COMMUNITY CHANGES IN ZOOPLANKTON AND MACROBENTHOS OF A PRAWN CULTURE FIELD IN RELATION TO HYDROGRAPHICAL CONDITIONS

By

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THESIS

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COLLEGE OF FISHERIES

PANANGAD, COCHIN

Dedicated To
My Beloved Parents and
Lord Shiridi Sai baba

DECLARATION

I hereby declare that this thesis entitled **"COMMUNITY CHANGES IN ZOOPLANKTON AND MACROBENTHOS OF A PRAWN CULTURE FIELD IN RELATION TO HYDROGRAPHICAL CONDITIONS"** is a bonafide record of research work done by me during the course of research and that the thesis has not formed the basis for the award to me of any degree, diploma, associateship, or other similar title, of any other University or Society.

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Certified that this thesis entitled **"COMMUNITY CHANGES IN ZOOPLANKTON AND MACROBENTHOS OF A PRAWN CULTURE FIELD IN RELATION TO HYDROGRAPHICAL CONDITIONS"** is a record of research work done independently by **Sri. SHREE RAM SUDHEER GUBBA** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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Introduction

1. INTRODUCTION

The Cochin backwater is the northern part of the Vembanad Lake, situated in the Kerala state, South West Coast of India. The Vembanad Lake which is the largest and the most extensive one in Kerala is situated between latitudes 9°28' and 10°10' N and longitudes 76°13' and 76°31' E. Its length is about 113 km and the width varies from a few hundred meters to about 14.5 km (Josanto, 1971). It is connected to the Arabian Sea through two openings, one at Cochin and the other at Azhikode. The main source of freshwater for the backwater is two major rivers, the Periyar and the Pamba, which open into the estuary, the former towards north of Cochin and the latter towards the southern extremity. Four other small rivers viz. the Achankoil, the Manimala, the Meenachil and the Muvattupuzha also flow into the backwater at the southern side. These rivers discharge large quantities of freshwater into the estuary especially during the southwest and northeast monsoons.

About 5200 ha of low-lying areas adjacent to the backwaters are suitable for aquaculture (Preetha and Pillai, 2000). The traditional fish/prawn culture operations in the fields adjacent to the Cochin backwater system have been in vogue for a long time.

The difference in the water levels between the successive tides is taken advantage of to regulate the flow of water in and out of these fields through sluices. These extensive culture systems are characterised by lack of supplementary feeding, multiple harvesting, little inputs towards selective stocking and inadequate management.

The traditional culture fields fall into two categories: the seasonal fields and the perennial fields. In seasonal fields, generally known as pokkali fields, paddy is grown during the monsoon months (June to September) when the backwater system is freshwater dominated. After the monsoon rice is harvested and when the water becomes brackish, the post larvae and juveniles of commercially important prawns are allowed to migrate into these fields in large numbers and they are trapped with the help of suitably located sluices.

The perennial fields where prawns are raised round the year are deeper than the seasonal paddy fields. The yields from these fields are generally higher than those from seasonal fields (George, 1974), because here prawns are cultured throughout the year and they would stay here long and attain larger size. No additional expenditure is involved in the perennial fields as in the preparation of seasonal fields for prawn culture after the harvest of paddy.

In both the types of ponds, prawns are allowed to grow and the tendency of prawns to escape after growing to a certain size from these fields during spring tide (the full/new moon periods) is taken advantage of to harvest them periodically, by filtering the outflow during low tides. This practice continues till the season ends in April.

No fertilizer or artificial feed is applied to enhance the production of either plankton or fish/prawn in these ponds. Thus the prawn/fish seeds that migrate into these fields completely depend on the availability of natural food in the form of plankton, benthos and detritus formed due to the decay of the roots of the paddy. Estuaries being natural transitional areas between marine and freshwater zones show wide range of fluctuations in hydrographical conditions. These fluctuations are reflected in the traditional culture fields also as they are extensions of the estuary and backwaters. Abiotic factors particularly hydrographical characteristics of the environment can exert profound influence on the growth and survival of the cultured organisms both directly as well as indirectly by affecting the plankton and benthos, which form their food.

Comprehensive knowledge on natural fish food comprising plankton and benthos is an essential prerequisite for successful fish culture operations. Studies on the occurrence and abundance of such organisms in relation to hydrographical conditions would be useful for evolving methods for improving the fishery potential of culture fields.

The present study was undertaken with a view to finding out the faunal variations of a brackishwater prawn culture field adjacent to the Vembanad Lake and to correlate them with the variations in hydrographical conditions and to compare the results with those obtained from observations in the adjacent lake.

This would also generate necessary information for quantifying the requirements of supplementary feed in the field. Such studies may also be useful for managing the hydrographical conditions for obtaining optimum production in the culture fields.

Review of Literature

2. REVIEW OF LITERATURE

2.1 HYDROGRAPHY

Hydrography of the Cochin backwaters has been studied by several workers and the literature available includes information on the seasonal and diel variations of temperature, salinity, dissolved oxygen, nutrients and pH in the area. Some of the important works are those of Balakrishnan (1957), Ramamirtham and Jayaraman (1963), Cheriyan (1967), Sankaranarayanan and Qasim (1969), Qasim *et al.* (1969), Qasim and Gopinathan (1969), Josanto (1971), Sreedharan and Salih (1974), Balakrishnan and Shynamma (1976) and Varma *et al.* (2002).

Environmental conditions of some seasonal and perennial prawn culture fields adjacent to the backwaters have been investigated by several authors including Sankaranarayanan *et al.* (1982), Gopinathan *et al.* (1982), Singh (1987), Mathew (1987), Gopalakrishnan *et al.* (1988), Jose *et al.* (1988), Joseph (1988), and Nair *et al.* (1988).

2.1.1 Salinity

Salinity is considered the environmental master factor in estuaries and backwaters (Kinne, 1971). The dominant feature of the estuarine environment is the fluctuations in salinity. Freshwater discharge from some major rivers, the tidal flow from the Arabian Sea, the coastal upwelling and sinking etc., have considerable effect on the hydrographical conditions of the Cochin backwaters and these factors bring about a well-defined seasonal pattern in salinity variations (Ramamirtham and Jayaraman, 1963; Qasim and Gopinathan, 1969).

Hydrographical studies by various authors cited above reveal the following. During the southwest monsoon (June-September) almost freshwater conditions prevail in the Vembanad Lake except in regions close to the Cochin barmouth. September to December is the season of fluctuating salinity and January to May is the season of high salinity. These three periods have been referred to as the monsoon season, the post-monsoon season and the pre-monsoon season, respectively by the various workers. According to Varma *et al.* (2002) the salinity of the Panangad area where the present study was conducted ranges between 0‰ and 32‰. Salinity decreases during the monsoon season reaching 0‰. The pre-monsoon period is the season of peak salinity in the area. These trends in the variations of salinity are also true of the salinity of the prawn culture fields adjacent to the Vembanad Lake (Gopinathan *et al.,* 1982; Sankaranarayanan *et al.,* 1982; Singh, 1987).

2.1.2 Temperature

Nair and Tranter (1971) have reported that the temperature does not vary much in the three seasons even though there are slight diurnal variations. Menon *et al.* (1971) reported that with the onset of monsoon there was a decrease in surface temperature and a certain amount of uniformity was maintained in temperature till the end of the monsoon. An increase in temperature towards the beginning of post-monsoon was well indicated. Temperature was found to be high throughout the latter half of the post-monsoon and pre-monsoon periods. According to Pillai *et al.* (1975) there was a gradual increase in temperature from February to April followed by a fall during July-August in the Vembanad Lake and adjacent waters. In general during the post-monsoon period, surface temperature showed a slight increase in the entire area. The temperature values ranged between 25.1°C and 33.0°C in the area between Alleppey and Azhikode. Balakrishnan and Shynamma (1976) reported that the lowest temperature values were observed during July-August period in the Cochin harbour area. In the pre-monsoon period the temperature was comparatively high at all depths. Based on the analysis of long-term temperature data from Panangad region of the Cochin backwaters

Varma *et al.* (2002) reported that surface temperature varied between 27.0°C and 35.0°C. High values were observed during March-April prior to the southwest monsoon. In general, they noted that there is an inverse relation between temperature and salinity variation except when both increased during summer (February-April) and decreased prior to the onset of monsoon.

Nair *et al.* (1988) reported that the annual variation in temperature in paddy-cum-prawn culture fields was small (~5°C) to affect the environment. Temperature was low during December to February and showed increasing trend afterwards. This was followed by a decrease during the monsoon months and again an increase during the later months.

Sankaranarayanan *et al.* (1982) found that temperature values were low during the southwest monsoon in the culture fields. The minimum temperature was recorded during December-January. The low temperature observed during these months was due to the winter effect. In general higher temperature was recorded during the pre-monsoon season and also during the post-monsoon season. Singh (1987) reported that temperature values reached the peak during the pre-monsoon and showed a declining trend during the monsoon months in the seasonal and perennial fields. He observed the temperature ranging between 24.5 and 32.5°C.

2.1.3 pH

pH is an important parameter to be considered because it affects the metabolism and other physiological processes of aquatic organisms.

Sankaranarayanan and Qasim (1969) reported that pH showed considerable fluctuations at the surface in the Cochin backwaters. During the period of freshwater discharge the values at all depths were found to decrease reaching a minimum during July and August. It is interesting to note that a clear stratification such as that noticed in temperature, salinity and oxygen was not observed with regard to the pH values. The pH of the entire water column either decreases or increases simultaneously. Mathew (1987) reported that there were no seasonal trends in variations of pH and it fluctuated from 6.0 to 9.2 in the perennial fields, from 6.7 to 8.2 in the seasonal fields and from 6.1 to 8.3 in the coconut groves adjacent to the Cochin backwaters. Nair *et al.* (1988) reported low pH values during the monsoon months in some paddy-cum-prawn culture fields of the Cochin backwaters. Sankaranarayanan *et al.* (1982) found that the pH values varied between 7.0 and 8.2 in some tidal pools of the region. Higher values were recorded during the pre-monsoon season when the salinity was high. Low pH values were confined to the southwest monsoon period when the system was dominated by freshwater. The pH at the bottom was approximately the same as that near the surface.

2.1.4 Alkalinity

Sankaranarayanan and Qasim (1969) reported that variations in alkalinity in the backwaters were very little during the pre-monsoon months. During the monsoon season wide fluctuations were noticed with values as low as 20 ppm at the surface and approximately 125 ppm at the bottom.

High values of total alkalinity with wide fluctuations were reported by Mathew (1987) in some prawn culture fields of the region. The values ranged from 10 to 130 ppm in perennial fields, from 22.5 to 111 ppm in seasonal fields and from 24 to 185 ppm in coconut groves. High values were generally recorded during the pre-monsoon and low values during the monsoon months.

2.1.5 Dissolved oxygen

Balakrishnan and Shynamma (1976) observed that the estuarine water is undersaturated at all depths and in all seasons in the Cochin harbour area of the Cochin backwaters and that this may be due to the utilisation of dissolved oxygen for the decomposition of organic matter. They observed that the values were minimum during daybreak and gradually increased as the day advanced. At night there was a general decline, with the values varying in different depths.

Nair *et al.* (1988) reported that dissolved oxygen varies widely with tides in the paddy-cum-prawn culture fields. Seasonal fields being shallow showed low oxygen when compared to the perennial fields. This could be attributed to the decomposition of organic matter present at the bottom.

Singh (1987) found that seasonal and perennial culture fields had low oxygen values during the pre-monsoon and the values increased with the onset of the monsoon. Dissolved oxygen values were high during the peak monsoon month (July).

Sankaranarayanan *et al.* (1982) observed high oxygen values (2-7ppm) during the pre-monsoon months in tidal ponds of Ramanthuruth Island whereas low values (<4ppm) were observed during the southwest monsoon period. The values steadily increased in the following months.

2.1.6 Nutrients

Seasonal variations in nutrients of the Vembanad Lake were studied by Sankaranarayanan and Qasim (1969) and they found that the nutrient concentration showed a marked seasonal rhythm induced by the local precipitation and land run off. They reported that during the pre-monsoon when the system is predominantly marine, the nutrient concentration is low and it is high during the monsoon due to the maximum influx of freshwater. The highest concentrations of phosphate phosphorus were observed in the southern region of the lake either during the monsoon or during the post-monsoon period, whereas in the lower reaches the values were low. They found that the nitrate values were very high during the monsoon period especially in the surface waters.

Joseph (1974) reported that nutrient distribution in the Cochin harbour showed marked seasonal variations. Phosphate showed very high concentration during the pre-monsoon period. The maximum phosphate concentration recorded was 18μg at/l. With the onset of the southwest monsoon, a decrease in phosphate concentration was observed. Phosphate concentration decreased with the intensification of the southwest monsoon and reached very low levels in June and July. Nitrate nitrogen remained almost uniform throughout the year.

Nair *et al.* (1988) reported that the nitrate values in the culture fields showed an increasing trend during the monsoon months due to freshwater discharge. The low nitrate concentration during the remaining period was due to less land drainage and high primary production.

Sankaranarayanan *et al.* (1982) reported that the inorganic phosphate values were high throughout the year in the tidal ponds of Ramanthuruth Island, and nitrate values varied between <1 and 15 μg at/l. Nitrate values showed a general decrease during March to May and during September and October and the highest values were recorded during June and August.

Sankaranarayanan and Qasim (1969) reported that silicate values remained low from December to April and became high during the monsoon months. The silicon cycle was entirely dependent upon the freshwater discharge, as evidenced by the fact that values decrease from the surface to bottom, showing a typically inverse relationship with the salinity profile. Maximum values recorded during July and August indicated that silicon is associated with the heavy silt load of the estuary. Sankaranarayanan *et al.* (1986) determined dissolved silicate for one year from the estuarine mouth to the freshwater region and found a linear relationship between silicate and salinity. Spatial and seasonal distribution of salinity and silicon in the estuary has been explained by Anirudhan *et al.* (1987). Anirudhan and Nambisan (1990) reported that the silicate concentration in the estuary is largely dependent on external sources such as river discharge and land drainage. They found that negative correlation exists between salinity and reactive-silicon indicating conservative behaviour of reactive silicon in the estuary. High monsoonal riverine input of reactive silicon is quantitatively lost in the estuary largely influenced by salinity.

2.2 ZOOPLANKTON

In the Cochin backwaters, the pioneering study on plankton was of George (1958) who enumerated the common groups and brought to light the relation existing between the seasonal changes of zooplankton population and some of the environmental factors.

There are several reports on the seasonal and spatial changes of zooplankton of the Vembanad Lake and connected backwaters (Nair and Tranter, 1971; Menon *et al.*, 1971; Haridas *et al.*, 1973; Wellershaus, 1974; Madhupratap, 1978).

Variations in the relative proportions of specific groups such as copepods, chaetognaths, hydromedusae, siphonophores, decapod larvae and cladocerans have been studied by various authors (Wellershaus, 1969, 1970; Abraham, 1970; Pillai, 1970, 1972; Pillai *et al.*, 1973; Srinivasan, 1972; Santhakumari and Vannucci, 1972; Mohammad and Rao, 1972; Pillai and Pillai, 1973).

Menon *et al.* (1971) investigated the total biomass and faunistic composition of the zooplankton in Cochin backwaters during January to December and found that three groups viz. copepods, decapod larvae and cladocerans dominated the total zooplankton. He observed that no single group continued to dominate the community though copepods were the major component of the community for most part of the year and abundance of cladocerans was noted only during the low salinity period.

Studies by several authors including Nair and Tranter (1971), Haridas *et al.* (1973), Wellershaus (1974), Madhupratap and Haridas (1975), Rao *et al.* (1975), Madhupratap (1978) and Silas and Pillai (1975) revealed that the composition and intensity of zooplankton are influenced mainly by salinity. These studies also show that the diversity and abundance of zooplankton is more during the pre-monsoon period which is characterized by high salinity.

Pillai and Pillai (1973) reported that the tidal influence is significant in the diel variations in the intensity of zooplankton.

Madhupratap and Haridas (1975) observed that the organisms characteristic of high salinity are eliminated during the monsoon and those characteristic of low salinity occupy the middle and upper reaches of the estuary. During the post-monsoon season the animals of high saline water begin to appear in the plankton. During the peak of the monsoon the backwaters enjoy freshwater conditions and the total biomass of zooplankton is greatly reduced (Rao *et al.*, 1975; Silas and Pillai, 1975).

Rao *et al.* (1975) observed that most of the estuarine species flourish in the region away from the barmouth towards the middle reaches of the estuary.

Silas and Pillai (1975) reported that majority of the zooplankton in the backwater belongs to the inshore population, some to the freshwater environment and a few are endemic. They also found that the food potential of zooplankton for plankton feeding fishes and their larvae is high. The influence of seasonal variations in environmental conditions on the distribution of zooplankton in the backwaters has also been studied by them.

Though there are several reports on zooplankton from Cochin backwaters with respect to various hydrographic parameters, studies on plankton of the prawn culture fields connected to the backwaters are rather limited.

Gopalakrishnan *et al.* (1988) who studied the zooplankton of some paddy-cum-prawn culture fields in and around Cochin reported that there is a scarcity of zooplankton in these fields. They also found that the seasonal culture fields had greater abundance of zooplankton compared to the perennial fields.

Jose *et al.* (1988) studied the zooplankton of a brackishwater fish farm in the area and reported that it is mainly composed of copepods with an annual mean of 170 Nos/l, which is 62.68% of the total plankton. The copepods were dominant during the saline period from January to May (140-1021 nos/l) whereas during the low saline phase from June to October their number was low and it ranged from 12 to 18 nos/l.

Joseph (1988) reported that in the culture fields the zooplankton are constituted mainly by copepods, rotifers and crustacean larvae.

2.3 BENTHOS

Estuarine benthic fauna generally consists of marine, brackishwater, freshwater and migratory forms. The faunistic composition of tropical estuarine benthos is represented by a wide spectrum of animals belonging to groups such as polychaetes, crustaceans, molluscs, nematodes, fishes etc.

Several investigations have been carried out on the distribution and abundance of benthic fauna in relation to hydrographic parameters and sediment characteristics in the Cochin backwaters (Desai and Krishnankutty, 1967, 1969; Devassy and Gopinathan, 1970; Ansari, 1974, 1977; Kurian *et al.*, 1975; Pillai, 1977; Saraladevi and Venugopal, 1989; Sunil Kumar, 1995, 2002). Benthic fauna of the seasonal and perennial fish/prawn culture fields connected to the backwater system has been studied by Srinivasan (1982), Sugunan (1983), Singh (1987), Jose *et al.* (1988), Joseph (1988), Aravindakshan *et al.* (1992), Balasubramanian *et al.* (1995), Sunil Kumar (1998, 2002) and Preetha and Pillai (2000). These studies have shown that among various environmental parameters that affect the distribution and abundance of benthic fauna, the most significant seems to be salinity and the nature of the substratum in the Cochin backwaters. They have reported that the occurrence of benthic fauna was poor during the monsoon and rich during the other periods.

Ansari (1974) and Kurian *et al.* (1975) reported that because of constant water flow and relative shallowness of the lake, dissolved oxygen might not be a limiting factor for the bottom fauna.

A progressive reduction in the faunal diversity and abundance with decreasing salinity from the lower reaches of the backwater towards the upper reaches has been observed by Ansari (1974, 1977), Saraladevi and Venugopal (1989) and Sunil Kumar (1995).

According to Pillai (1977) the low density of bottom fauna during the monsoon months may be due to the fall in salinity. He observed that recolonization of bottom fauna started during the beginning of the post-monsoon season and steadily increased and the maximum was recorded during the pre-monsoon season.

Desai and Krishnankutty (1969) compared the estuarine benthic fauna with marine benthic fauna and of the near shore regions of the

Arabian Sea and reported the difference between the two ecologically different systems and the factors governing the abundance of benthos.

Devassy and Gopinathan (1970) reported that there was an increase in the benthic biomass from marine to freshwater region during the monsoon, which they attributed to the disappearance of transition from marine to freshwater conditions.

Jose *et al.* (1988) and Sunil Kumar (1998, 2002) reported that changes in the ecological conditions like salinity, temperature and dissolved oxygen during the monsoon period seem to be not affecting the benthic secondary production in the culture fields. However, Gopalan *et al.* (1987) observed rich bottom fauna during the monsoon in the estuary. Sunil Kumar (1998, 2002) observed the same in the prawn culture fields also.

The benthic fauna is mainly composed of polychaetes, molluscs and crustaceans in the order of abundance in the backwaters and the culture fields (Ansari, 1974; Kurian *et al.*, 1975; Pillai, 1977; Singh, 1987; Jose *et al.*, 1988; Saraladevi and Venugopal, 1989; Aravindakshan *et al.*, 1992; Sunil Kumar, 1995, 1998, 2002). The polychaete abundance is restricted to locations of fine deposits of sand, silt and clay (Kurian, 1972; Ansari, 1974). Pillai (1977) reported that polychaete fauna showed decrease in number during the monsoon and the maximum numbers were recorded during the pre-monsoon.

Kurian *et al.* (1975) reported that in the Cochin backwaters bivalves formed the major component of Mollusca and they were abundant in the low salinity region of the estuary. Bivalves being filter feeders are distributed mainly in the sandy region of the estuary.

Ansari (1974) found the occurrence of crustaceans throughout the estuary in all types of substrate and concluded that they are epibenthic in nature and have no substratum preference.

Sunil Kumar (1995) reported that there is a strong association between various species of bottom fauna, rather than competition for space and food in the Cochin backwaters. Aravindakshan *et al.* (1992) reported that in the culture fields benthos showed little coexistence and that they preferred independent existence.

Substratum with thick clay supported a poor fauna, whereas that with dominance of fine sand fraction and with sand, silt and clay in more or less equal proportions supported dense and varied benthic population in the backwater and culture ponds (Desai and Krishnankutty, 1967; Kurian, 1967; Pillai, 1977; Singh, 1987; Aravindakshan *et al.,* 1992; Sunil Kumar, 1995, 2002).

Sunil Kumar (1998) reported that clayey-sand or silty-sand along with rich availability of organic matter might not be suitable for high benthic production because it provides little interstices and burrowing of benthos becomes difficult.

Biomass distribution, horizontal zonation, relative dominance and vertical distribution of polychaetes were studied by Sunil Kumar (2002) in the littoral sediment of Cochin estuarine mangrove habitat and found that there was substantial amount of polychaete biomass existing in the region and it could be used for assessing the commercial demersal fishery potential.

A comparative study on the faunistic composition of bottom macrofauna and their seasonal distribution and abundance in perennial and seasonal culture systems and adjacent backwater area has been carried out by Singh (1987). He reported that besides the physico-chemical environmental parameters, human interference like dredging also was one of the factors responsible for changing the benthic ecology as well as the species diversity.

Joseph (1988) reported that in the culture fields meiofauna is mainly composed of nematodes and copepods and macrobenthos is constituted mainly by amphipod, tanaidaceans, polychaetes, chironomid larvae and gastropods in the order of abundance.

Balasubramanian *et al.* (1995) reported that the prawn culture fields in and around Cochin backwaters were found to be rich in nutrients and primary production and have detritus dominated simple food chain aided by a substratum predominantly of fine sand, silt, and clay and rich in organic content and benthos.

Sunil Kumar (1998) compared the community structure and distribution of benthos of a prawn culture field with the macrofauna of mangroves in the surrounding margin of culture field and reported that there is a rich population density and diversity of species in the prawn culture field, compared to the mangroves and it was related to the variability of the substratum characteristics.

The meiobenthos of three different types of traditional prawn culture systems around Cochin were studied by Preetha and Pillai (2000) and they reported that nematodes were the most dominant group (79.6%) of the total meiofauna followed by harpacticoids and polychaetes. The perennial ponds had the highest abundance of meiobenthos (69.9%) followed by canals (17.9%) and seasonal culture fields (12.2%).

