0.21	2±0	0.27±0.06	9±1	0.73±0.03
2×10^6	14±7	0.83±0.15	7±4	0.59±0.19	2±4	0.63±0.23	7±3	0.61±0.14
4×10^6	19±9	0.92±0.20	12±6	0.78±0.16	3±5	0.61±0.34	14±4	0.86±0.11

Table 19.c. Results of three-way ANOVA comparing the reproductive potential of *B.rotundiformis* in relation to salinity, set of experiment and feed concentration

Sources	Sum of Squares	df	Mean Square	F-ratio	P
Set of expt.	0.06	1	0.06	1.25	0.27
Feed concentration	1.74	3	0.58	11.94	0.00**
Salinity	1.48	3	0.49	10.18	0.00**
Set + Feed concentration	0.11	3	0.04	0.75	0.52
Set + Salinity	0.19	3	0.06	1.30	0.28
Feed concentration + Salinity	0.51	9	0.06	1.16	0.33
Set + Feed concentration + Salinity	0.50	9	0.06	1.14	0.34
Error	5.57	115	0.05		

* Significant at 5% level

** Significant at 1% level

DISCUSSION

The results indicated that the different variables – salinity, feed type, feed concentration and set of experiment influence the reproductive potential of *Brachionus rotundiformis* in varying magnitudes.

Of the 4 types of feeds tested, viz. *Nannochloropsis oculata, Chlorella marina, Isochrysis galbana* and baker's yeast; *Nannochloropsis oculata* gave maximum **r** value of 1.756 at a feed concentration of 8 million cells per ml at 14 ppt salinity. The $\mathbf{r}_{max}$ values decreased in the order, *Nannochloropsis oculata* → *Chlorella marina* → *Isochrysis galbana* → Baker's yeast. The **r** values were very low in baker's yeast compared to algae. The present observation is in agreement with the findings of Gopakumar(1998) who reported high values of **r** in microalgae when compared to their combinations with baker's yeast. Also, Hagiwara *et al.*(1995a) suggested that *Nannochloropsis oculata* is the most suitable diet for optimum reproductive potential of *B.rotundiformis.*

Salinity was found to influence the **r** values in all the 4 feed types tested in the present work. Ito,1960; Ruttner-Kolisko,1972; Pascual & Yufera, 1983 and Lubzens *et al.*,1985 also pointed out that, the reproductive rates of rotifers are strongly influenced by the salinity of the culture medium. In the present study, the $\mathbf{r}_{max}$ values of 1.756 for *Nannochloropsis oculata* and 1.573 for *Chlorella marina* were recorded at salinities 14 ppt and 21 ppt respectively. In the case of *Chlorella marina*, **r** value of 1.563 was obtained at 14 ppt salinity which was very close to 1.573. So, the optimum salinity for r_{max} in *Nannochloropsis oculata* and *Chlorella marina* was 14 ppt. This is in agreement with the finding of Hagiwara *et al.*(1995a), who observed the optimum salinity for the best **r** value for *B.rotundiformis* as 11 ppt. Again, Anitha(2003), recorded the highest **r** value for *B.rotundiformis* at 15 ppt salinity which is more close to 14 ppt, reported during the present study. When the feed type employed was *Isochrysis galbana*, $\mathbf{r}_{max}$ was noticed at 7 ppt salinity. So, the optimum salinity at which $\mathbf{r}_{max}$ was observed in the 3 types of algae tested was between 7 and 14 ppt. Above or below this salinity, the **r** values were found to decrease. When baker's yeast was used as feed, the $\mathbf{r}_{max}$ was only 0.978 which was much lower than that obtained, when algae were employed. However, the optimum **r** value was at 7 ppt salinity when baker's yeast was used as feed. The **r** values were found to decline above this salinity. The **r** values were the least at 35 ppt in the 3 types of feeds – *Nanochloropsis oculata, Chlorella marina* and *Isochrysis galbana.* In baker's yeast, the minimum **r** value was observed at 21 ppt. James and Abu-Rezeq(1990) summarized that the productivity of *B.rotundiformis* depends on the salinity of the culture medium used and on the rotifer strain cultured.