Materials and Methods

3. MATERIALS AND METHODS

Based on variations in the salinity of the Cochin backwaters three hydrographical seasons can be made out annually *viz.* the monsoon season (June-September), the post-monsoon season (October-January) and pre-monsoon season (February-May). As a result of the freshwater influx due to heavy rains through the rivers, the monsoon season is characterized by very low salinity often below 1‰ throughout the backwater except at the barmouth region. During the post-monsoon season the salinity gradually rises up and the area attains saline water conditions in the summer season (Cheriyan, 1967). The prawn filtration field of the College of Fisheries at Panangad where the present study was conducted is connected to the southern part of the Cochin backwaters. Since the culture field was very shallow and the depth was below 1m, vertical variations in the hydrographical parameters were not considered as significant as pointed out by Sankaranarayanan *et al.* (1982) and Nair *et al.* (1988). Monthly samples for hydrographical and biological studies were collected during the period from November 2002 to July 2003 involving the above mentioned three hydrographical seasons of varying salinities. Samples were also collected simultaneously from a station located in the adjacent backwater system. This station is situated in the narrow arm between Panangad and Kumbalam (Fig. 1; Plate 1). The methods used to collect the hydrographical and biological data for the present study are described below.

3.1 HYDROGRAPHICAL PARAMETERS

Hydrographical features like temperature, pH, transparency, salinity, total alkalinity, dissolved oxygen, nitrate-N, phosphate-P and

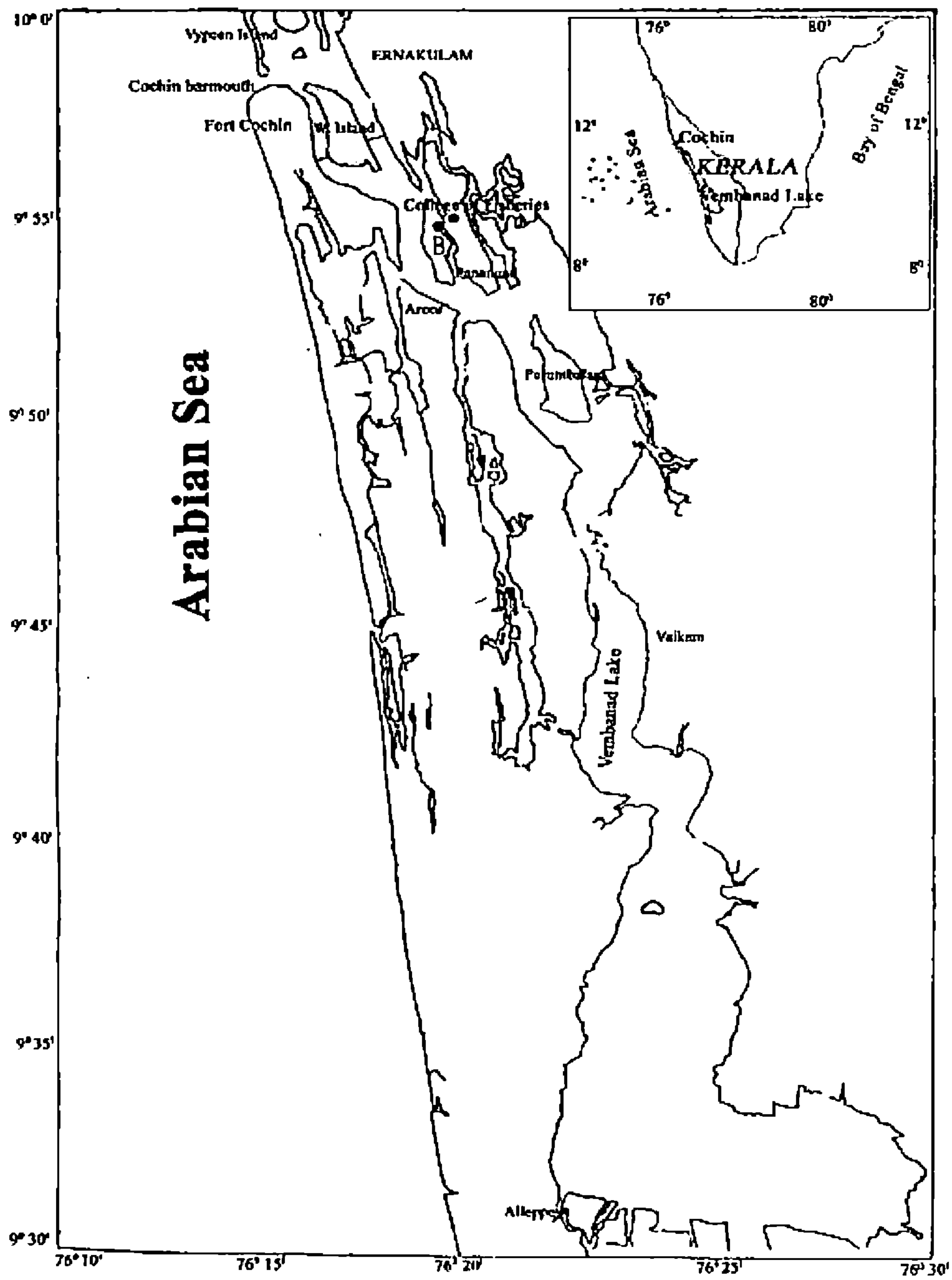

Fig. 1. Study area

The culture field is in the campus of College of Fisheries. Stn.B is in the adjacent region of Cochin backwater.

(A)

(B)

Plate 1. Photographs showing the culture field and adjacent backwater studied , (A) Culture field and backwater
(B) Culture field

(C)

(D)

Plate 1. (Contd.) (C) Culture field (another view)

(D) Backwater

silicate-Si were observed. Surface water samples were collected using a clean plastic bucket for studying the hydrographical parameters.

3.1.1 Temperature

The surface water temperature was recorded using a precision centigrade thermometer immediately after collecting the water.

3.1.2 pH

pH was determined using universal pH indicator solution by colour comparison. Values were periodically checked with digital pH meter.

3.1.3 Transparency

A Secchi disc was used for determining the transparency of the water column. It was lowered into the water and the depth at which it disappeared was noted. It was then slowly raised upwards and the depth at which it reappeared was noted. The average value of these two readings was calculated and expressed in centimeters.

3.1.4 Salinity

Salinity was estimated using Knudsen-Mohr titration method. The silver nitrate solution was prepared by dissolving 16.5 g in 500 ml distilled water. This solution was standardised against 15 ml of standard seawater of chlorinity 19.374 approved by I.A.P.S.O. and supplied by the Institute of Oceanographic Sciences, Wormly, Godalming, Surrey England. 5 ml of sample was used and titre value was scaled up equivalent to 15 ml. Standard procedure as described in Strickland and Parsons (1972) was employed. Chlorinity was converted to salinity using the relation S‰ = Chlorinity x 1.80655 as given in International Oceanographic Tables (UNESCO, 1968).

3.1.5 Total Alkalinity

Alkalinity was determined by acidimetric titration following standard method (Lenore *et al.*, 1998).

3.1.6 Dissolved oxygen

Standard Winkler's method (Strickland and Parsons, 1972) was followed for the estimation of dissolved oxygen content of water samples. Surface water samples were collected in 125 ml clean oxygen bottles and care was taken to avoid trapping of air bubbles during collection.

3.1.7 Nutrients

For the estimation of nutrients surface water samples were collected and stored in clean plastic bottles of 250 ml capacity. Nitrate-N, Phosphate-P and Silicate-Silicon were the nutrients estimated.

All these bottles were stored in an icebox with ice and subsequently kept in a freezer to prevent the loss of nutrients during storage.

Water samples collected in polythene bottles were analyzed in the laboratory following standard photometric methods using U.V-vis spectrophotometer (JASCO, V-530). Phosphate and Reactive Silicon were measured by standard molybdenum blue spectrophotometric method and nitrate was estimated by standard method by cadmium reduction followed by spectrophotometry (Grasshoff *et al.*, 1983).

3.1.8 Soil texture

Soil texture analysis was done with the objective of determining the textural composition viz. sand, silt and clay content and to classify the soils to any particular textural group and to identify the dominant grain sizes present in the soil. Textural composition was estimated by mechanical analysis method of Chattopadhyay (1998) as described below.

For soil texture analysis the sediment samples were collected (in triplicate) using Van Veen grab from the culture field and the backwater. The soil samples were placed in plastic trays and dried under shade. After drying, the soil samples were ground with a wooden pestle and mortar.

20g of dried soil sample was taken in 500 ml beaker and 250 ml of distilled water was added. Then boiled for 10-15 minutes and supernatant water was decanted. 30 ml of 6% H_2O_2 was added and digested on a hot plate; digestion was continued till the frothing is stopped. 30 ml of 2 N HCl and 100 ml distilled water were added, and boiled for few minutes. The soil suspension was allowed to stand for one hour with frequent stirring to make the soil free of carbonates. After one hour the solution was filtered and washed repeatedly with hot water till the filtrate become chloride free; tested with silver nitrate solution. The suspension was transferred to a 250 ml conical flask; 5 ml of 2 N NaOH was added. The solution was stirred for half an hour with a mechanical stirrer and the contents were transferred to 1000 ml tall cylinder. Volume was made up with distilled water and the entire volume was stirred thoroughly with the help of a stirrer. Suspension was allowed to stand for exactly 4 minutes. A 20 ml pipette was lowered to 10 cm depth of the suspension and 20 ml of the content was collected and transferred to a 50 ml tared beaker marked as beaker A. The volume of the cylinder was made upto 1000 ml with distilled water, and stirred as before and allowed to stand for 6 hours. Same procedure was repeated to collect 20 ml of suspension to a tared beaker marked as B. Suspensions taken in two beakers were dried in an oven to constant weights.

Actual weights of dry materials in the beakers were obtained by subtracting the weights of the empty beakers from the values of beakers + dried materials as follows

Percentage of clay = Y x 250

Percentage of silt = (X-Y) x 250

Percentage of Sand = 100 – (X x 250),

Where, 'X' is the weight of dry material in beaker A.

'Y' is the weight of dry material in beaker B.

3.2 COLLECTION OF ZOOPLANKTON

Zooplankton samples were collected once in a month from the culture field and the adjacent backwater. Samples were collected from three different spots from the culture field and the data obtained were pooled together to get an average picture, while single sample was collected from the backwater.

50 litres of water was taken using a bucket and filtered through a conical plankton net made of bolting silk No. 25 (63 micro meter mesh size). The plankton collected at the cod end of the net in the collecting bucket was transferred to plastic bottles and preserved in 5% formalin for analysis.

As the plankton samples contained detritus, phytoplankton and decaying leaves, twigs etc, the numerical estimation of zooplankton alone was considered in the present investigation.

The preserved sample of zooplankton was made up to 50 ml in a measuring cylinder and stirred for uniform distribution. Soon after stirring 1 ml representative subsample was transferred to a plankton-counting chamber (Sedgwick-Rafter cell) using a pipette and observed under a stereoscopic binocular zoom microscope for identification and counting. The animals were identified up to group level. Three subsamples of 1ml each were thus analysed and average number of each group per litre of water (No./l) was calculated.

3.3 COLLECTION OF MACROBENTHOS

Bottom samples for macrobenthos were taken from three different places in the culture field, whereas a single sample was collected from the adjacent backwater by using Van Veen grab having an area of 0.042 m^2. While collecting the sample, it was ensured that the grab was full and the top layer was undisturbed by opening the window of the grab and observing the grab contents superficially.

The content of the grab was transferred to plastic trays and for separating the animals from the sediment sample hand-sieving (0.33 mm mesh size) method was employed using filtered water. After a cursory examination, the residue from the sieve was transferred to plastic containers and preserved in 5% formalin for analysis.

The macrobenthos were sorted out using a fine needle and a fine pipette. They were identified up to group level and counted under a stereoscopic binocular zoom microscope. The results were calculated as No./m^2.

3.4 STATISTICAL ANALYSIS

To study the relationship between the total number of zooplankton and different hydrographic parameters, linear correlation coefficients ('r') were worked out (Snedecor and Cochran, 1968). In the case of macrobenthos, correlation of total number with sediment texture (sand, silt and clay), salinity, dissolved oxygen and pH were estimated. The computed values of correlation coefficient ('r') between any two variables were tested for significance at 5% level.

The correlation coefficient ('r') was estimated by using the following formula,

$$r = \frac{\Sigma xy - \Sigma x \Sigma y/n}{[\Sigma x^2 - (\Sigma x)^2/n]\ [\Sigma y^2 - (\Sigma y)^2/n]}$$

Results

4.RESULTS

4.1 HYDROGRAPHICAL CONDITIONS IN THE CULTURE FIELD AND BACKWATER

4.1.1 Temperature

The water temperature in the culture field varied from 26.0 to 33.5°C. The minimum was recorded in November and the maximum in May (Table 1; Fig. 2). In the backwater temperature ranged from 26.0 to 32.5°C. The minimum and maximum temperatures were recorded in November and May, respectively (Table 2; Fig.2). Average temperatures during the study period were 28.8°C and 29.1°C in the culture field and backwater, respectively.

4.1.2 Salinity

In contrast to temperature, wide ranges of salinity variations were recorded from both the culture field and the backwater (Fig. 3). Salinity ranged between 0.51 and 27.37‰ and 0.38 and 28.78‰ in the culture field and backwater, respectively. The highest salinities of 27.37‰ and 28.78‰ were recorded in January and February in the culture field and backwater, respectively. In both the culture field and backwater low values (<1‰) were recorded in July and November (Table 1, 2).

4.1.3 Transparency

The transparency values were relatively less in both the culture field and backwater. In the culture field Secchi disc readings ranged from 30 to 38cm, while in the backwater they ranged between 30 and 35cm during the period of observation (Table 1, 2; Fig. 4).

Table 1. Monthly variations in hydrographical parameters in the culture field

Parameter	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Average
Temperature (°C)	26.0	27.7	28.2	30.0	29.1	30.2	33.5	27.0	28.0	28.8
Salinity (ppt)	0.84	13.20	27.37	26.49	18.39	19.90	17.11	4.85	0.51	14.29
Transparency (cm)	37.5	36.0	38.0	35.0	32.0	30.0	35.0	35.0	32.0	34.5
pH	6.5	9.0	9.0	10.0	7.0	10.0	10.0	7.0	7.0	8.4
Dissolved O_2 (ml/l)	2.31	4.84	3.05	3.59	2.29	3.20	6.08	4.13	3.89	3.70
Alkalinity (ppm)	65	40	41	44	39	40	33	18	12	37
Nitrate-N (μ mol/l)	6.30	2.95	2.32	0.92	1.39	1.33	5.54	9.29	9.33	4.37
Phosphate-P (μ mol/l)	1.04	1.20	0.72	0.72	2.54	1.87	ND	0.04	ND	0.90
Silicate-Si (μ mol/l)	47.64	26.85	7.28	8.35	20.12	14.52	16.36	45.68	55.54	24.34

ND: Not detected

Table 2. Monthly variations in hydrographical parameters in the backwater

Parameter	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Average
Temperature (°C)	26.0	28.2	29.1	30.6	29.6	30.0	32.5	28.0	28.5	29.1
Salinity (ppt)	0.56	16.18	28.27	28.78	19.92	20.18	14.30	7.91	0.38	15.17
Transparency (cm)	31	32	30	32	30	35	32	33	34	32
pH	7.0	9.0	10.0	9.7	8.0	9.5	10.0	7.5	7.0	8.6
Dissolved O_2 (ml/l)	3.96	3.87	3.60	2.86	3.73	2.95	6.32	4.37	4.50	4.02
Alkalinity (ppm)	44	47	42	47	36	40	26	22	10	35
Nitrate-N (µ mol/l)	10.00	3.61	2.92	1.98	1.13	1.85	9.35	9.42	10.38	5.62
Phosphate-P (µ mol/l)	0.04	0.72	0.14	1.34	2.49	2.30	1.05	0.86	ND	1.00
Silicate-Si (µ mol/l)	53.36	22.52	10.23	15.23	18.27	13.07	20.78	52.21	65.66	30.15

ND: Not detected

4.1.4 pH

In the culture field pH varied between 6.5 and 10.0, while in the backwater it varied between 7.0 and 10.0. It was observed that both in the culture field and backwater alkaline conditions prevailed in most of the months. In both the culture field and backwater the lowest pH was recorded in November followed by June and July, coinciding with the northeast monsoon and southwest monsoon, respectively (Table 1, 2).

In both places high pH values were recorded during the pre-monsoon period. It remained more or less the same during the pre-monsoon period and with the onset of southwest monsoon the values decreased (Fig. 5). In March a sudden drop in pH was observed in both the culture field and backwater.

4.1.5 Dissolved Oxygen

In both the culture field and backwater wide monthly fluctuations were observed in dissolved oxygen in different months (Fig. 6). The values varied from 2.29 to 6.08 ml/l and from 2.86 to 6.32 ml/l in the culture field and backwater, respectively (Table 1, 2). In the culture field the lowest value was recorded in March while the highest value was noted in May. In the backwater the lowest value was observed in February and the highest value in May.

The average values during the study period were 3.70 ml/l and 4.02 ml/l in the culture field and backwater, respectively. Both the culture field and the backwater showed comparatively low oxygen values during the pre-monsoon and high values during the monsoon months (Fig. 6).

4.1.6 Total Alkalinity

Total alkalinity ranged from 12 to 65 ppm and from 10 to 47 ppm in the culture field and backwater, respectively. In the culture field the highest alkalinity was recorded in November and the lowest value in July. In the backwater the highest value was observed in December and February, whereas the lowest value was recorded in July (Table 1, 2). In both the culture field and the backwater relatively higher values were observed during the pre- and post-monsoon months. Decrease in total alkalinity was observed with the onset of the monsoon (Fig. 7).

4.1.7 Nutrients

4.1.7.1 Nitrate-N

In the culture field nitrate-N varied between 0.92 and 9.33 μmol/l. There was a general decrease during the pre-monsoon period. High values were recorded during the monsoon period (Table 1; Fig.8). Nitrate values in the backwater varied between 1.13 and 10.38 μmol/l. Low values were observed during the pre-monsoon months whereas high values were recorded during the monsoon period (Table 2; Fig.8). On an average nitrate content was found to be slightly more in the backwater (5.62 μmol/l) than in the culture field (4.37 μmol/l).

4.1.7.2 Phosphate-P

Phosphate-P values were found to be relatively low in both the culture field and the backwater (Table 1, 2). In the culture field the concentration of phosphate-P varied between nil and 2.54 μmol/l with an average of 0.90 μmol/l, whereas in the backwater it varied between nil and 2.49 μmol/l, with an average of 1.00 μmol/l. Monthly variations in phosphate values are shown in Fig. 9. It showed comparatively high values during the pre-monsoon months.

4.1.7.3 Silicate-Si

Silicate-Si concentration showed wide variations in different months in both the culture field and backwater (Table 1, 2; Fig. 10). In the culture field the values ranged between 7.28 and 55.54 µmol/l with an average of 24.34 µmol/l while in the backwater they ranged from 10.23 to 65.66 µmol/l, with an average of 30.15 µmol/l. In both places silicon values remained low during the pre-monsoon months and high values were recorded during the monsoon and post-monsoon months (Fig. 10).

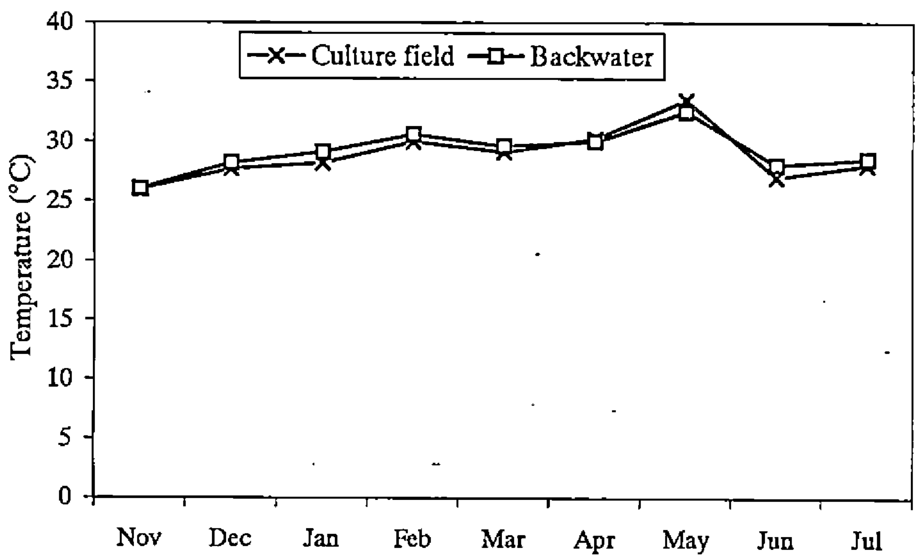

Fig. 2. Monthly variations in temperature in the culture field and backwater

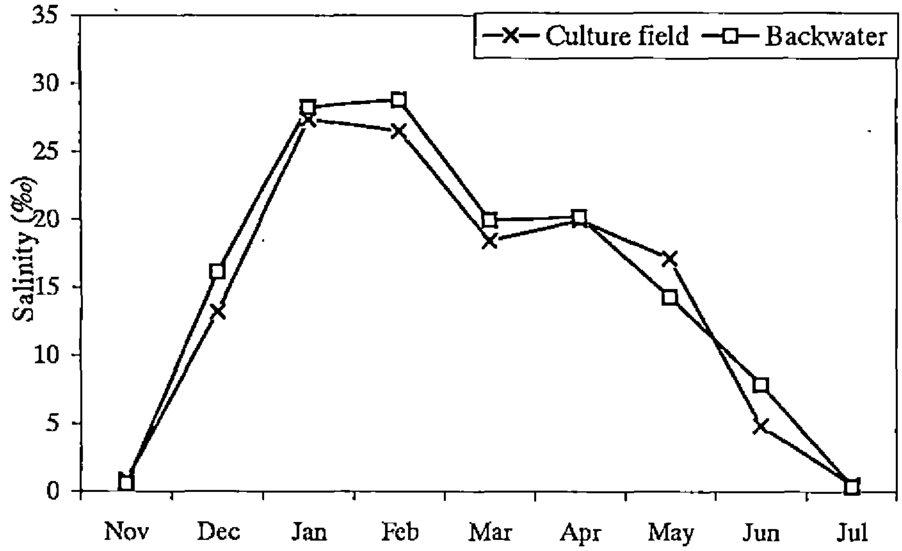

Fig. 3. Monthly variations in salinity in the culture field and backwater

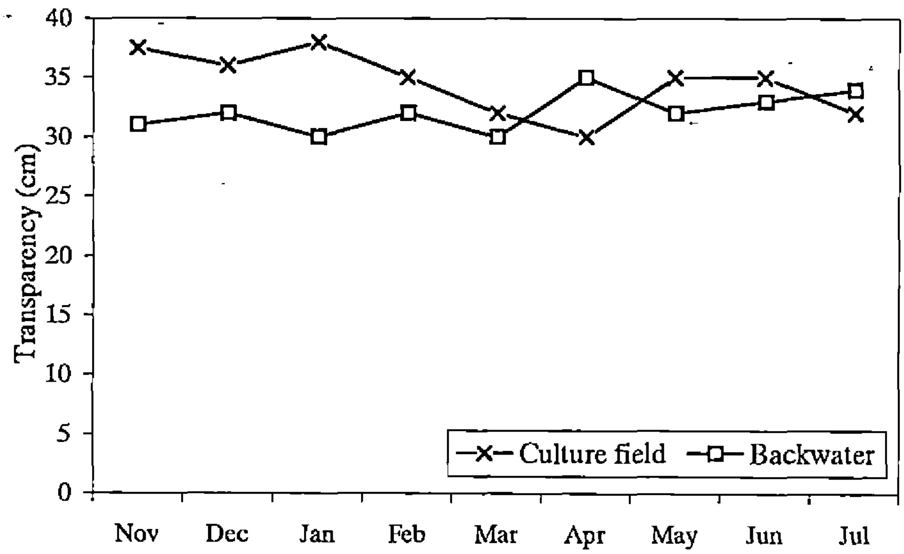

Fig. 4. Monthly variations in transparency in the culture field and backwater

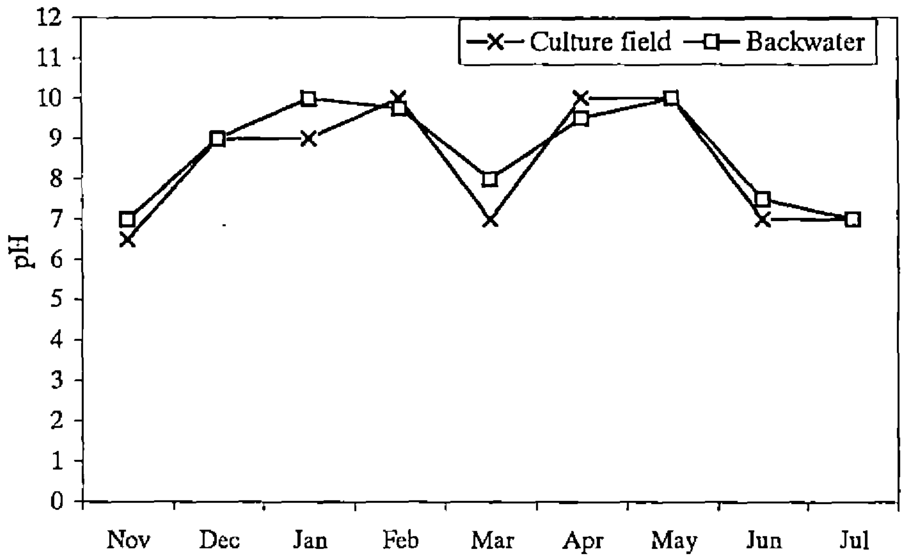

Fig. 5. Monthly variations in pH in the culture field and backwater

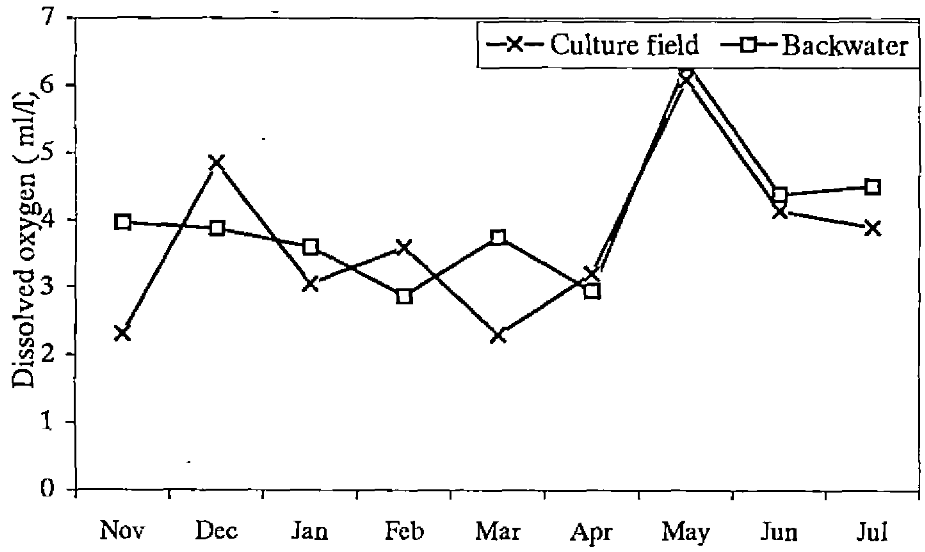

Fig. 6. Monthly variations in dissolved oxygen in the culture field and backwater

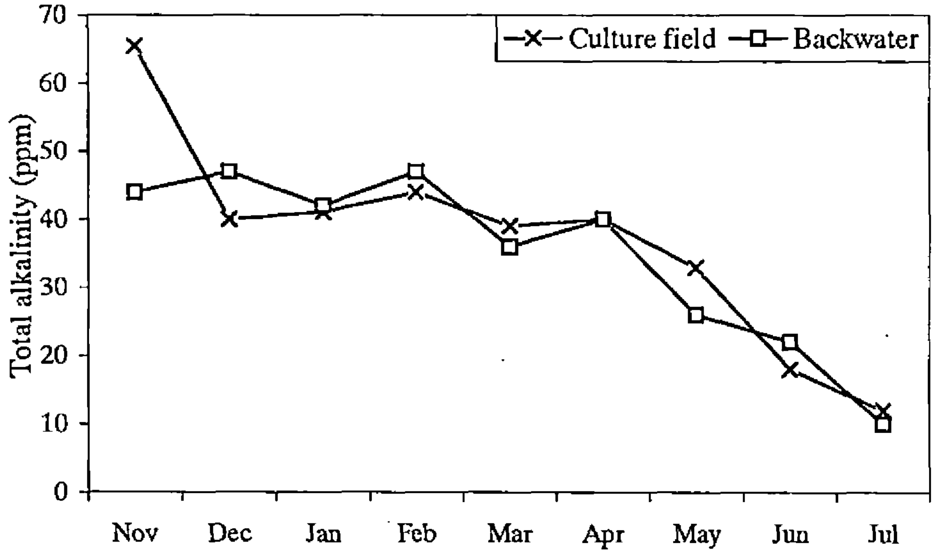

Fig. 7. Monthly variations in total alkalinity in the culture field and backwater

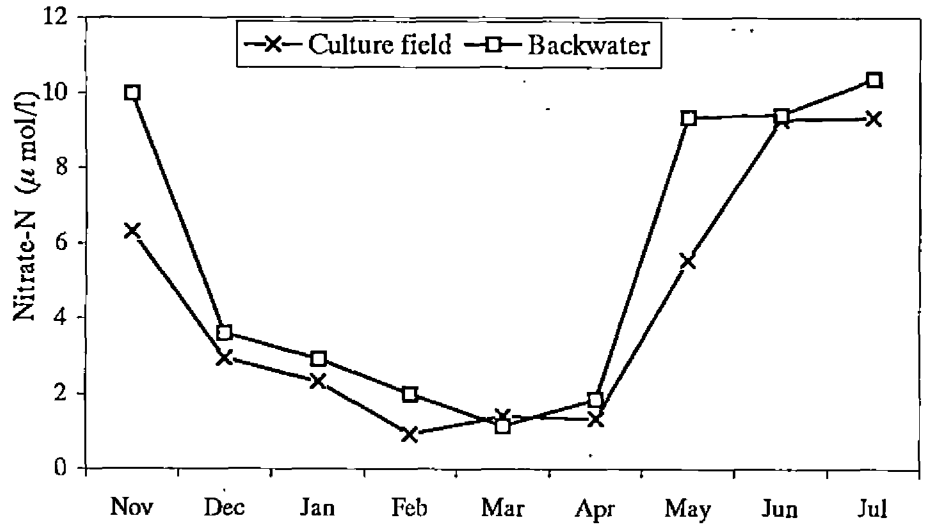

Fig. 8. Monthly variations in nitrate-N in the culture field and backwater

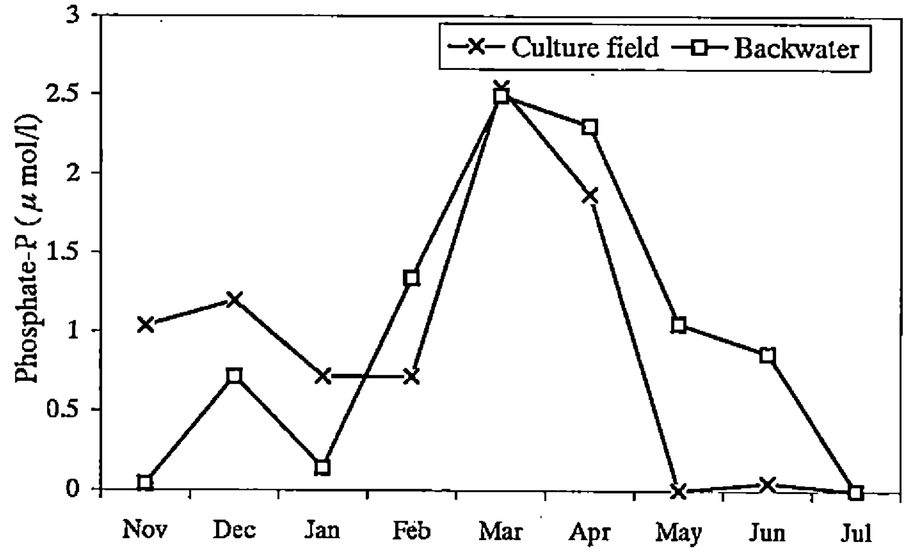

Fig. 9. Monthly variations in phosphate-P in the culture field and backwater

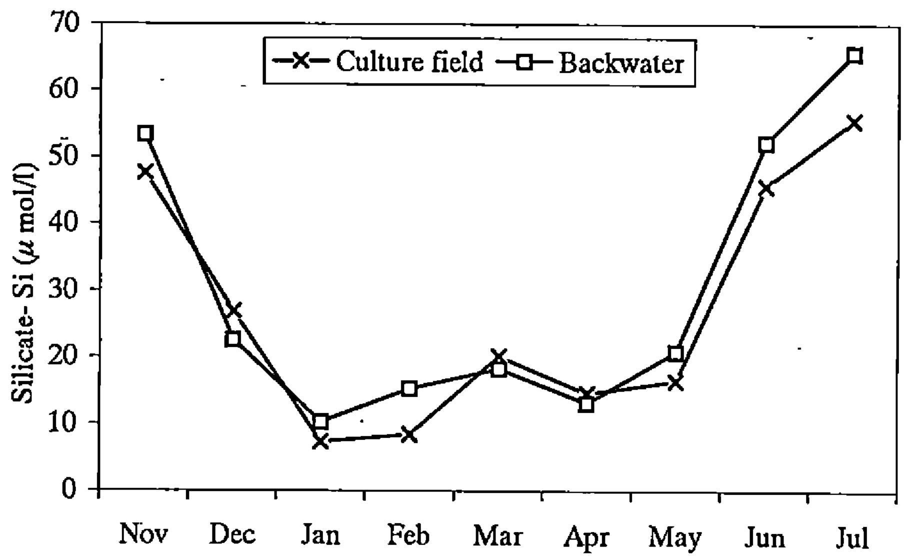

Fig. 10. Monthly variations in Silicate-Si in the culture field and backwater

4.1.8 Soil texture

Textural composition of the sediment in the culture filed and backwater are given in Table 3 and Fig. 11,12. Average sediment characteristics during different seasons in the culture field and backwater are presented in Table 4.

The substratum was generally sandy in the culture field during the period of investigation. During the post-monsoon and monsoon the silt and clay fractions of the sediment were slightly high with the nature of substratum becoming clayey sand and sandy clay, respectively. During the pre-monsoon the substratum was considerably stable and sandy in nature with slight variations in sand-silt-clay fractions (Table 4, Fig. 11).

In the backwater the substratum was generally silty sand in nature. During the monsoon and the post-monsoon the substratum was silty sand while during the pre-monsoon it was sandy silt in nature (Table 4, Fig.12).

Table 3. Textural composition of the sediment in the culture field and backwater (percentage)

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Average
Culture field										
Sand (%)	74.5	52.5	58.3	79.4	74.1	84.2	94.2	66.4	75.9	73.3
Silt (%)	15.5	15.0	25.0	9.5	12.7	6.8	1.4	14.0	10.0	12.2
Clay (%)	10.0	32.5	16.7	11.1	13.2	9.0	4.4	19.6	14.1	14.5
Backwater										
Sand (%)	56.8	32.5	75.5	67.5	76.0	72.5	69.0	64.4	45.3	62.2
Silt (%)	32.2	30.0	8.5	16.5	14.8	21.5	28.0	23.1	33.6	25.3
Clay (%)	11.0	37.5	16.0	16.0	9.2	6.0	3.0	12.5	21.1	12.5

Table 4. Sediment characteristics in relation to seasons in the culture field and backwater

Pond				
	Sand (%)	Silt (%)	Clay (%)	Sediment Type
Monsoon (June &July)	71.18	12.00	16.82	Sandy clay
Post-monsoon (Nov. to Jan.)	62.10	18.50	19.40	Clayey sand
Pre-monsoon (Feb. to May)	83.01	7.61	9.38	Sandy
Backwater				
Monsoon (June &July)	54.88	38.36	6.76	Silty sand
Post-monsoon (Nov. to Jan.)	54.97	23.52	21.51	Silty sand
Pre-monsoon (Feb. to May)	71.31	20.22	8.47	Sandy silt

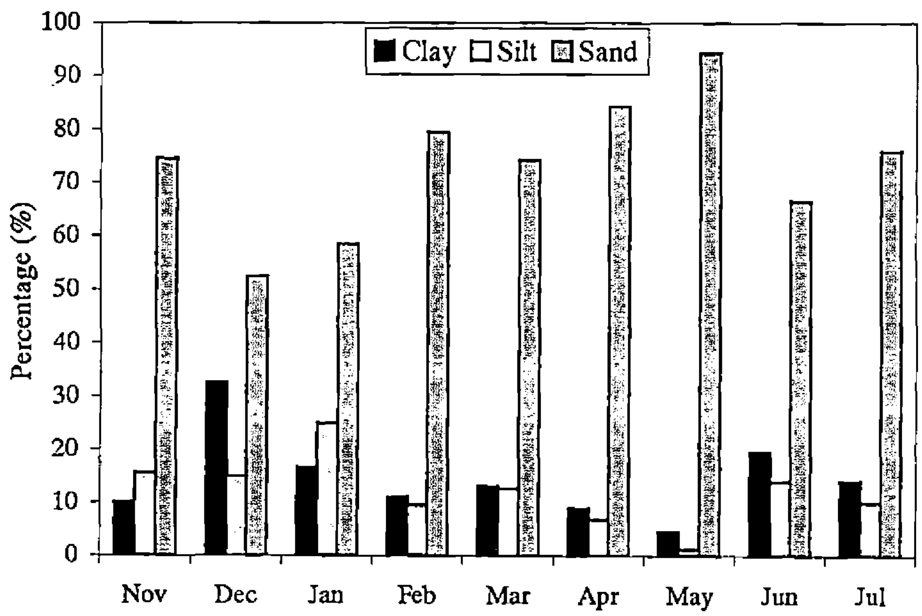

Fig. 11. Monthly variations in soil texture in the culture field

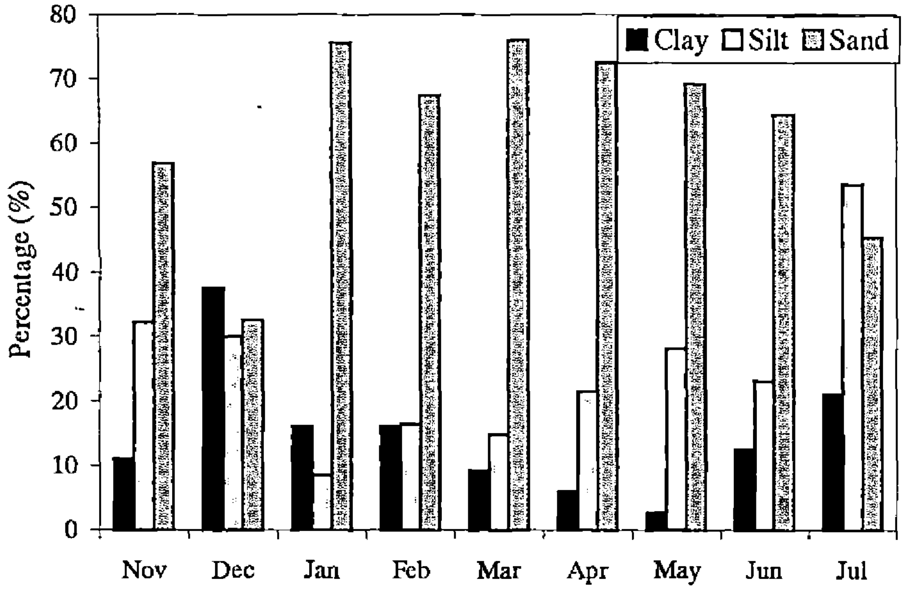

Fig. 12. Monthly variations in soil texture in the backwater

4.2 ZOOPLANKTON

The major groups of zooplankton encountered during the period of investigation were copepods, crustacean larvae, nematodes (though benthic in nature, young ones were found in plankton), tintinnids, veliger larvae of molluscs, rotifers, fish eggs, polychaete larvae, urochordates and cladocerans.

Considering their frequency of occurrence and abundance (excluding unusual swarms), groups such as copepods, crustacean larvae, tintinnids, veliger larvae, nematodes and rotifers were treated as individual groups, while the groups constituting less than 0.5% in total were included under the category 'others'.

Numerical abundance (No./l) of various zooplankton groups encountered in the culture field is given in Table 5 and Fig. 13,14. The number of organisms ranged between 10 and 27 No./l and the monthly average was 16.4 No./l. The maximum number was observed in March. However, the monthly variations in the intensity of zooplankton were not much pronounced.

Among the various groups crustacean larvae, copepods and tintinnids were found to be the major contributors in the culture field in the order of abundance. Crustacean larvae and copepods were encountered throughout the period of investigation with considerable variations in intensity in different months. The crustacean larvae were the most predominant component of the zooplankton with the average of 6.6 No./l, which is 39.71% of the total plankton. They showed their maximum abundance (10-11 No./l) during December, April and July. Small numbers (<5 No./l) were recorded during November, January and May while February, March, and June showed moderate (5-8 No./l) numbers (Fig.14).

Copepods, which come second in abundance with an average of 4.7 No./l, formed 28.44% of the total plankton. They showed maximum abundance in July. Seasonal variations in abundance were not much in the case of copepods also (Fig.14). Their number was moderate in January, March and June, whereas during the other months they were few in numbers. Tintinnids formed about 15.86% of the total plankton. Their number was maximum in April. During January, February and June they were less than 5 No./l. Nematodes were recorded during January to May except February. During the other months they were absent. In March there was an increase (6 No./l) of nematodes and during the rest of the months they were less than 2 No./l. Rotifers were recorded in November and July with a density of 3 No./l and 1 No/l, respectively. Gastropod veliger larvae were recorded during December and February.

In the backwater the total number of zooplankton ranged between 6 and 32 No./l with an average of 17.5 No./l (Table 6 and Fig. 13). The zooplankton in the backwater also has not shown any clear month wise pattern in their abundance (Fig.13). They showed maximum abundance

(>30 No./l) during March and June. Crustacean larvae and copepods were the major components of the zooplankton in the backwater.

Table 5. Monthly variations in the abundance (No./l) of zooplankton in the culture field

Group	Copepods	Crustacean larvae	Tintinnids	Nematodes	Veliger larvae	Rotifers	Others	Total
November	3	2	0	0	0	3	2	10
December	3	10	0	0	2	0	0	15
January	5	4	2	1	1	0	0	13
February	2	6	4	0	2	0	1	15
March	7	8	6	6	0	0	0	27
April	2	10	10	1	0	0	0	23
May	3	4	0	2	0	0	1	10
June	6	5	2	0	0	0	1	14
July	12	11	0	0	0	1	0	24
Total	43	60	24	10	5	4	5	151
Average	4.7	6.6	2.6	1.1	0.5	0.4	0.5	16.4
Percentage	28.44	39.71	15.86	6.61	3.27	2.62	3.27	

Table 6. Monthly variations in the abundance (No./l) of zooplankton in the backwater

Group	Copepods	Crustacean larvae	Tintinnids	Nematodes	Rotifers	Others	Total
November	15	6	0	0	1	4	26
December	2	3	0	0	0	2	7
January	3	2	0	0	0	1	6
February	7	5	4	0	0	0	16
March	10	16	0	5	0	0	31
April	6	2	2	0	0	0	10
May	3	13	1	0	2	2	21
June	9	17	2	0	3	1	32
July	5	6	0	0	0	0	11
Total	60	70	9	5	6	10	160
Average	6.6	7.7	1.0	0.5	0.6	1.1	17.5
Percentage	37.47	43.72	5.62	3.09	3.71	6.24	

As in the prawn filtration field crustacean larvae constituted the major portion of the zooplankton in the backwater with an average of 7.7 No./l, which is around 43.72% of the total plankton. Maximum abundance (16-17 No./l) was observed in March and June. Another peak (13 No./l) was reported in May. During the other months they were between 2 and 6 No./l (Fig. 15).

Copepods showed an annual mean of 6.6 No./l, which is 37.47% of the total zooplankton. The maximum number (15 No./l) was reported in November. Moderate (6-10 No./l) abundance was observed during most of the months. As shown in Fig. 15 after recording its maximum number there is a sudden fall in abundance in December (2 No./l). Thereafter it gradually increased and reached its second maximum

(10 No./l) in March. In April there is a fall in abundance. Then another high was observed in June (9 No./l). Thus the copepod abundance showed high and low values intermittently. Tintinnids were found during February and June with sudden increase in March with a density of 156 No./l. Rotifers were reported during November, May and June when the salinity was low. A few nematodes were observed in March and they were absent during the rest of the months.

Correlation between zooplankton and hydrographic parameters for the culture field and backwater are presented in Table 7.

a) Salinity

No correlation was observed between total zooplankton abundance and salinity both in the culture field ($r = 0.0125$) and backwater ($r = 0.0925$). In the culture field tintinnids ($r = 0.4824$) and nematodes ($r = 0.3038$) positively correlated with salinity, whereas rotifers ($r = -0.6526$) and copepods ($r = -0.4829$) negatively correlated with salinity, but 'r' values were not significant ($P < 0.05$). Crustacean larvae did not show any correlation with salinity.

In the backwater also tintinnids ($r = 0.1813$) and nematodes ($r = 0.1813$) positively correlated, whereas, rotifers ($r = -0.4036$), copepods ($r = -0.4178$) and crustacean larvae ($r = -0.2536$) negatively correlated with salinity, but the correlation coefficients were not significant statistically.

b) Temperature

In the culture field regarding the affinity of individual groups of zooplankton with temperature, except rotifers ($r = -0.5272$) and copepods ($r = -0.2824$) all other groups were positively correlated, but 'r' values were not significant statistically. While in the backwater, except copepods ($r = -0.5605$) all are positively correlated, but 'r' values were not significant ($P<0.05$).

c) pH

Negative correlation was observed between zooplankton abundance and pH, both in the culture field (r = -0.1959) and backwater (r = -0.2578), but 'r' values were statistically not significant.

In both the culture field (r = -0.6265) and backwater (r = -0.6540) copepods negatively correlated with pH, but not significant. In the culture field, except tintinnids (r = 0.3056) all other groups negatively correlated with pH, whereas in the backwater all the groups negatively correlated, but the correlation coefficients were not significant.

d) Dissolved Oxygen

In the culture field negative correlation was observed between dissolved oxygen and total zooplankton abundance (r = -0.3843), but the correlation was not significant (P <0.05). It showed no influence on zooplankton abundance in the backwater. In the culture field dissolved oxygen has no influence on the distribution of crustacean larvae whereas it negatively correlated with all other groups, but 'r' values were not significant.

In the backwater crustacean larvae (r = 0.5057) and rotifers (r = 0.6124) have shown positive correlation with dissolved oxygen, while tintinnids (r = -0.1156), nematodes (r = -0.1156) and copepods (r = -0.2147) negatively correlated, but the correlation coefficients were not significant statistically.

e) Total Alkalinity

In the culture field zooplankton abundance negatively correlated with alkalinity (r = -0.3710) but it was not significant statistically (P <0.05), whereas no influence was observed in backwater zooplankton. In the culture field copepods (r = -0.6908) negatively correlated with alkalinity and it was statistically significant. Crustacean larvae (r = -0.4849) negatively correlated with alkalinity, whereas rotifers (r = 0.4843) positively correlated but not significant statistically.

In the backwater crustacean larvae (r = -0.4745) and rotifers (r = -0.4121) though negatively correlated with total alkalinity correlation coefficients were not significant statistically ($P < 0.05$), whereas tintinnids, nematodes and copepods were not influenced by changes in total alkalinity.