The $\mathbf{r}_{max}$ values in all the 4 feed types employed were observed at the highest feed concentration used for the study which were 8 x 10^6 cells per ml in *Nannochloropsis oculata* and *Chlorella marina* and 4 x 10^6 cells per ml in *Isochrysis galbana* and baker's yeast. James and Abu- Rezeq (1988) observed that the rotifer fed with *Chlorella sp.* showed an increase in population density, production and growth rate upto a feed concentration of $10\text{x}10^6$ cells per ml. The reproductive rate and survival of *B.plicatilis* depends on the concentration of food in the culture medium(Hirayama *et al.*,1979; Lubzens,1981; Snell *et al.*,1983; Yamasaki *et al.*,1984). Yufera *et al.*(1983)observed an optimum concentration of the algae, *Nannochloropsis* sp. as high as $70\text{x}10^6$ cells per ml for an increase in density of rotifer, *B.plicatilis* in culture. They also reported a linear relationship between rotifer population growth rate and cell densities of *Chlorella,* and, according to them the increase in rotifer growth rate between 5 and 15×10^6 cells per ml algal concentrations was highly significant. A significant increase in the production of *B.plicatilis* was achieved at a density of 50×10^6cells per ml of *Chlorogibba trochisciaeformis*(Rafiuddin and Neelakantan, 1990). Again, Gopakumar(1998) reported the optimum **r** value for S strain of *B.plicatilis* when *Chlorella marina* was used, at a feed concentration of 4×10^6 cells per ml, while, Anitha(2003) recorded the highest **r** value when *Isochrysis galbana* was used at a feed concentration of 2×10^6 cells per ml. The above works indicate that the feed concentration of algae required to have the $\mathbf{r}_{max}$ for rotifers, vary for different species/strains, and this explains the difference in the feed concentration at which $\mathbf{r}_{max}$ was obtained in the present work. During the present study, the minimum **r** values were observed at 2×10^6 cells per ml in *Nannochloropsis oculata*, 1×10^6 cells per ml in *Chlorella marina* and 1×10^6 cells per ml in *Isochrysis galbana.* In baker's yeast, the **r** value was the least, in feed concentrations of both 0.5×10^6 and 1×10^6 cells per ml. And, these low values can be due to insufficient feeding.

The results of the present work points out that the reproductive potential of *B.rotundiformis* is influenced by salinity, feed type and feed concentrations, at a magnitude higher than that of sets of experiments. Among the interactions, the salinity and feed concentrations together interact the **r** values significantly with respect to all the three microalgae tested for the present study. Hirayama & Ogawa(1972) also showed that filtration rates of *B.plicatilis* change with salinity and food concentration. Compared to that of baker's yeast, the reproductive potentials were higher in all the 3 algal feeds tested during this experiment. The maximum **r** values were noticed between 7 and 14 ppt salinity in these 3 algal feeds. Carmona *et al.*(1995) observed that *B.rotundiformis* is euryhaline. This observation is true for the present experimental study also. Among the 4 feeds tested, *Nannochloropsis oculata* gave maximum **r** value for *B.rotundiformis*. In another study, James and Al-Khars(1990) noticed that the total w3 HUFA and the essential fatty acid eicosapentaenoic acid(EPA) content were significantly higher in *Nannochloropsis* sp. compared to *Chlorella* sp., showing that the former is more suitable for aquacultural purposes since EPA is mandatory for the feeding of marine fish larvae. In a similar study, James and Abu-Rezeq(1989) also indicated that the rotifers produced using *Nannochloropsis* sp. contain adequate quantities of the essential fatty acids required for feeding marine fish larvae, and, therefore no further nutritional enrichment of rotifers is required which could save space and manpower utilization in a marine fish hatchery. The information on reproductive potential of rotifers, influence of variables like salinity, feed type and feed concentrations along with their combined interactions on **r** values will be helpful in culture activities of rotifers. As *B.rotundiformis* cultures are widely being used as an excellent live feed organism in the successful larval rearing operations of marine finfishes, the results of this experiment can be effectively used in aquaculture practices.