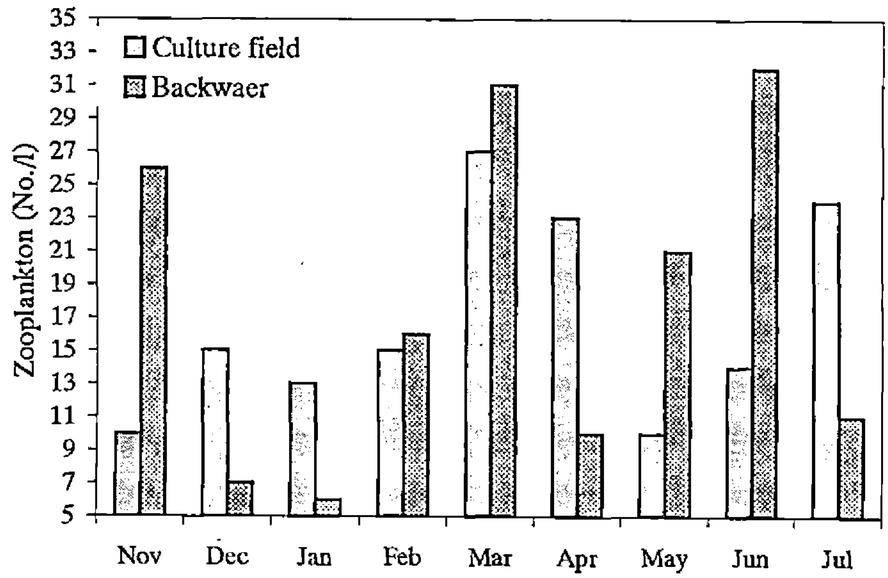

Fig. 13. Monthly variations in the abundance of total zooplankton in the culture field and backwater

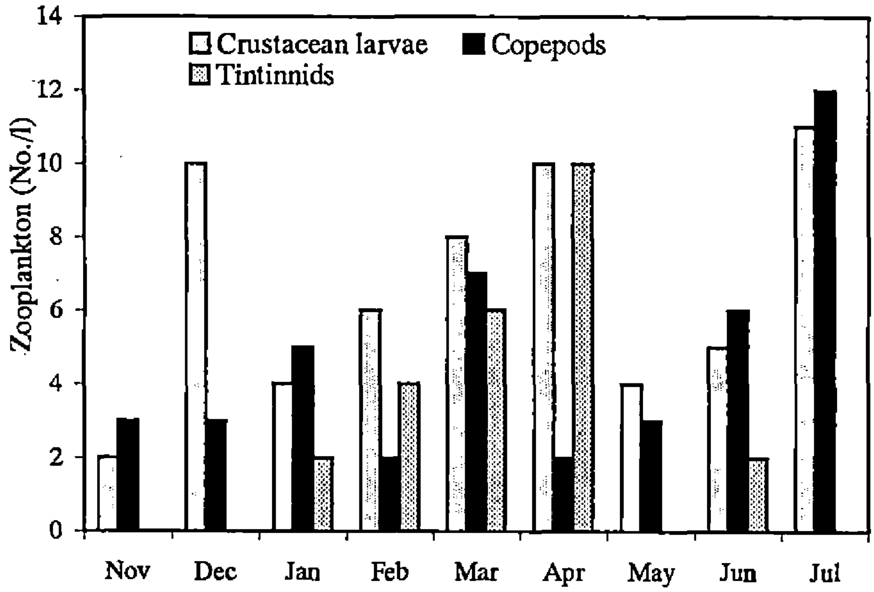

Fig. 14. Abundance of crustacean larvae, copepods and tintinnids in the culture field

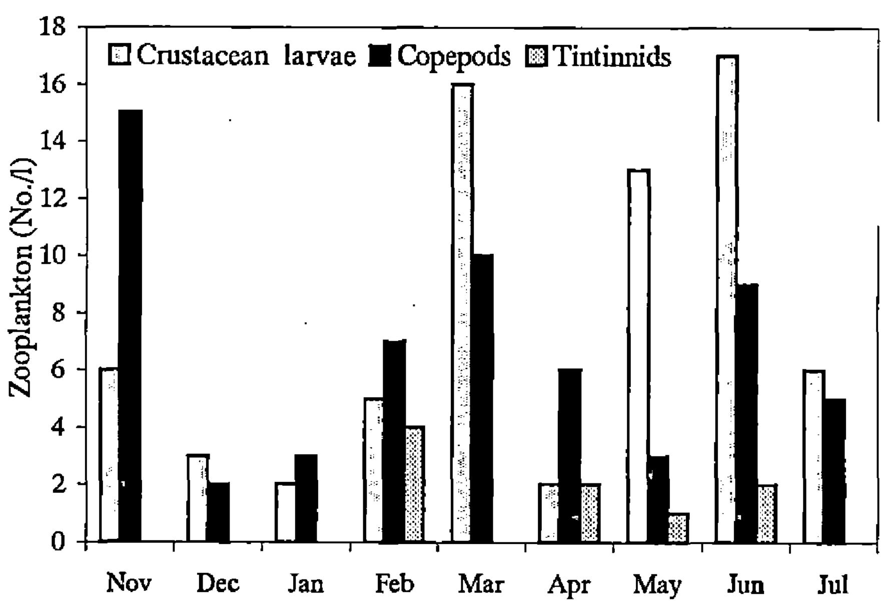

Fig. 15. Abundance of crustacean larvae, copepods and tintinnids in the backwater

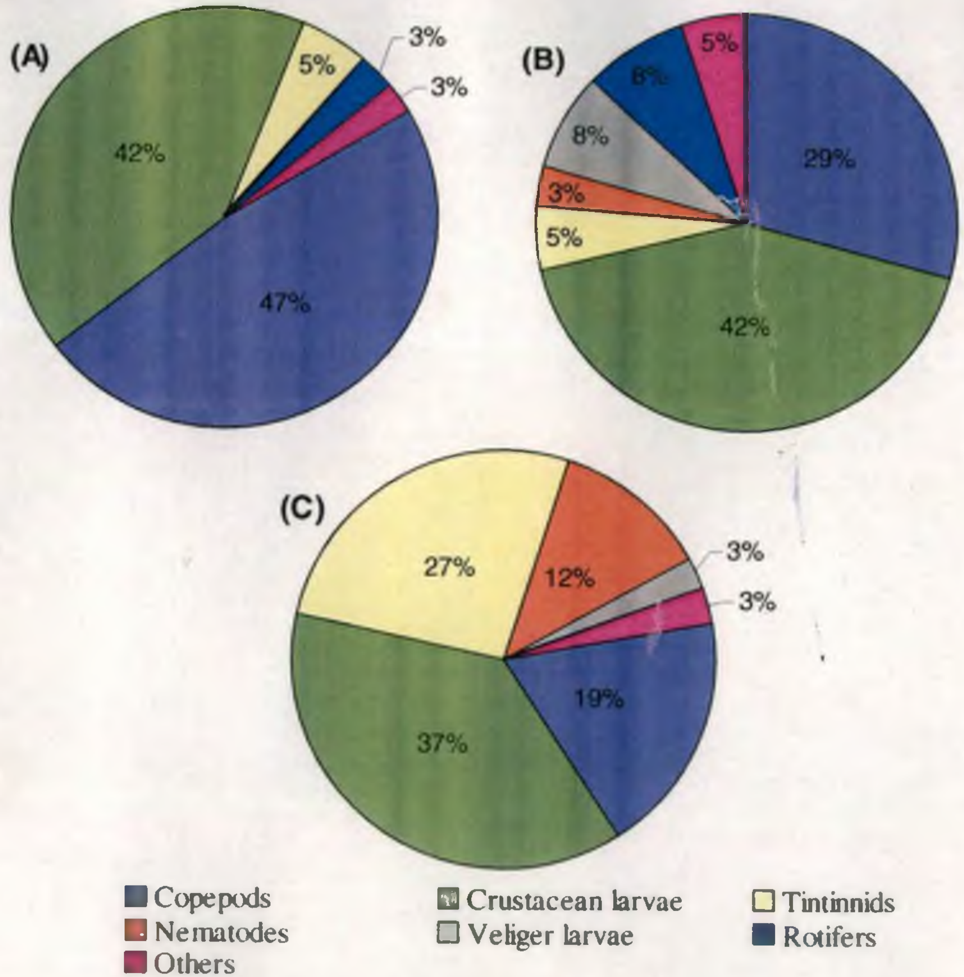

Fig. 16. Percentage composition of various zooplankton groups in (A) Monsoon, (B) Post-monsoon and (C) Pre-monsoon seasons in the culture field

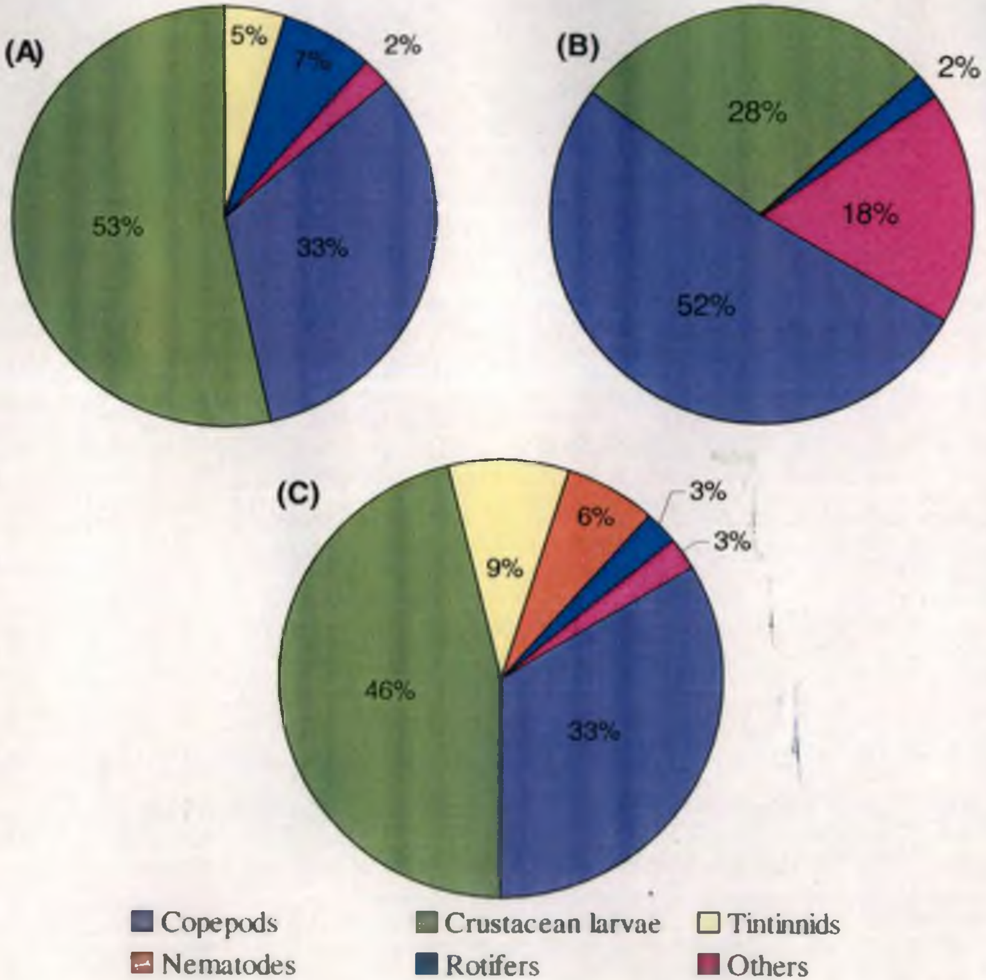

Fig. 17. Percentage composition of various zooplankton groups in (A) Monsoon, (B) Post-monsoon and (C) Pre-monsoon seasons in the backwater

Table 7. Correlation between zooplankton and various hydrographic parameters

	Total Zooplankton	Copepods	Crustacean Larvae	Tintinnids	Nematodes	Rotifers
Culture field						
pH	-0.1959	-0.6265	0.0957	0.3056	-0.1229	-0.5817
Transparency	*-0.8462	-0.2898	*-0.7310	*-0.6759	-0.3574	0.3002
Temperature	0.0019	-0.2824	0.0401	0.2369	0.3304	-0.5272
Dissolved O_2	-0.3843	-0.1104	0.0740	-0.4326	-0.2590	-0.4080
Salinity	0.0125	-0.4829	-0.0426	0.4824	0.3038	-0.6526
Alkalinity	-0.3710	*-0.6908	-0.4849	0.0975	0.0482	0.4843
Nitrate-N	-0.1879	0.5744	-0.1148	-0.6066	-0.3912	0.3942
Phosphate-P	0.5516	-0.2339	0.2800	*0.6856	0.6380	-0.0701
Silicate-Si	0.0507	0.5921	0.0823	-0.4785	-0.3291	0.6157
Backwater						
pH	-0.2578	-0.6540	-0.3386	-0.1887	-0.1887	-0.2055
Transparency	-0.4655	-0.1897	-0.1834	-0.4612	-0.4612	0.0881
Temperature	0.0570	-0.5605	0.1517	0.1004	0.1004	----
Dissolved O_2	-0.0495	-0.2147	0.5057	-0.1156	-0.1156	0.6124
Salinity	0.0925	-0.4178	-0.2536	0.1813	0.1813	-0.4036
Alkalinity	-0.0094	0.0976	-0.4745	0.0372	0.0372	-0.4121
Nitrate-N	-0.3241	0.2199	0.3061	-0.4285	-0.4285	0.6457
Phosphate-P	0.5950	0.0594	0.2870	0.6236	0.6236	-0.1496
Silicate-Si	-0.1351	0.4261	0.2455	-0.2217	-0.2217	0.3785

*'r' is significant at 5% level ($P < 0.05$)

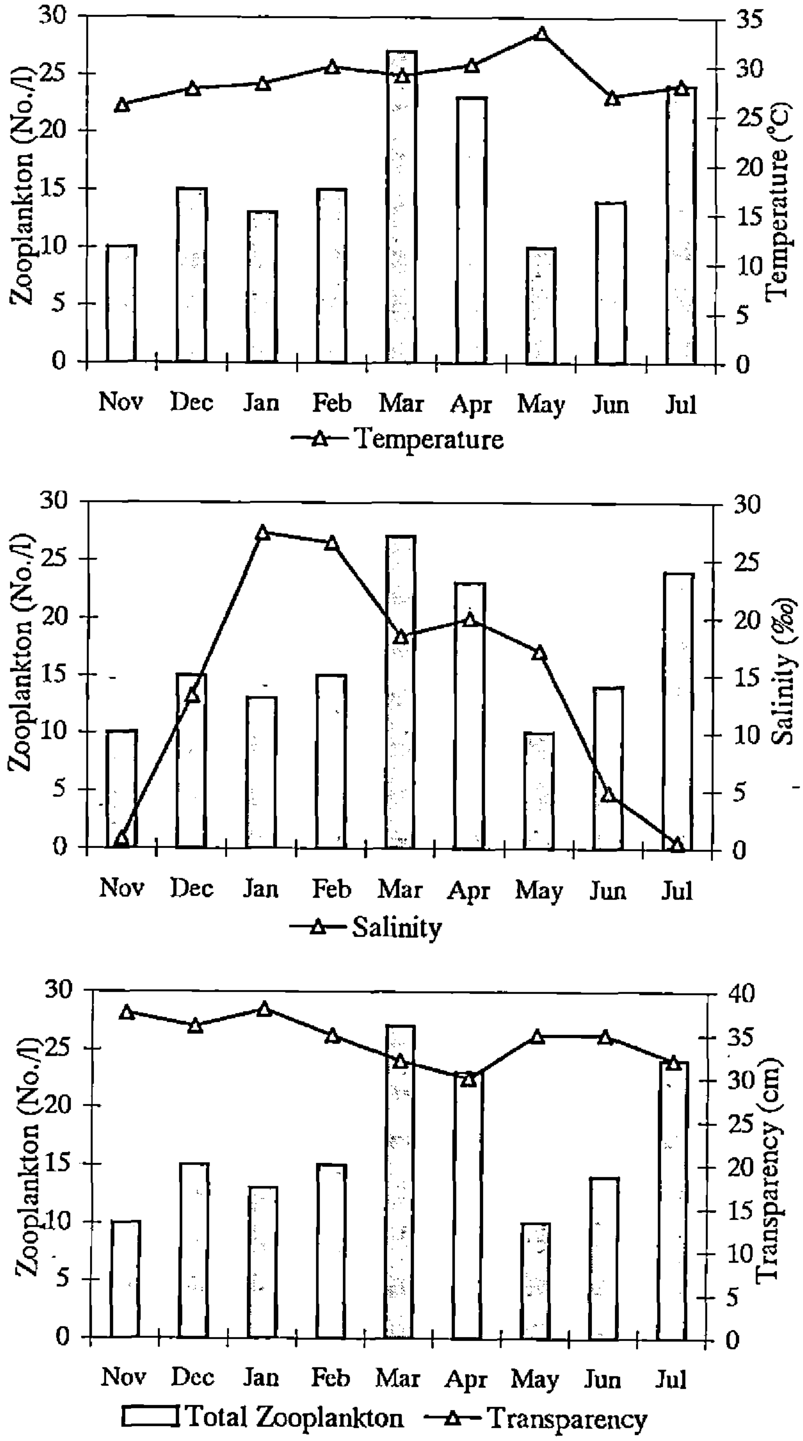

Fig. 18. Monthly variations in total zooplankton abundance in relation to hydrographic parameters in the culture field

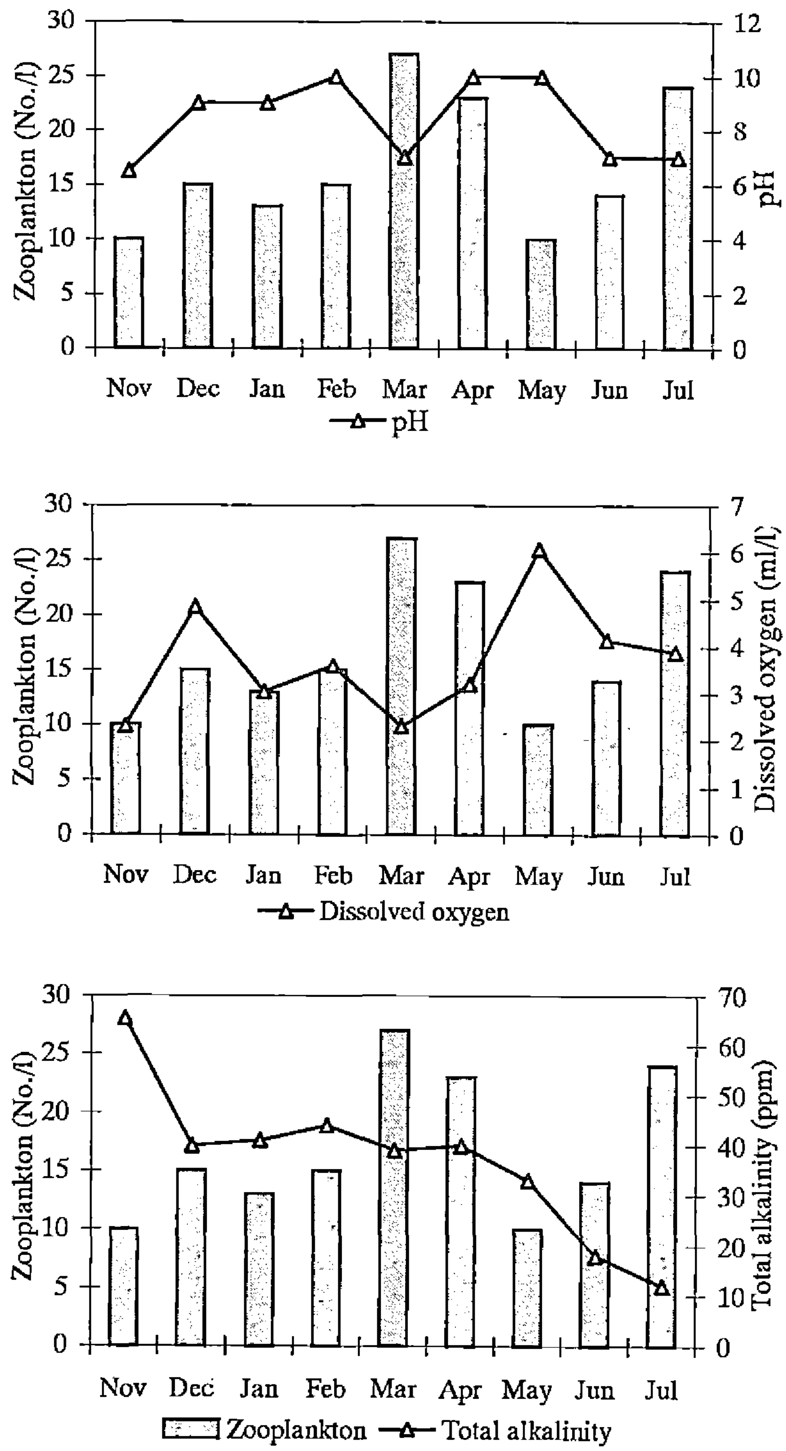

Fig. 18. (Contd.) Monthly variations in total zooplankton abundance in relation to hydrographic parameters in the culture field

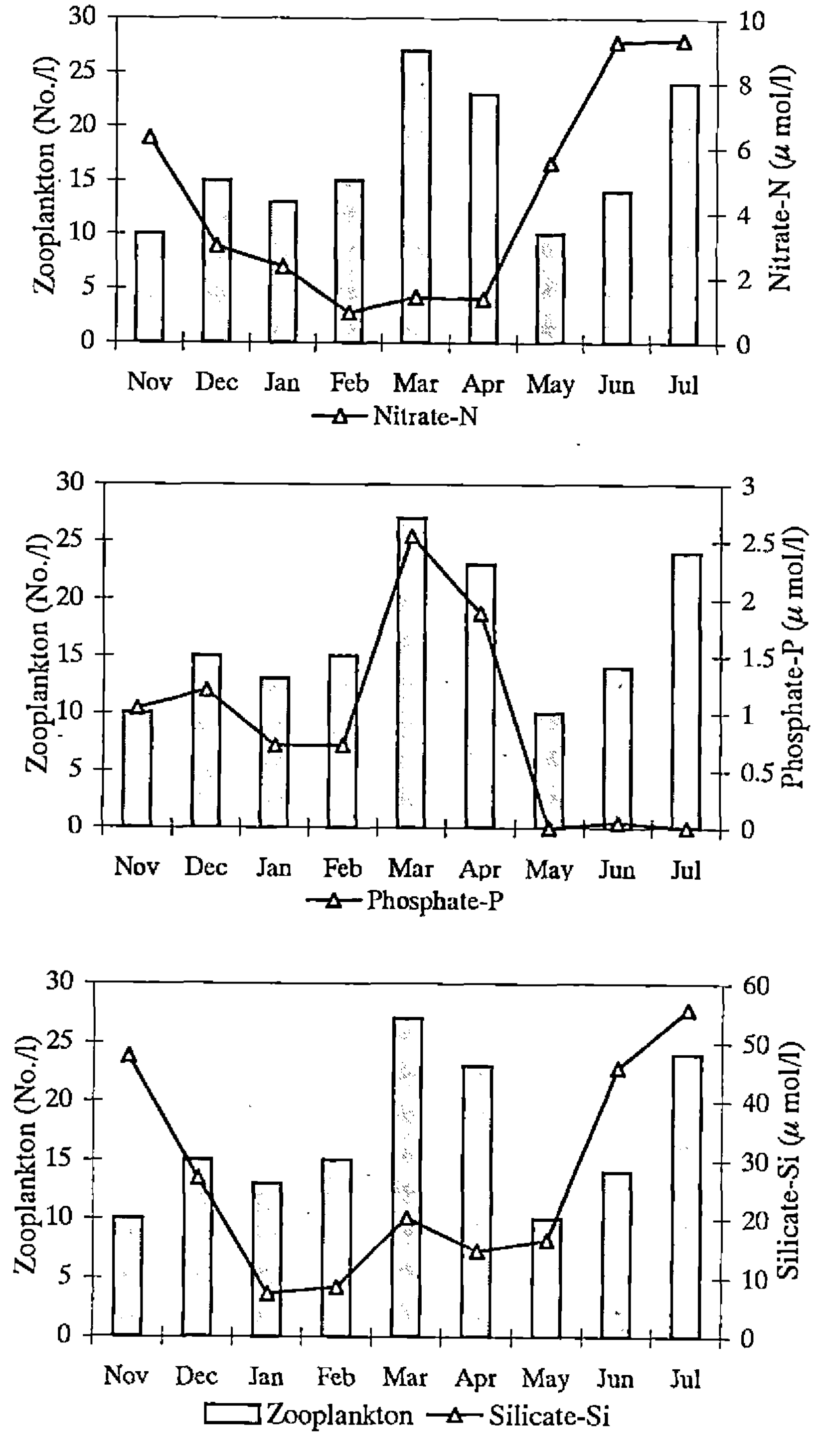

Fig. 18. (Contd.) Monthly variations in total zooplankton abundance in relation to hydrographic parameters in the culture field

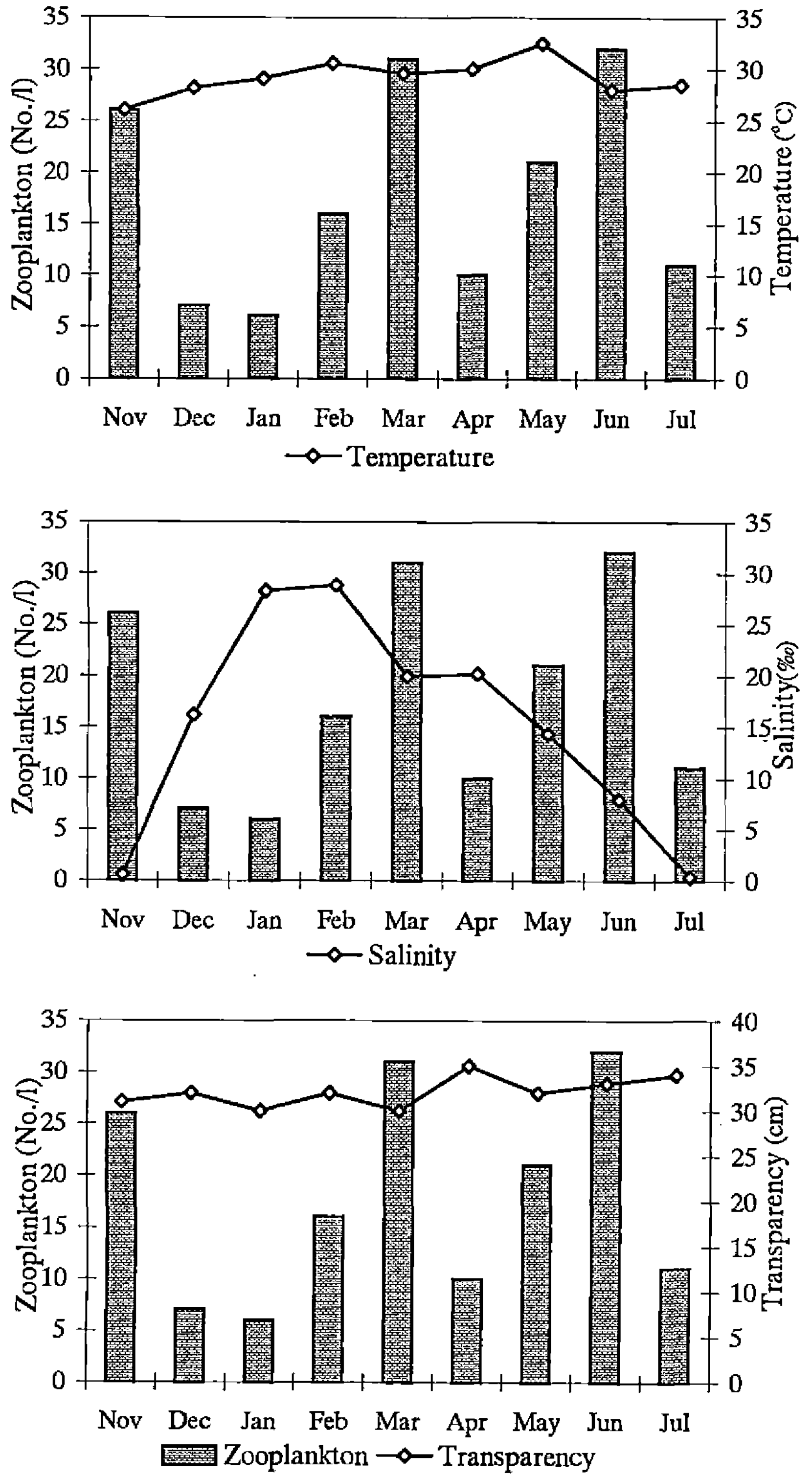

Fig. 19. Monthly variations in total zooplankton abundance in relation to hydrographic parameters in the backwater

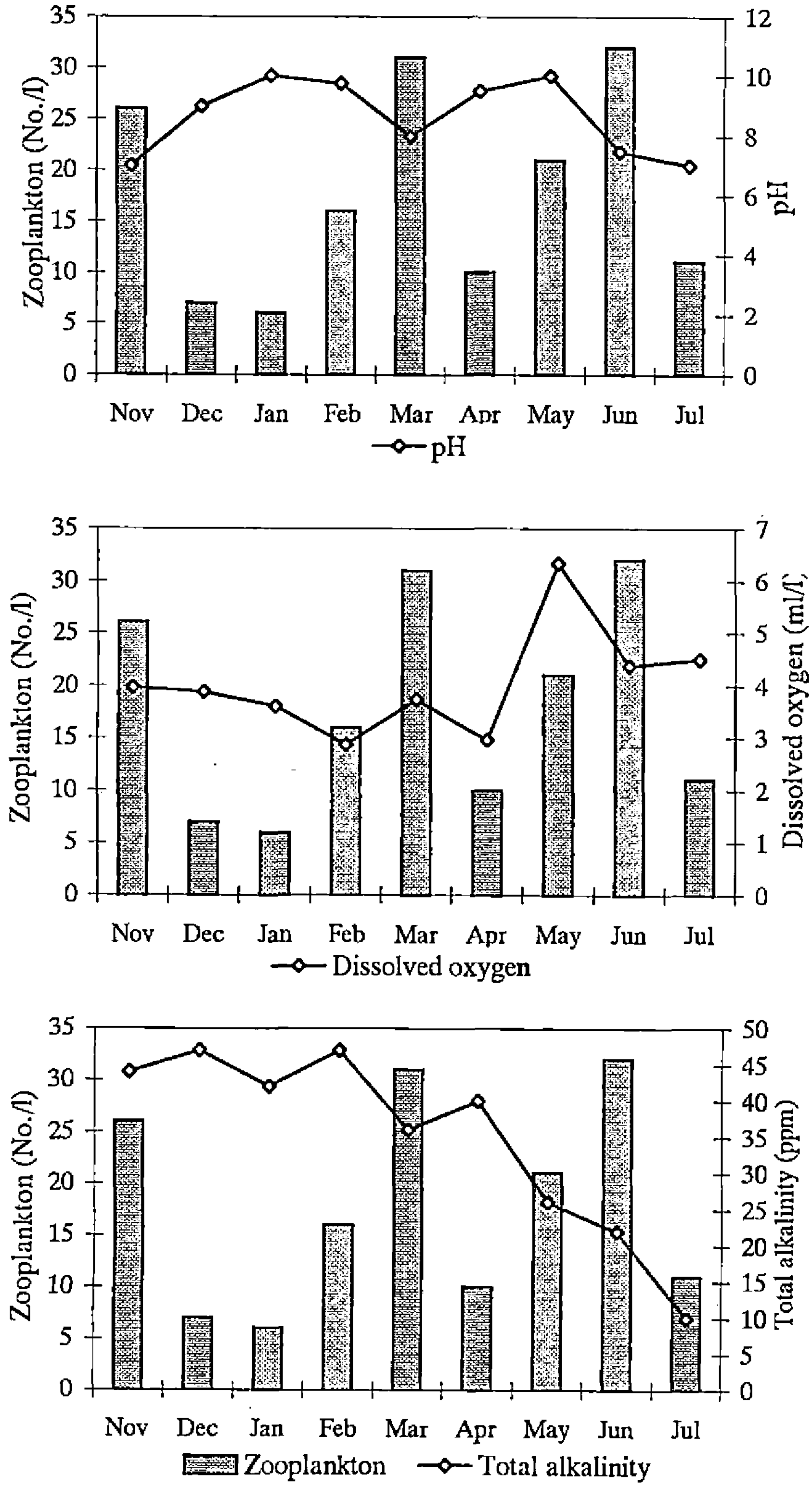

Fig. 19. (Contd.) Monthly variations in total zooplankton abundance in relation to hydrographic parameters in the backwater

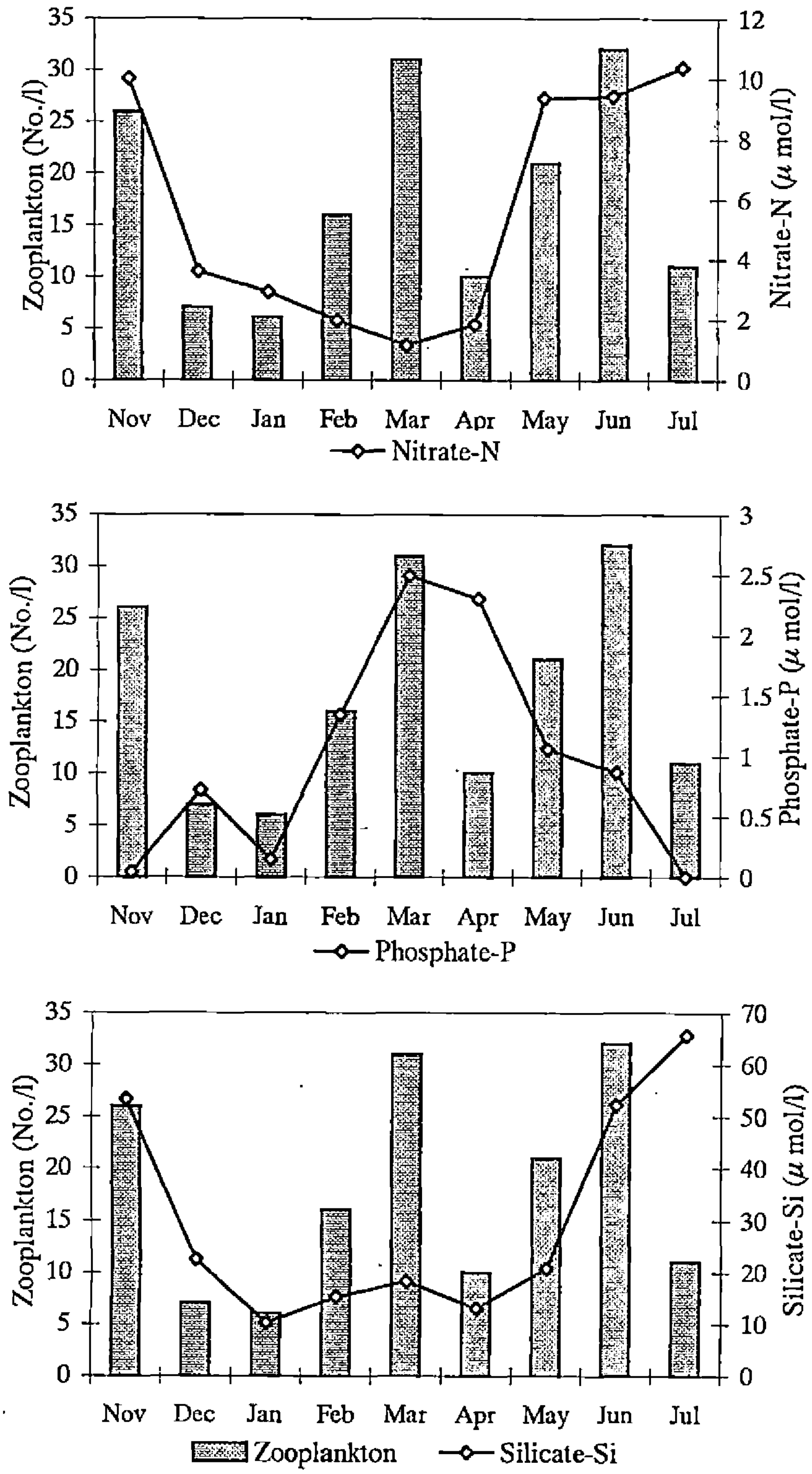

Fig. 19. (Contd.) Monthly variations in total zooplankton abundance in relation to hydrographic parameters in the backwater

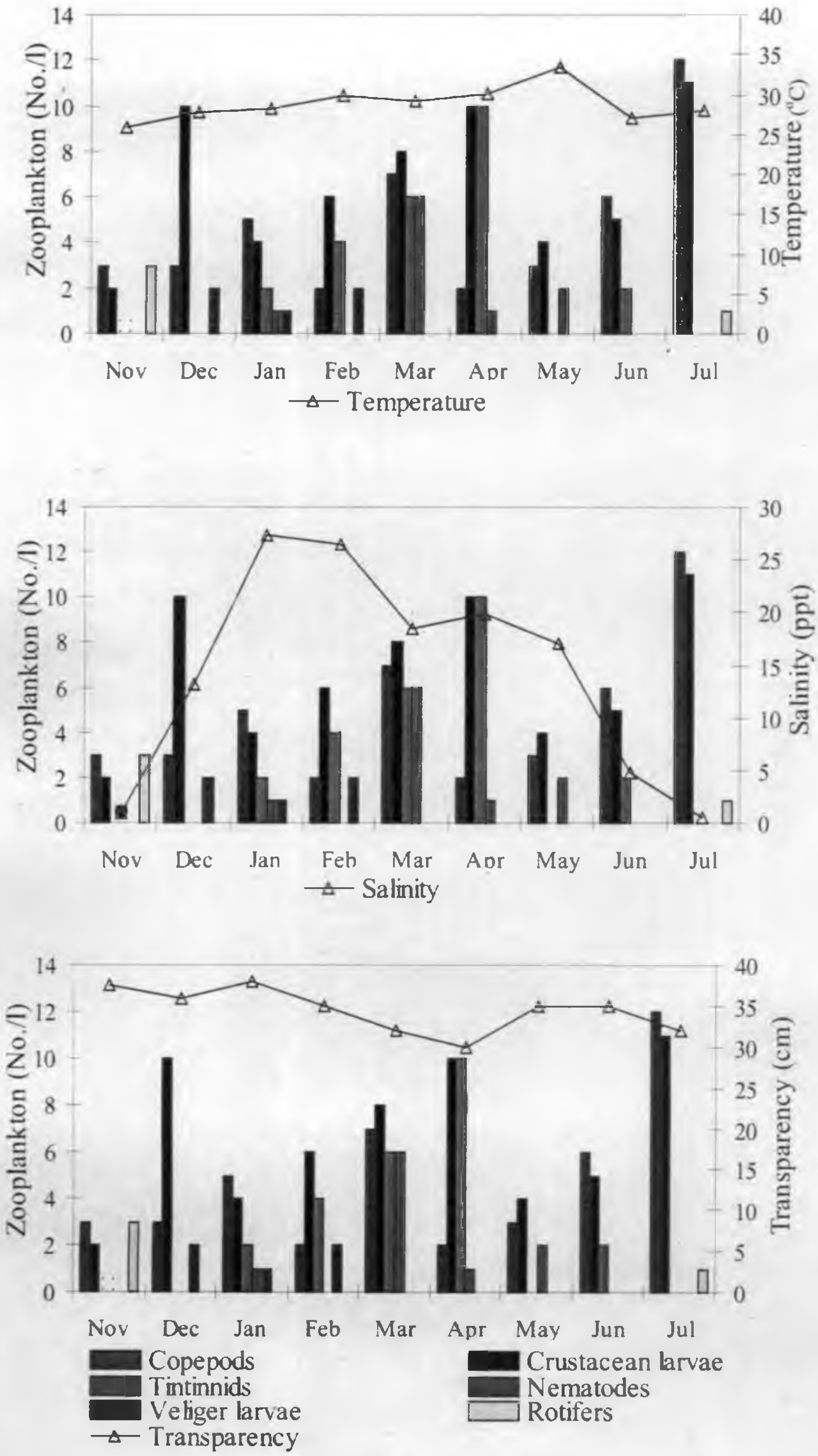

Fig. 20. Abundance of zooplankton groups in relation to hydrographic parameters in the culture field

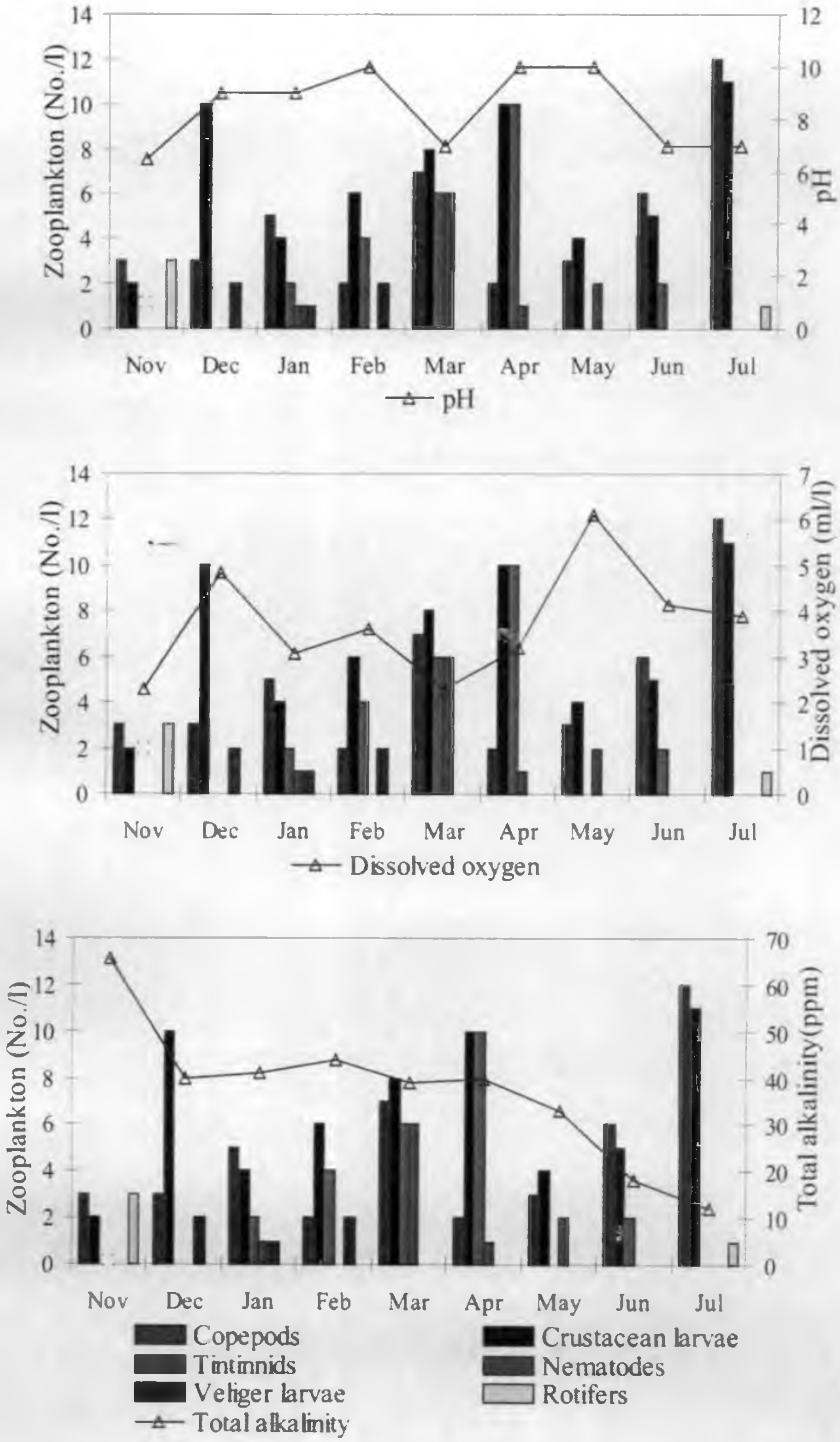

Fig. 20. (Contd.) Abundance of zooplankton groups in relation to hydrographic parameters in the culture field

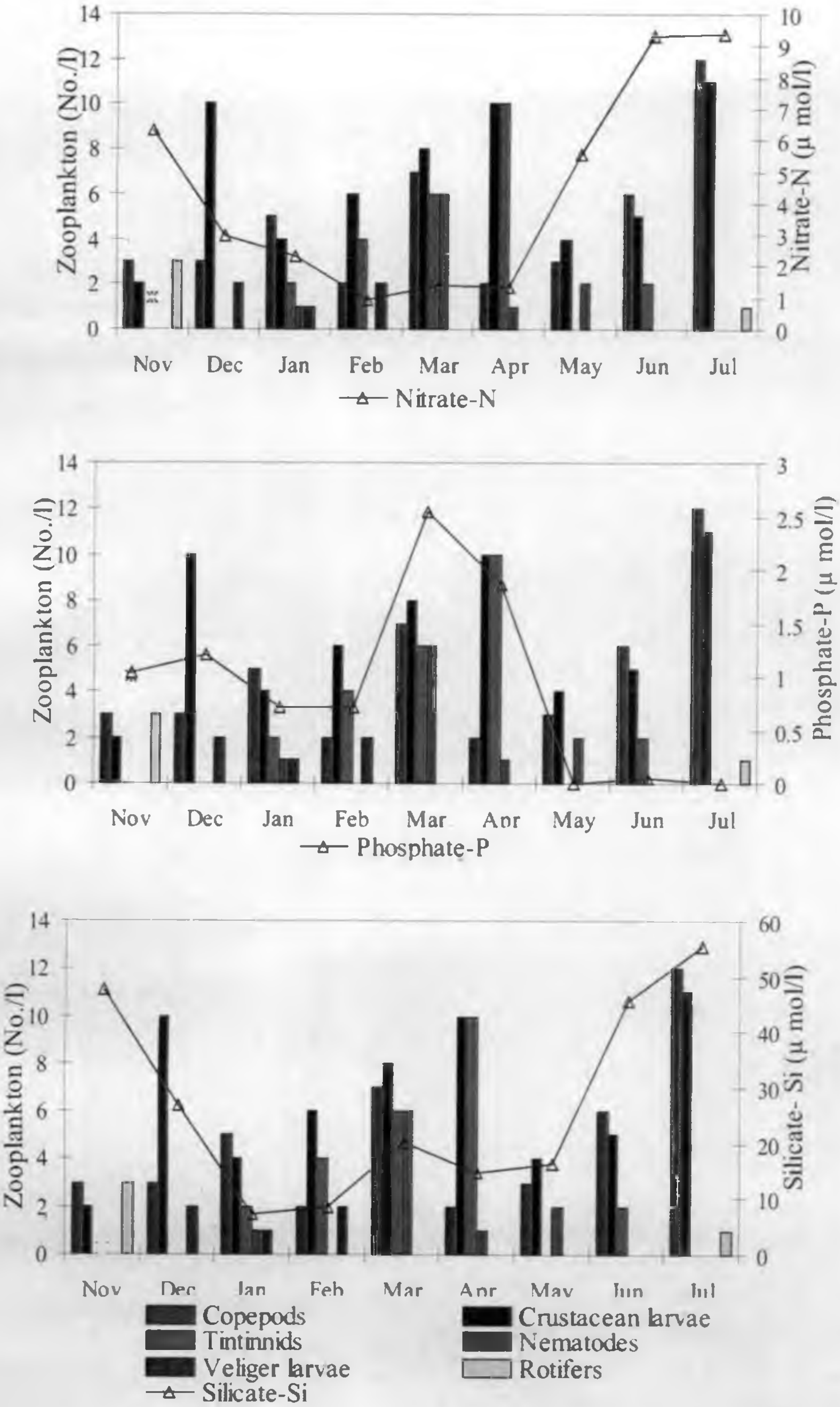

Fig. 20. (Contd.) Abundance of zooplankton groups in relation to hydrographic parameters in the culture field