SUMMARY

1. The importance of the present investigation, along with a detailed literature search on taxonomy, distribution, ecology and culture of rotifers are described.
2. The study was conducted with samples collected from nine stations, with varying ecological conditions in central part of Kerala, along Cochin backwater system, for the period from August 2000 to July 2002.
3. The present work is presented in three chapters. Each chapter is divided into four parts – Introduction, Materials and Methods, Results and Discussion.
4. Chapter '1' is on Taxonomy. Under this chapter, rotifers collected from all the nine stations were identified and described in detail along with photographs. 20 genera of rotifers, belonging to 13 families, coming under two orders were recorded from the study area. The genus *Brachionus* alone was studied upto species level and 13 species of *Brachionus* were also recorded. All the species/genera are reported for the first time from this region.
5. Chapter '2' is on Distribution and Ecology of rotifers in the nine selected stations. Under this chapter, monthwise collections of water as well as plankton samples were made from each station, using standard methods. Water samples were analysed to estimate 13 different environmental characteristics, adopting standard methods. The different species/genera of rotifers and other zooplankton groups were identified, counted and recorded. The Biodiversity indices of rotifers were calculated. Statistical interpretations of data were presented, based on correlation analysis and ANOVA. The results in this chapter are presented in two parts – Part I is on distribution and Part II is on ecology.

6. Under Distribution, both qualitative and quantitative aspects of rotifer fauna in the nine stations were studied. Among the 20 genera of rotifers recorded from the study area during the study period, a minimum of 13 and a maximum of 19 genera were recorded in varying numbers in different stations. Eight genera, namely, *Brachionus, Anuraeopsis, Lecane, Monostyla, Trichocerca, Polyarthra, Encentrum* and *Testudinella* were noticed from all the nine stations. The family Brachionidae comprised of four genera namely *Brachionus, Keratella, Platyias* and *Anuraeopsis*. Of the 13 species of *Brachionus*, *B.plicatilis* and *B.rotundiformis* were recorded from all the stations studied and the number of *Brachionus* species ranged between 5 and 9 in different stations. Under quantitative studies on distribution, numerical as well as percentage composition of rotifers, family Brachionidae and different species of *Brachionus* in the nine stations were presented. The maximum density of rotifers was recorded at station II, followed by station III and the minimum was noticed at station VI. The genus *Brachionus* dominated over other genera, in 8 out of 9 stations studied. The seasonal distribution of rotifers in the study area, showed the maximum density during premonsoon, followed by monsoon and the minimum during the postmonsoon season. Out of the 13 families, family Brachionidae dominated in majority of stations (7 out of 9 stations). Of the four genera under the family Brachionidae, the genus *Brachionus* dominated in all the nine stations. Of the 13 species of *Brachionus*, *B.rotundiformis* dominated in all the nine stations. The analysis of variance(ANOVA) showed that the variations in the numerical abundance of rotifers, family Brachionidae and genus *Brachionus* between

stations were highly significant. The variations of all the 4 diversity indices – Richness, Evenness, Shannon and Simpson – between stations with respect to rotifers were statistically significant. This indicate the variability in rotifer assemblages in these stations. Apart from rotifers, the monthwise and seasonwise distribution of zooplankton along with the interrelationship between the numerical abundance of zooplankton and that of rotifers were also presented.

7. Under Ecology, the studies on the interrelationship between the numerical abundance of rotifers and 13 different environmental characteristics in the respective stations as well as in the study area as a whole were studied using Correlation analysis. The studies in the area as a whole indicated significant positive correlations of rotifers with phosphate, nitrite, BOD, chlorophyll a and Total Suspended Solids. These relationships were true for the numerical abundance of family Brachionidae as well as genus *Brachionus,* in the study area as a whole. Eventhough BOD was found to be positively correlated with rotifers in the study area as a whole, very high BOD was found to be not favourable for rotifer production. The affinity of rotifers to lower salinities was noticed. The different stations had varying environmental characteristics and consequently they differ in rotifer assemblages also. The present investigation points out that the combined interactions of different environmental factors on the distribution and abundance of rotifers are more reliable than the correlation of a single parameter on the distribution and abundance of rotifers in each ecosystem.
8. Chapter '3' is based on an experimental study conducted to assess the reproductive potentials of rotifers in live cultures. The rotifer, *Brachionus*

rotundiformis is isolated from the study area and experiments were conducted to find out the reproductive potential, using, salinities, feed types and feed concentrations as variables. The studies indicated that, these three variables exert significant influence on reproductive potential of this rotifer. The $\mathbf{r}_{max}$ values were found to decrease in the order, *Nannochloropsis oculata* → *Chlorella marina* → *Isochrysis galbana* → Baker's yeast. In all the 4 feed types tested, the $\mathbf{r}_{max}$ values were maximum at the highest feed concentrations taken during the experiment. The influence of salinity, feed type and feed concentration, individually as well as their combined interactions on the reproductive potential of this species were presented.

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