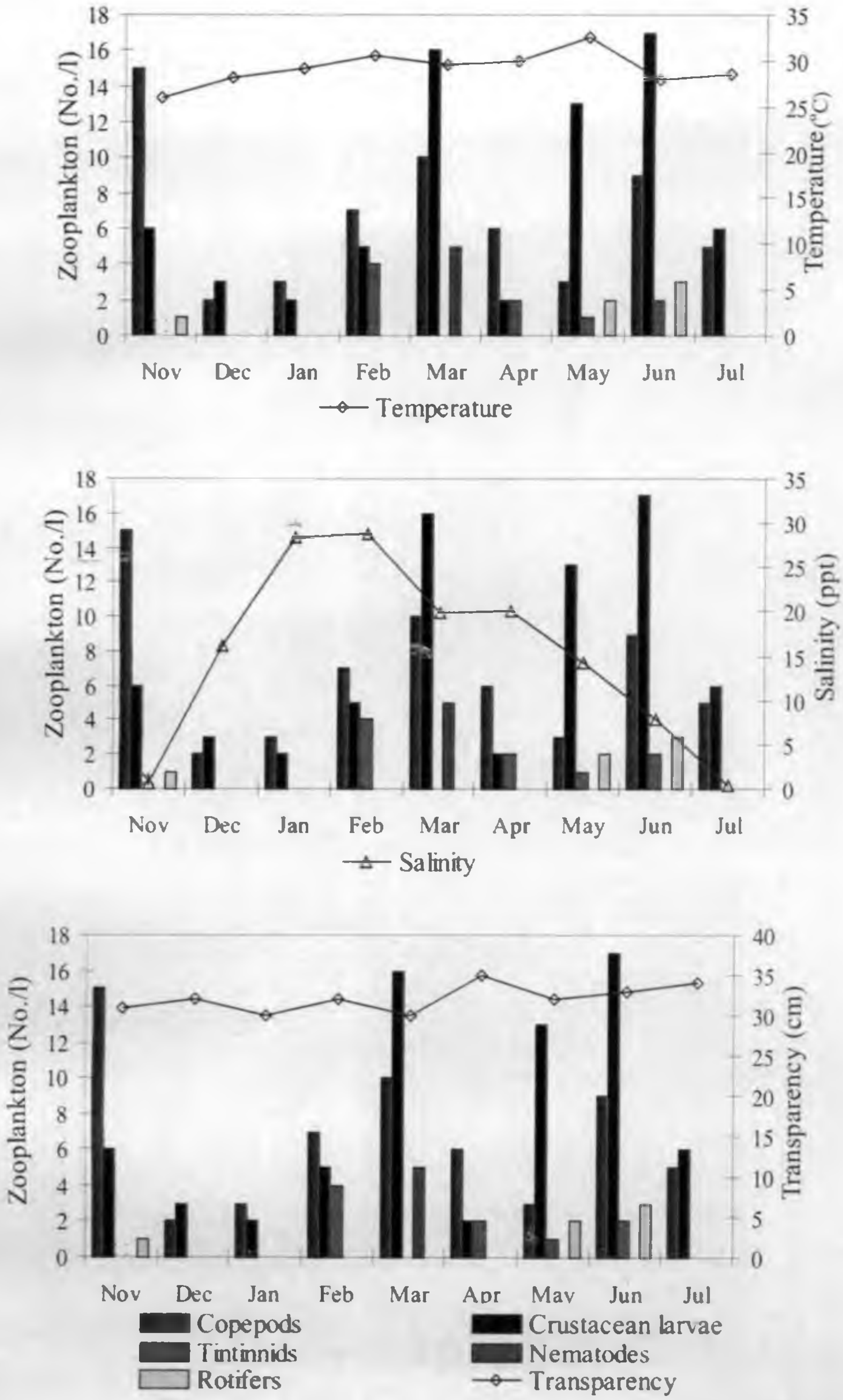

Fig. 21. Abundance of zooplankton groups in relation to hydrographic parameters in the backwater

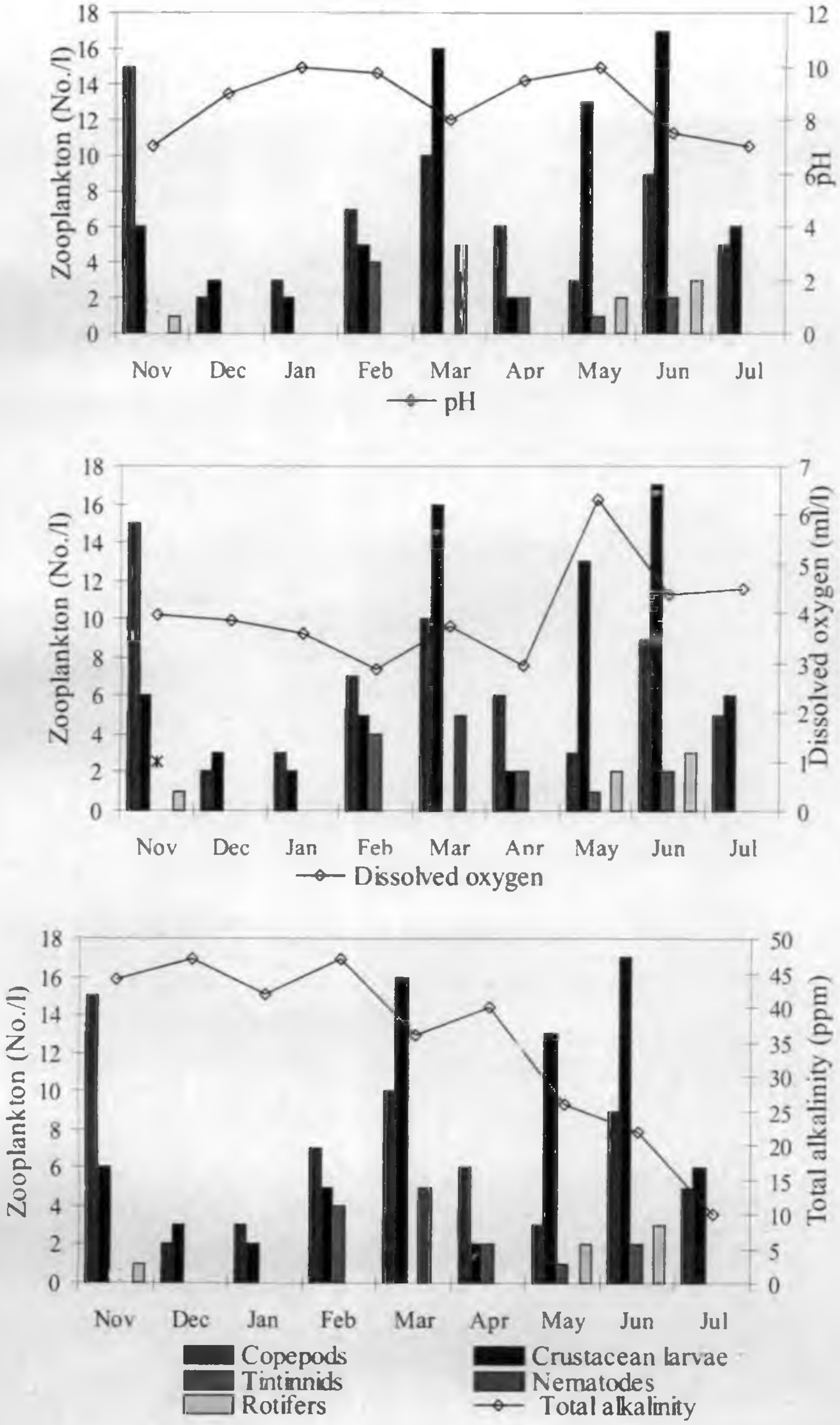

Fig. 21. (Contd.) Abundance of zooplankton groups in relation to hydrographic parameters in the backwater

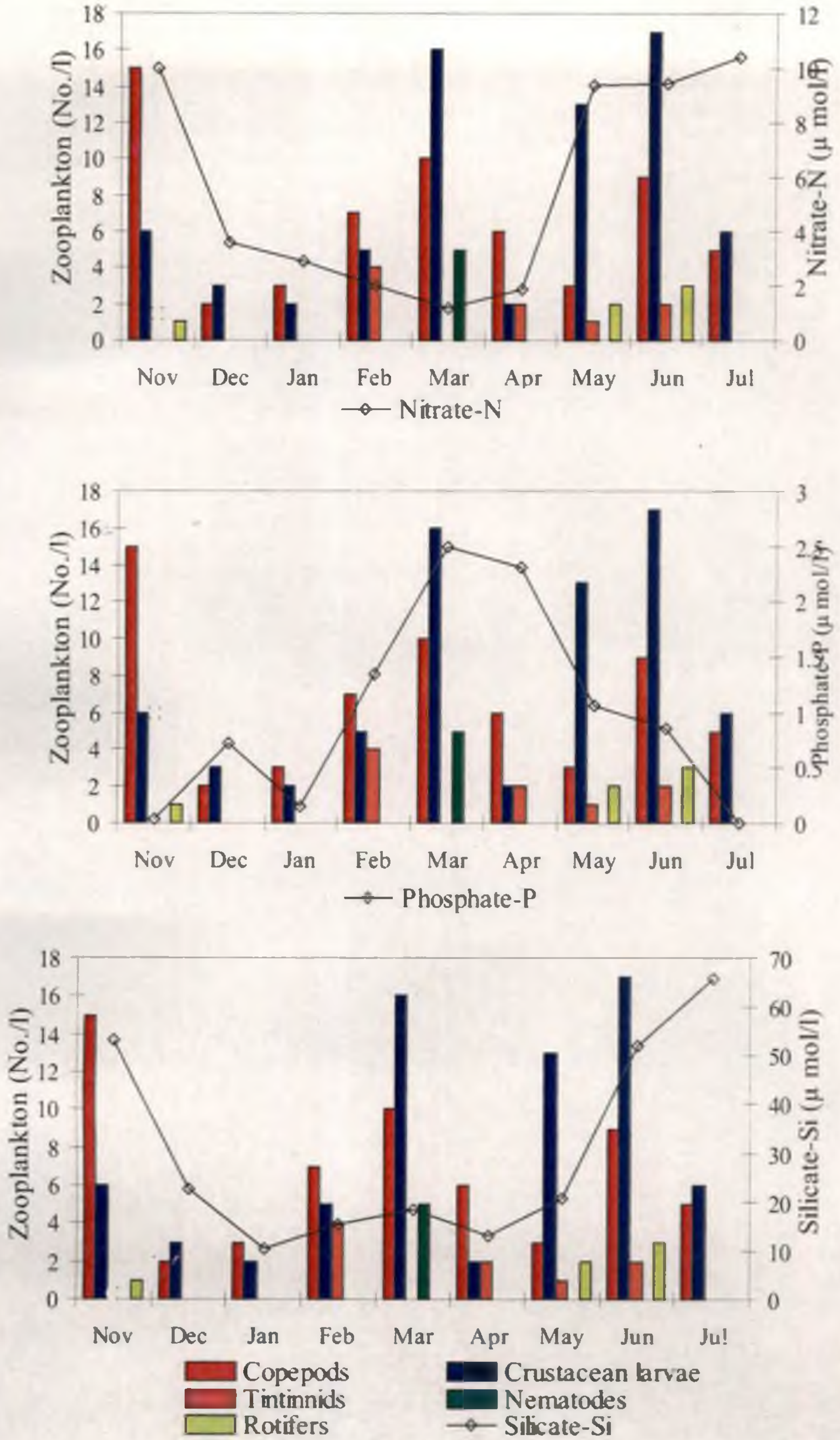

Fig. 21. (Contd.) Abundance of zooplankton groups in relation to various hydrographic parameters in the backwater

4.3 MACROBENTHOS

The abundance of macrobenthos in the culture field and the backwater are given in Table 8 and 9, respectively.

The macrobenthic groups obtained during the present investigation were mainly polychaetes, tanaidaceans, amphipods, bivalves, gastropods, isopods and chironomid larvae.

In the culture field the macrobenthic population showed wide variations in their abundance in different months (Fig.22, 23). It varied between nil and 4281 No./m^2 with an average of 1532 No./m^2 during the period of investigation. The benthic populations recorded their maximum during November and December with a density of 4279 No./m^2 and 4281 No./m^2, respectively. The benthic populations were high during the post-monsoon months and it gradually decreased during the pre-monsoon period with complete absence in May. It showed increasing trend with the onset of monsoon. Tanaidaceans, gastropods and polychaetes were the most prominent groups in the prawn filtration field. Tanaidaceans were the most important group with an average monthly value of 563 No./m^2, forming 36.78% of the macrobenthos. They showed maximum abundance in November (2254 No./m^2). Gastropods were the second major group with an average monthly value of 504 No./m^2, which is 32.90% of the macrobenthic populations. They showed maximum abundance during December (1984 No./m^2). Polychaetes contributed to the benthos with an average of 238 No./m^2, which is 15.55% of the benthic populations. They were maximum during July (1024 No./m^2). Amphipods contributed to the benthos with an average of 95 No./m^2, which is 6.20% of the benthos. They were abundant during post-monsoon months and the maximum number was recorded in December (355 No./m^2). Their number gradually decreased during pre-monsoon and they were absent in May and June. Bivalves contributed to the benthos with an average of 90 No./m^2, which is

5.88 % of the benthos. They were maximum during the post-monsoon and showed a decreasing trend and were absent from April to July. Chironomid larvae were recorded during November, December, and July and were absent during the other months. In April the prawn filtration field was completely drained off after harvesting and all the groups were absent except few amphipods (24 No./m^2).

The macrobenthos of the backwater also showed wide variations in their abundance in different months (Fig.22, 24). Their intensity varied between 476 and 17428 No./m^2 with a mean of 5910 No./m^2. The maximum number was observed in January and the minimum in July.

Gastropods with an average of 3611 No./m^2 constituted 61.10% of the total, dominating the benthos of the backwater. Polychaetes were next to gastropods in abundance with a mean of 727 No./m^2, which constituted 12.3% of the total, followed by tanaidaceans with an average of 693 No./m^2 forming 11.72% of the total benthos. Bivalves contributed to the benthic population with an average of 605 No./m^2, which is 10.25% of the total. Their maximum number was recorded in December (3429 No./m^2). Amphipods with an average of 272 No./m^2 constituted 4.60% of the total benthos. Isopods and chironomid larvae were not found in backwater samples.

Table 8: Monthly variations in the abundance (No./m^2) of various groups of benthic organisms in the culture field

Group	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total	Average	Percentage (%)
Polychaetes	280	281	37	345	154	0	0	24	1024	2145	238	15.55
Amphipods	206	355	127	72	48	24	0	0	24	856	95	6.20
Tanaidaceans	2254	1376	1196	119	79	0	0	24	24	5072	563	36.78
Bivalves	402	259	95	24	32	0	0	0	0	812	90	5.88
Gastropods	889	1984	159	0	910	0	0	238	357	4537	504	32.90
Isopods	0	0	11	12	0	0	0	0	0	23	2	0.16
Chironomid larvae	248	26	0	0	0	0	0	0	71	345	38	2.50
Total	4279	4281	1625	572	1223	24	0	286	1500	13790	1532	

Table 9: Monthly variations in abundance (No./m^2) of various groups of benthic organisms in the backwater

Group	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Total	Avg.	Percentage (%)
Polychaetes	1619	857	2214	952	786	48	0	0	71	6547	727	12.30
Amphipods	0	119	500	1071	595	119	0	0	48	2452	272	4.60
Tanaidaceans	0	71	3619	905	619	169	0	738	119	6238	693	11.72
Bivalves	667	3429	619	476	0	0	0	24	238	5453	605	10.25
Gastropods	0	0	10476	8810	1524	2357	1000	8334	0	32501	3611	61.10
Isopods	0	0	0	0	0	0	0	0	0	0	0	0
Chironomid larvae	0	0	0	0	0	0	0	0	0	0	0	0
Total	2286	4476	17428	12214	3524	2691	1000	9096	476	53191	5910	

The correlation coefficients were worked out for the total benthos and individual groups in relation with sand, silt and clay content of the sediment, salinity, pH and dissolved oxygen in the prawn filtration field and backwater and are presented in Table 10.

a) Soil texture

In the prawn filtration field the total number of benthic organisms was positively correlated with clay (r = 0.5445) and silt (r = 0.4886) whereas it was negatively correlated with sand (r = - 0.5948), but the correlation coefficients were statistically not significant. In the culture field various benthic groups showed positive correlation with clay but the correlation was statistically significant only in the case of amphipods (r = 0.6942) and gastropods (r = 0.7519).

Tanaidaceans (r =0.5979), amphipods (r = 0.4730), bivalves (r = 0.4234) and gastropods (r = 0.3049) positively correlated with silt, but the 'r' values were statistically non-significant ($P < 0.05$), whereas no correlation was observed between polychaete abundance and silt fraction of the sediment in the culture field. In the culture field all the groups were negatively correlated with sand but the correlation was significant only in the case of amphipods (r = -0.6812).

In the backwater total abundance of benthos is negatively correlated with silt (r = -0.6921) and it is significant ($P < 0.05$) also. The positive correlation with sand (r = 0.3617) and clay (r = 0.1313) was not significant. In the backwater bivalves showed significant correlation (r = 0.8827) with clay fraction, while the polychaetes were only feebly (r = 0.2120) correlated and being not significant. The rest of the groups showed no correlation. Bivalves were negatively correlated with sand (r = -0.7616) and it was significant.

Table 10. Correlation between benthos and sediment texture, salinity, pH, and dissolved oxygen

Culture field						
Parameter/groups	Sand	Silt	Clay	Salinity	P^H	Dissolved O_2
Total Benthos	-0.5948	0.4886	0.5445	-0.3827	-0.3815	-0.2244
Polychaetes	-0.0405	-0.0518	0.1066	-0.4942	-0.3737	-0.0518
Amphipods	* 0.6812	0.4730	* 0.6942	-0.0644	-0.0282	-0.0479
Tanaidaceans	-0.5055	0.5979	0.3139	-0.2194	-0.2675	-0.3083
Bivalves	-0.4179	0.4234	0.3173	-0.3415	-0.3184	-0.2719
Gastropods	-0.6311	0.3049	*0.7519	-0.2874	-0.3191	-0.0359
Backwater						
Total Benthos	0.3617	*-0.6921	0.1313	0.3815	-0.4280	0.0112
Polychaetes	0.1121	-0.4511	0.2120	0.3307	0.1429	-0.3837
Amphipods	0.3934	-0.5838	0.0295	*0.7610	0.4110	-0.5679
Tanaidaceans	0.4472	-0.6189	0.0215	0.5821	0.4001	-0.2767
Bivalves	*-0.7616	0.1085	*0.8827	0.0502	0.0989	-0.1371
Gastropods	0.5050	-0.6581	-0.0951	0.5913	0.3881	-0.3461

* 'r' is significant at 5% level ($P < 0.05$)

b) Salinity

In the culture field total benthos (r = -0.3827), Polychaetes (r = - 0.4942), tanaidaceans (r = -0.2194), bivalves (r = -0.3415) and gastropods (r = -0.2874) were negatively correlated with salinity, but the 'r' values were not significant.

In the backwater all the groups have shown positive correlation with salinity, but it was highly significant only in the case of amphipods (r = 0.7610). The total benthos (r = 0.3815) and groups like polychaetes (r = 0.3307), tanaidaceans (r = 0.5821) and gastropods (r = 0.5913) showed moderate correlation and these were not significant. Bivalves have not shown any correlation with salinity.

c) pH

In the culture field total benthos (r = -0.3815), polychaetes (r = -0.3737), tanaidaceans (r = -0.2675), bivalves (r = -0.3184) and gastropods (r = -0.3191) were negatively correlated with pH, but the 'r' values were not significant.

In the backwater total benthos negatively (r = -0.4280) correlated with pH while amphipods (r = 0.4110), tanaidaceans (r = 0.4001), gastropods (r = 0.3881) and polychaetes (r = 0.1429) were positively correlated but the correlation coefficients were not significant statistically ($P < 0.05$).

d) Dissolved oxygen

In the culture field total benthos (r = -0.2244), tanaidaceans (r = -0.3083) and bivalves (r = -0.2719) negatively correlated, but 'r' values were not significant, whereas other groups did not show any correlation.

In the backwater total benthic abundance did not show any correlation, whereas polychaetes (r = -0.3837), amphipods (r = -0.5679), tanaidaceans (r = -0.2767), bivalves (r = -0.1371) and gastropods (r = -0.3416) negatively correlated with dissolved oxygen, but the correlation coefficients were not significant statistically ($P<0.05$).

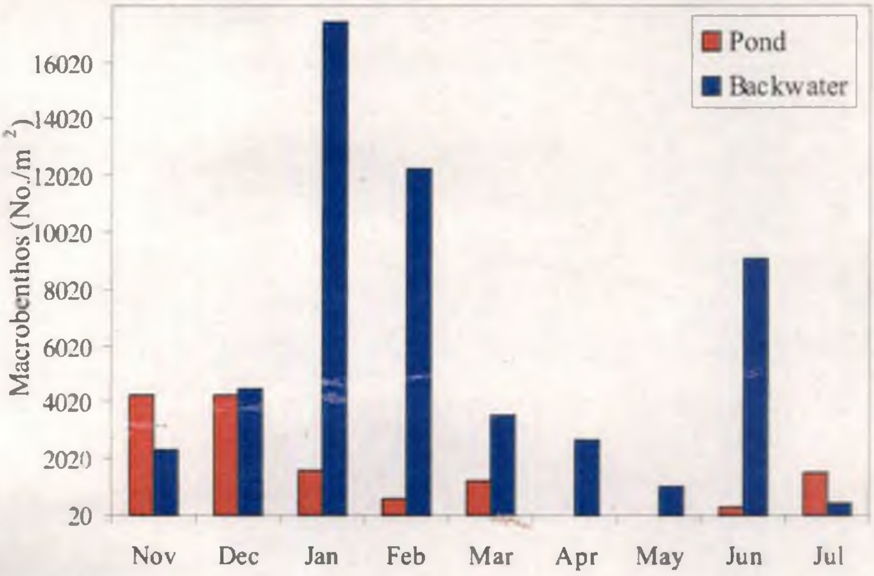

Fig. 22. Monthly variations in the abundance of total macrobenthos in the culture field and backwater

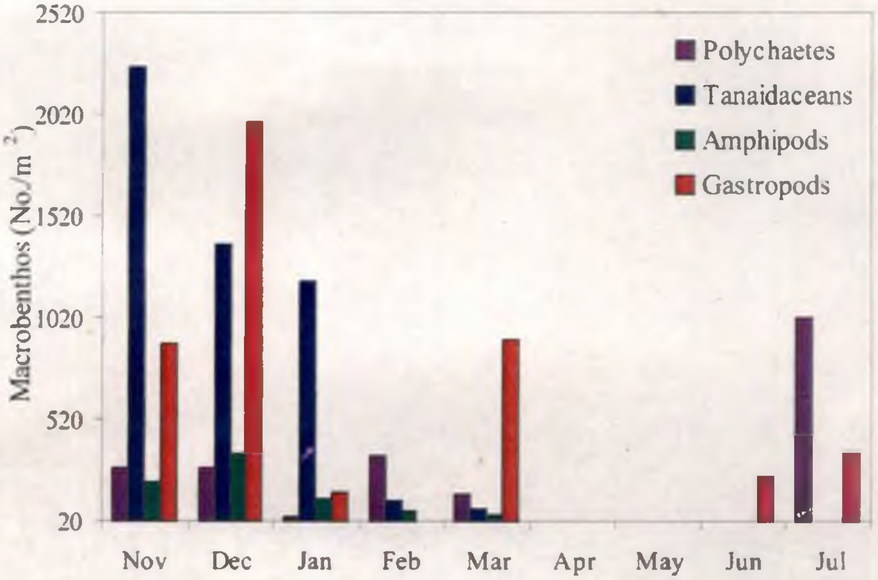

Fig. 23. Monthly variations in macrobenthos of the culture field

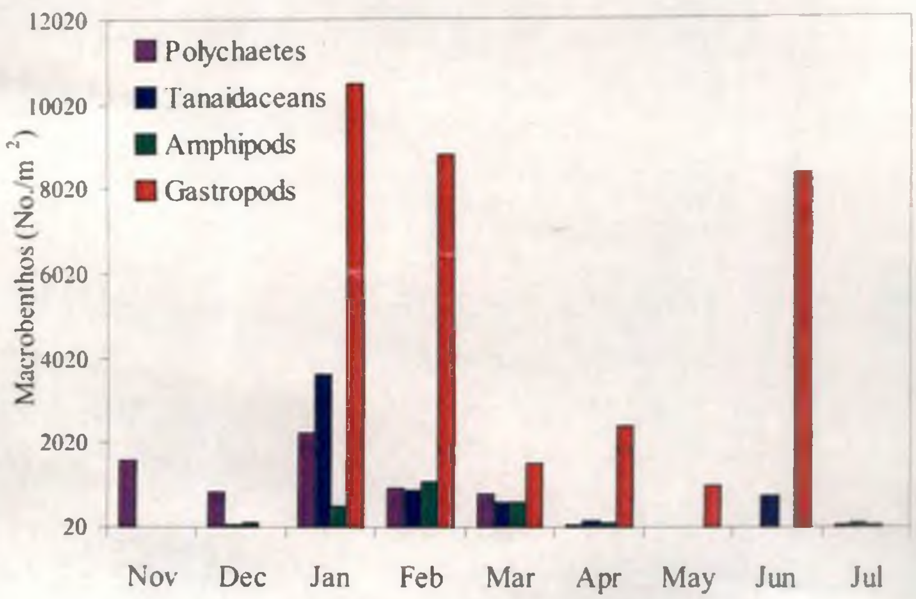

Fig. 24. Monthly variations in macrobenthos of the backwater

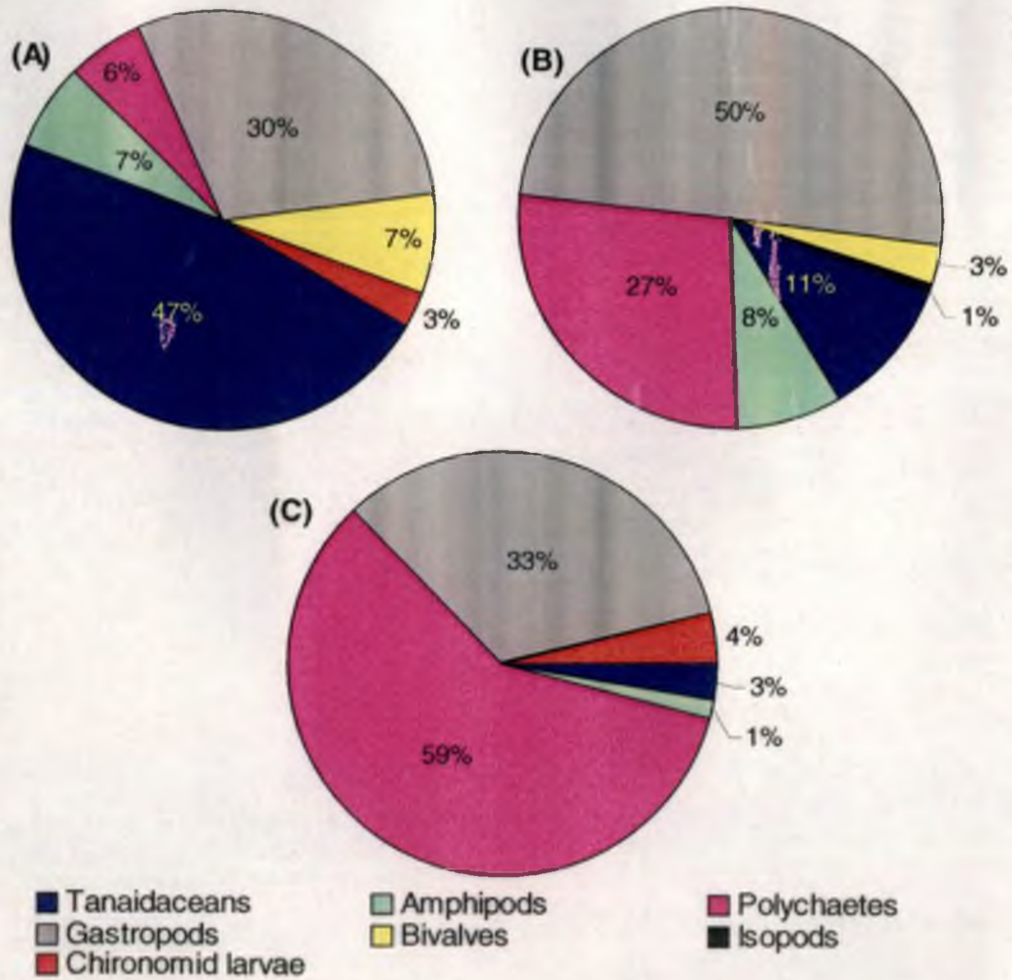

Fig. 25. Percentage composition of various benthic groups during (A) Post-monsoon, (B) Pre-monsoon and (C) Monsoon seasons in the culture field

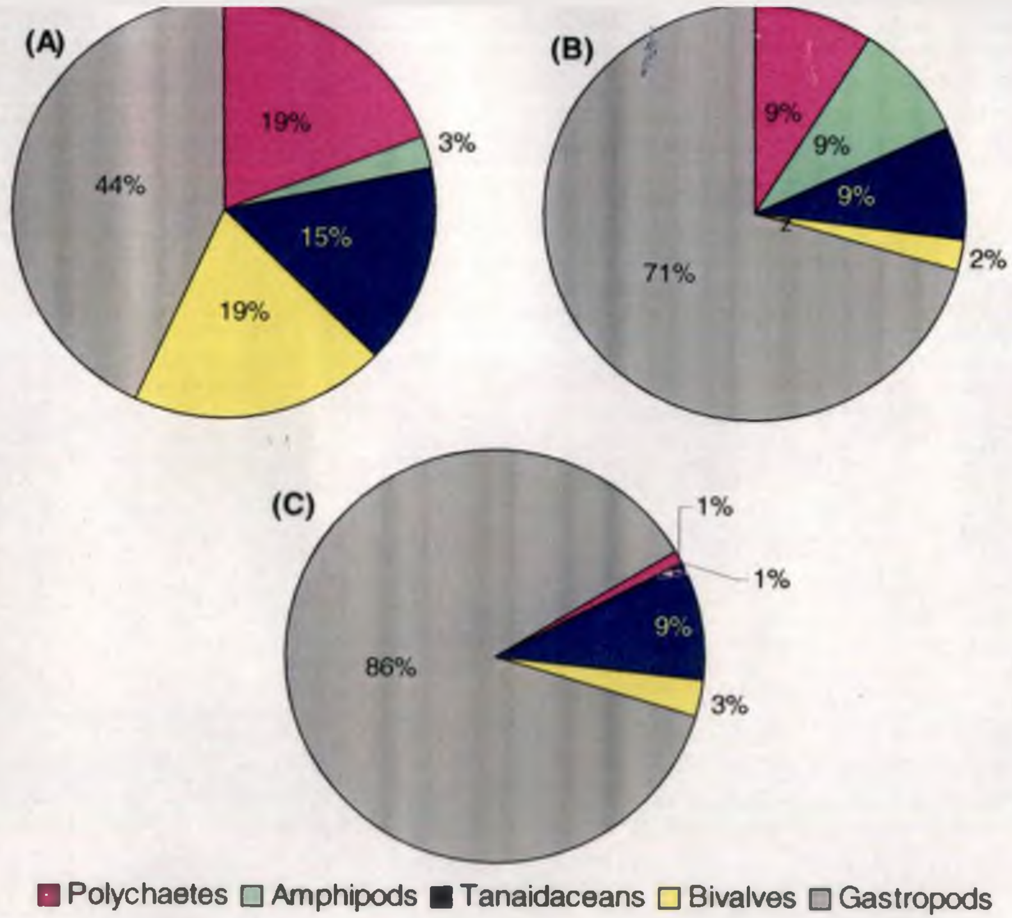

Fig. 26. Percentage composition of various benthic groups during (A) Post-monsoon, (B) Pre-monsoon and (C) Monsoon seasons in the backwater

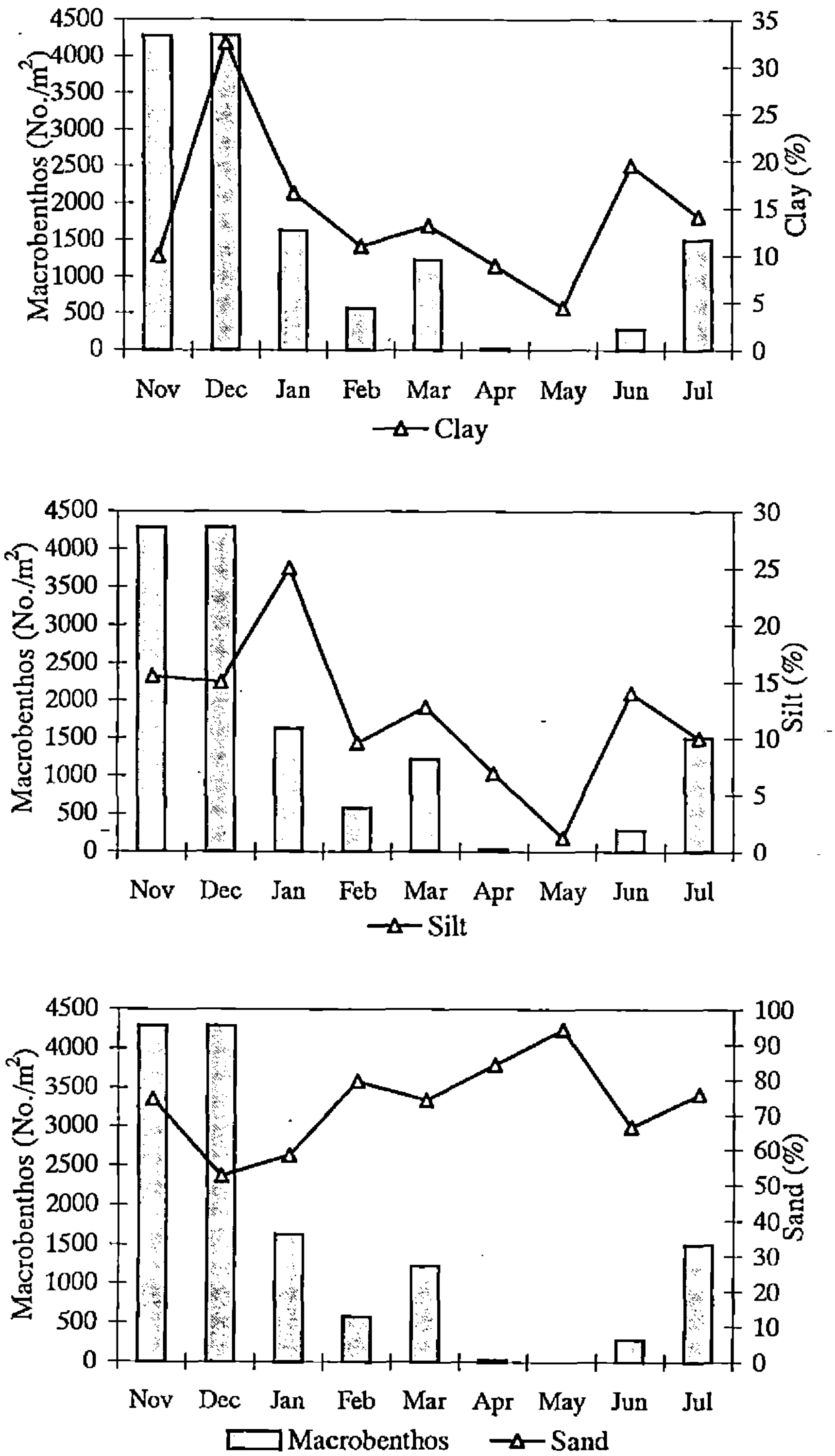

Fig. 27. Monthly variations in the abundance of macrobenthos in relation to hydrographic parameters in the culture field

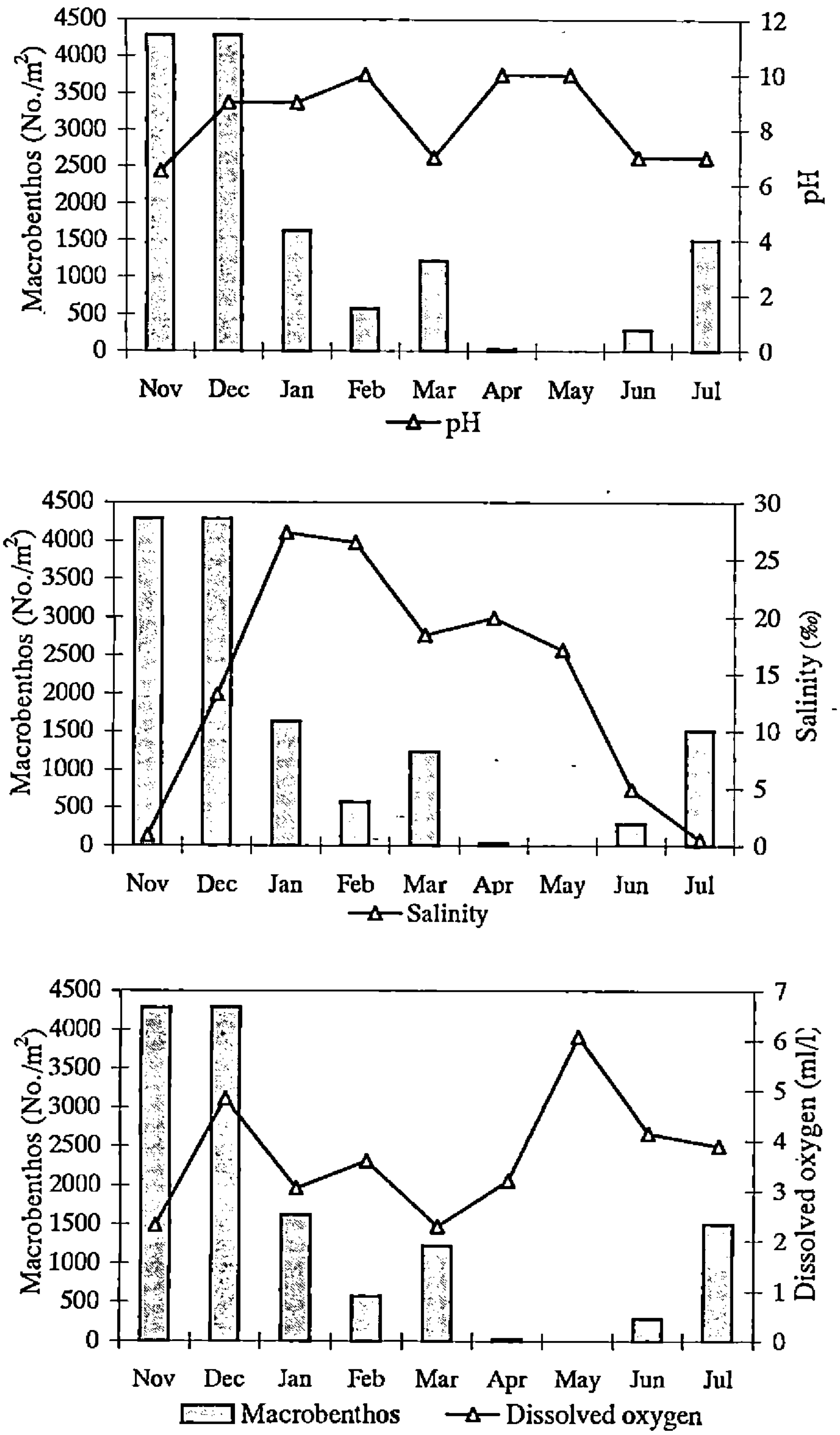

Fig. 27. (Contd.) Monthly variations in the abundance of macrobenthos relation to hydrographic parameters in the culture field

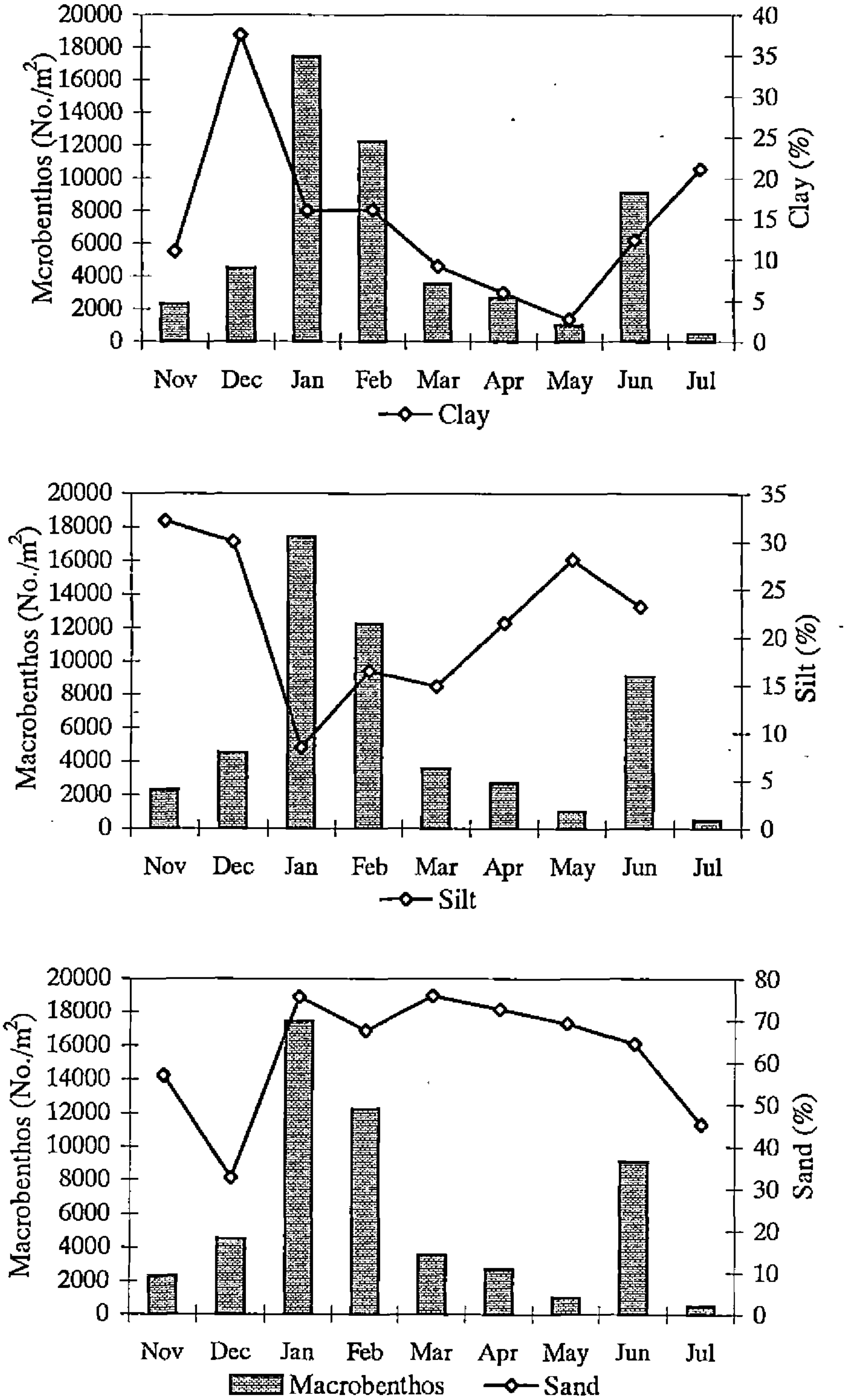

Fig. 28. Monthly variations in the abundance of macrobenthos in relation to hydrographic parameters in the backwater

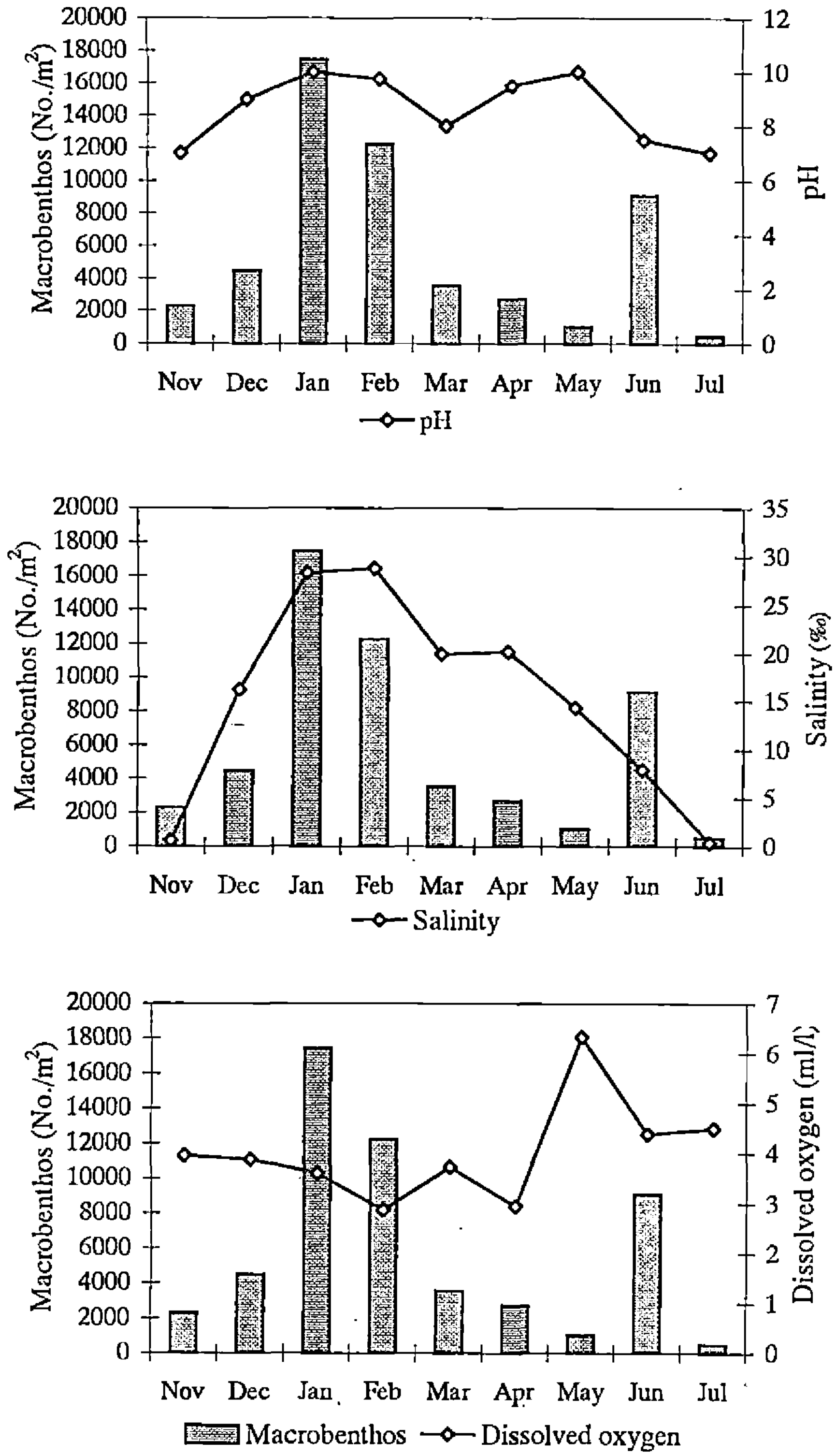

Fig. 28. (Contd.) Monthly variations in the abundance of macrobenthos in relation to hydrographic parameters in the backwater

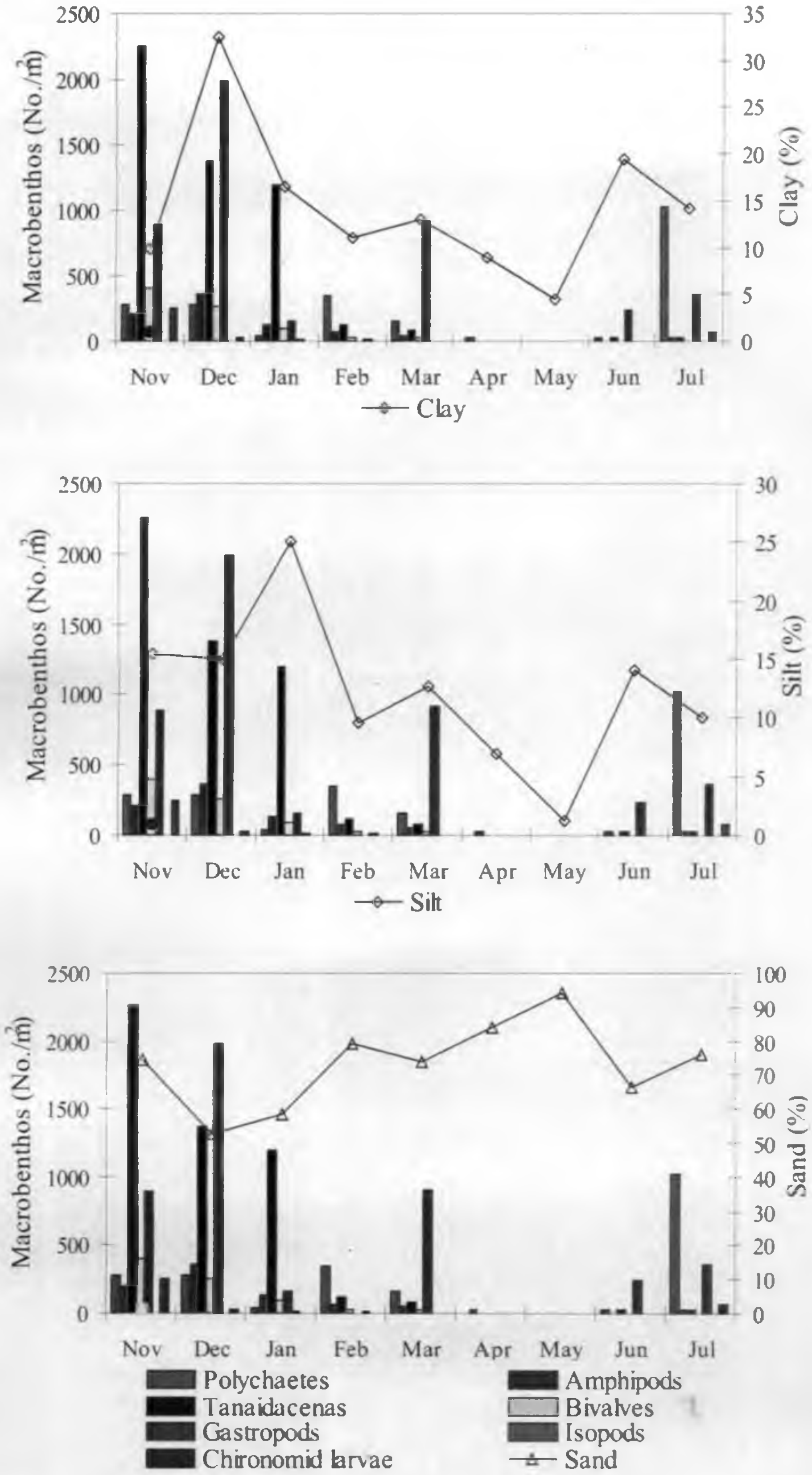

Fig. 29. Abundance of macrobenthic groups in relation to hydrographic parameters in the culture field

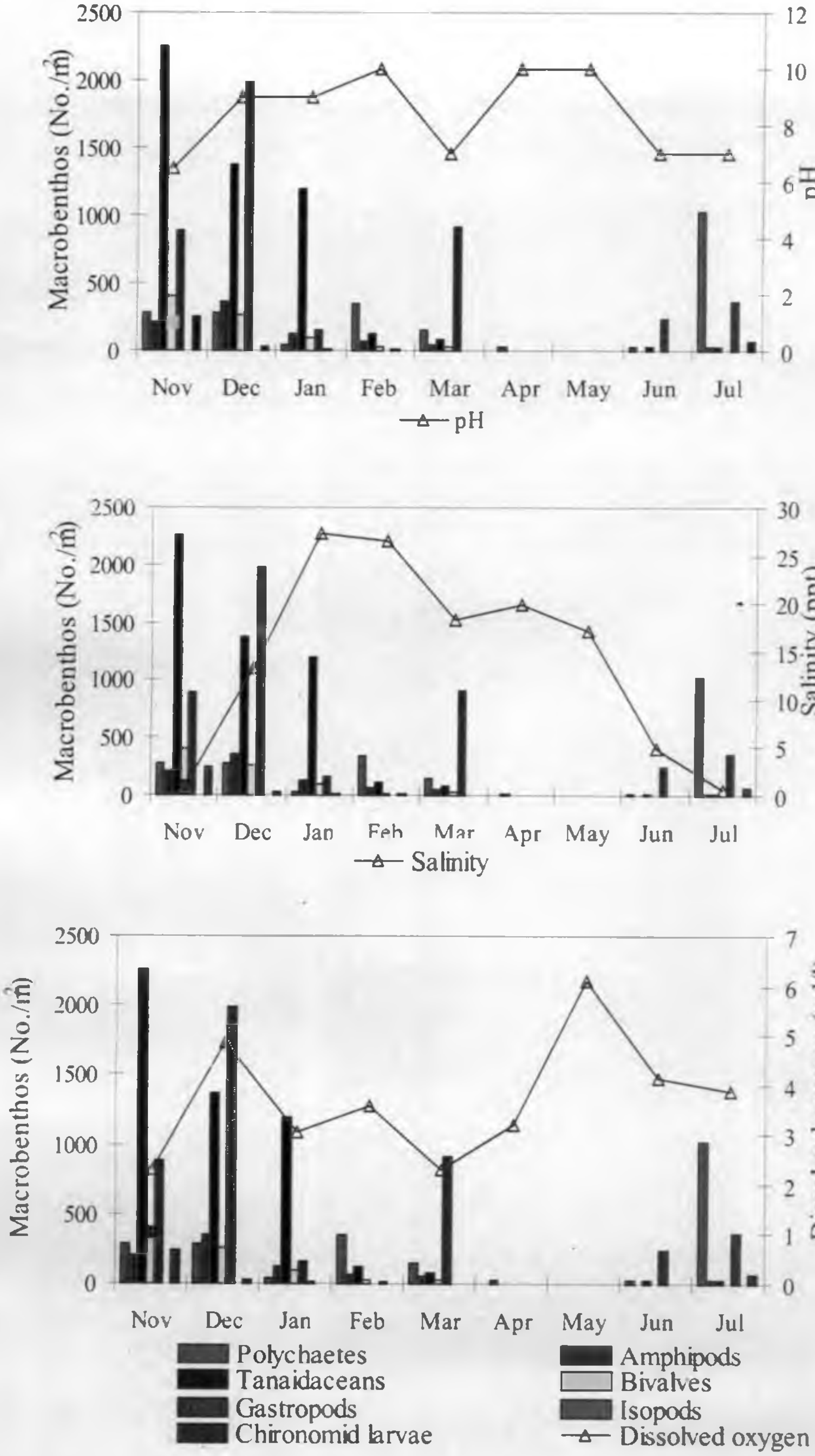

Fig. 29. (Contd.) Abundance of macrobenthic groups in relation to hydrographic parameters in the culture field

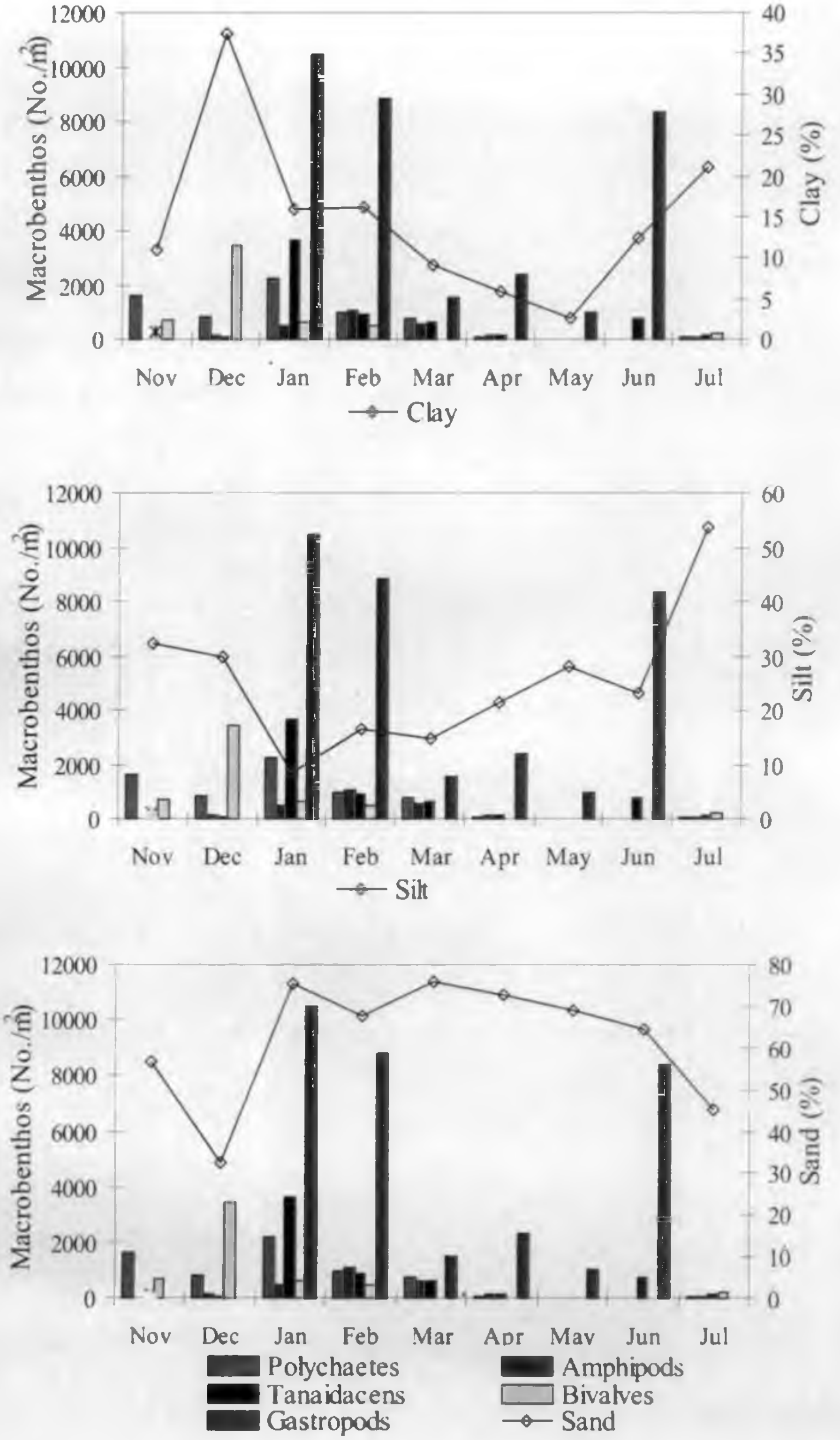

Fig. 30. Abundance of macrobenthic groups in relation to hydrographic parameters in the backwater

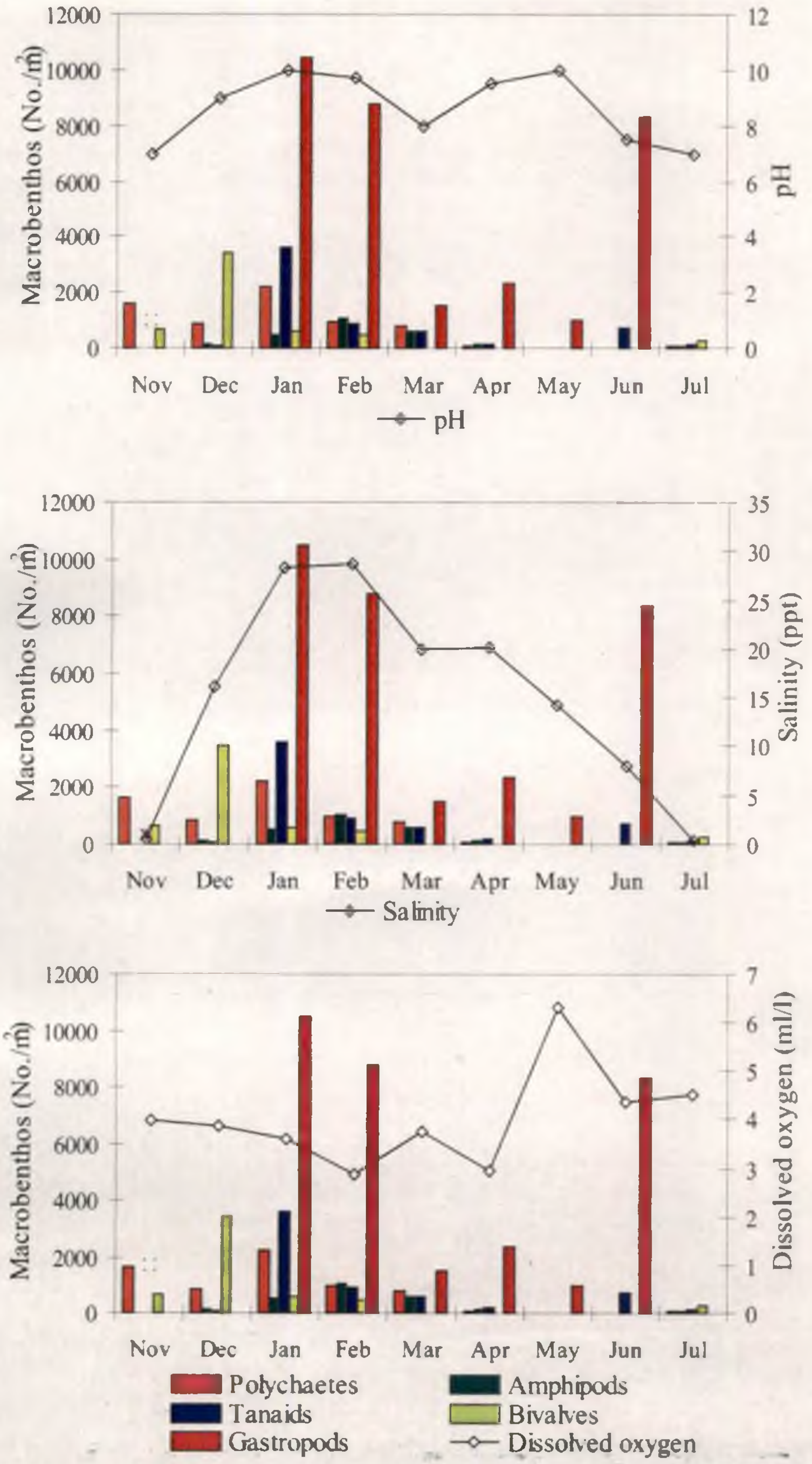

Fig. 30. (Contd.) Abundance of macrobenthic groups in relation to hydrographic parameters in the backwater

Discussion

5. DISCUSSION

5.1 HYDROGRAPHICAL CONDITIONS IN THE CULTURE FIELD AND BACKWATER

5.1.1 Temperature

In the culture field and backwater temperature remained more or less the same and the peak values were obtained during the pre-monsoon showing a declining trend with the onset of the monsoon (Table 1, 2; Fig. 2). Gopinathan *et al.* (1982), Sankaranarayanan *et al.* (1982) and Nair *et al.* (1988) reported similar trends in temperature of the culture fields. Similar trend in temperature has also been reported by Varma *et al.* (2002) and Haridevi *et al.* (2003) from the Panangad Jetty region, which is near to the present study area. The lowest temperature was recorded in November in both the culture field and the adjacent backwater. The low values observed during this period could be attributed to the winter effect. Similar values have been reported by Sankaranarayanan *et al.* (1982) from the tidal ponds of Ramanthuruth Island (Cochin). There was a gradual increase in temperature from December with the advance of summer and high values (>29°C) were recorded during February and May and it may be due to the warm weather and maximum solar radiation during this period (Silas and Pillai, 1975). With the onset of the monsoon in June, a sudden drop in temperature was noticed in the surface layers, concurrent with the freshwater influx.

5.1.2 Salinity

Among the hydrographic parameters studied, salinity was highly variable both in the culture field and in the backwater during different months (Table 1, 2; Fig. 3).

Similar values have been reported by Gopinathan *et al.* (1982), Sankaranarayanan *et al.* (1982) and Joseph (1988) from the culture fields. Salinity varied from time to time, depending on the influence of freshwater influx and penetration of saline water into the culture field through the estuary. Values of salinity ranging from those of marine to almost freshwater conditions were recorded during the period of investigation. Variations in salinity values (2.50-31.05‰) are typical of brackishwater ponds located along the Cochin backwaters which are influenced by monsoon rain and influx of freshwater from rivers (Pillai, 1977).

The values were low (<5‰) during June, July and November in the culture field and in July and November in the backwater, when the monsoons were active and freshwater flow predominated over the tidal flow in the surface layers of the backwater. The salinity values started increasing from December and high values (>25‰) were observed in January and February in both the places. However, there was a slight drop in salinity during March and May. According to the rainfall data of the Cochin Port Trust there was 5.5 cm rainfall on the previous two days of the sampling in March. In April (10.4cm) and May (56.5cm) also there was considerable rainfall in the area. Generally a day with 0.25 cm or more rain is treated as a rainy day (Menon and Rajan, 1989) and these rains may be the reason for the decrease in salinity during this period. Sankaranarayanan *et al.* (1982) have also reported a slight drop in salinity during April and May from some culture fields adjacent to Cochin backwaters and this he attributed to the effect of pre-monsoon showers.

Gopinathan *et al.* (1982) reported low salinity values from the fields adjacent to the part of the Cochin backwaters south of the Cochin barmouth whereas relatively high values were recorded in the fields of the part of the backwaters north of the barmouth having two connections with the sea. Josanto (1971), Gopinathan *et al.* (1974), Pillai *et al.* (1975), Varma *et al.* (2002) and Haridevi *et al.* (2003) also have reported similar salinity variations in the Cochin backwaters.

5.1.3 Transparency

Factors affecting the transparency of the water in the estuary are silt, planktonic organisms and suspended organic matter (McCombie, 1953). In the culture fields, turbidity from planktonic organisms is often desirable, to a certain extent whereas that caused by suspended clay particles is generally undesirable. Joseph (1974) has reported that during the monsoon period the water was turbid in the Cochin estuary owing to the silt discharged into the estuary by the rivers. Boyd *et al.* (1978) have observed that almost all problems related to dissolved oxygen in culture fields are the consequences of heavy plankton blooms. Such plankton densities result in Secchi disc visibilities of 30 to 45 cm. The probability of problems with low dissolved oxygen concentration increases as Secchi disc visibility decreases below 20 cm. In the present investigation, Secchi disc readings were within the congenial level in both the culture field and the backwater (Table 1,2; Fig. 4). Higher readings were observed in the culture field, which could be attributed to the low plankton production.

Statistically significant negative correlation ($r = -0.8462$) was observed between transparency and zooplankton abundance in the culture field in the present study. When zooplankton abundance was high the transparency was low. The low transparency may also be due to suspended silt and clay particles.

5.1.4 pH

Water body is buffered largely by carbonate system involving carbon dioxide, bicarbonate and carbonate. In this concept pH is determined by the ratio between these constituents (Stumm and Morgan, 1970). Phytoplankton and other aquatic vegetation remove carbon dioxide from the water during photosynthesis, which can an cause increase in pH of water during the day time and a decrease at night.

In both places high pH (>9) values were recorded during the late post-monsoon (December and January) and pre-monsoon period (February to May) with a slight drop in March. High pH is possibly due to the influence of high carbonate ratio in the carbonate system It remained more or less the same during the remaining pre-monsoon period and with the onset of the monsoon a sudden drop was noticed. The drop in pH in March may be due to the heavy rains during the previous two days of the sampling.

Sankaranayaranan *et al.* (1982) and Nair *et al.* (1988) observed high pH values during pre-monsoon season in the tidal ponds of Ramanthuruth Island, when salinity values were high. Low pH values were confined to the southwest monsoon period when the system was dominated by freshwater. Similar trend was observed during the present investigation also (Table 1,2; Fig. 5).

5.1.5 Dissolved Oxygen

Dissolved oxygen is an essential factor in the aquatic ecosystem. The atmosphere is a vast reservoir of oxygen, but atmospheric oxygen is only slightly soluble in water. The solubility of oxygen in water is mainly influenced by temperature and salinity. Solubility of oxygen decreases with increase in salinity and temperature. Low values of dissolved oxygen noticed during pre-monsoon months when the salinity and temperature values were high, may be due to the above relationship to some extent.

Although atmospheric oxygen will diffuse into water, the rate of diffusion is quite slow in the near stagnation conditions of the culture fields. Photosynthesis by phytoplankton is the primary source of dissolved oxygen in most aquaculture systems (Hepher, 1963; Boyd, 1979). The primary loss of oxygen from a water body is caused by the respiration of organisms, decomposition of organic matter and by diffusion of dissolved oxygen into the air (Boyd *et al.*, 1978).

In the present investigation high dissolved oxygen values were observed in the late pre-monsoon (May) and monsoon period from the culture field and backwater (Table 1,2; Fig. 6). Haridas *et al.* (1973) and Pillai *et al.* (1975) reported high dissolved oxygen values during the monsoon period and low values during the post-monsoon and early pre-monsoon periods from the Cochin backwaters. Haridevi *et al.* (2003) also observed similar trend from the present study area. Qasim *et al.* (1969) stated that the higher oxygen concentration during this period could be due to the higher primary production occurring in the surface layers.

5.1.6 Total Alkalinity

Alkalinity of the water sample is defined as the capacity of the sample to neutralize strong acid to the designated pH. It is numerically expressed in ppm (parts per million) unit as equivalent $CaCO_3$. The availability of carbon dioxide for phytoplankton growth is related to alkalinity. Waters with total alkalinity less than 20 ppm usually contain relatively little available carbon dioxide. Waters with total alkalinity of 20 to 150 ppm contain suitable quantities of carbon dioxide to permit plankton production (Boyd, 1979).

In the present investigation the total alkalinity levels were in desirable range except during the monsoon period in the culture field when very low values were recorded whereas in the backwater they were in optimum range throughout the period (Table 1, 2; Fig. 7). Low values during monsoon may be due considerable influx of rainwater which is free from any alkalinity causing substances.

In both the culture field and the backwater relatively higher values were observed during the pre- and post-monsoon months, while a pronounced fall was observed during the monsoon months. Similar trend has been reported by Silas and Pillai (1975) from the Cochin backwater. They observed a pronounced fall in total alkalinity during the monsoon months and the values showed increasing trend during the post-monsoon period. Alkalinity values in the summer months did not show much variation.

5.1.7 Nutrients

Nutrient distribution in the Cochin backwaters shows a marked rhythm mainly due to the local precipitations and river run-off. Its concentration remains homogeneous throughout the water column during the period when the estuarine system remains predominantly marine, while high values are encountered during monsoon season (Sankaranarayanan and Qasim, 1969; Silas and Pillai, 1975; Sankaranarayanan *et al.*, 1982, Anirudhan *et al.*, 1987).

Physico-chemical conditions in the Cochin backwaters, connected canals, adjacent paddy fields and the perennial fields are controlled by tides (Sankaranarayanan *et al.*, 1986). Since the prawn culture fields are shallow, it is believed that one of the major factors governing the distribution of nutrients may be the variations in the regenerative property of the bottom mud rich in organic matter due to biological and chemical oxidation (Sankaranarayanan *et al.*, 1982; Nair *et al.*, 1988). In shallow systems the major recycling of nutrients is effected through sediments (Reddy and Sankaranarayanan, 1972).

5.1.7.1 Nitrate-N

In the present investigation high values (> 9 µmol/l) were observed during the monsoon and late post-monsoon when fresh water condition prevailed in both the culture field and the backwater (Table 1,2; Fig. 8). Low values were observed during the pre-monsoon months. On an average nitrate values were little high in backwater than in the culture field. Nair *et al.* (1988) reported increasing trend in the nitrate-N values in the culture fields during the monsoon months due to freshwater discharge and low values during the remaining period due to less land drainage and high primary production. In the present investigation also similar trend was observed from the culture field and backwater. Haridevi *et al.* (2003) reported high monthly fluctuations in nitrate concentration in this region. The range was between 0.1 and 21.3 µmol/l. High values were reported during monsoon and low values during pre-monsoon. Sreedharan and Salih (1974) reported that except for monsoon months nitrate was low (1.5-5.5 µg at/l) in the Cochin backwater. But during the monsoon it suddenly increased to 25-30 µg at /l. Sheeba *et al.* (1996) noticed a nitrate concentration of 10.09-14.53 µ mol/l in Nettoor mangrove area in the Cochin backwaters.

5.1.7.2 Phosphate-P

In the present investigation phosphate values were relatively low both in the culture field and in the backwater and did not show pronounced seasonal variations unlike nitrate values (Table 1, 2; Fig. 9).

Comparatively high values were observed during the pre-monsoon months while very low values and complete absence were observed during the monsoon months in both the places. Similar trend was observed by Joseph (1974) in the Cochin harbour area and in its vicinity. He reported that during the monsoon period the water is turbid owing to the silt discharged into the estuary by the rivers. He attributed the rapid decline of the high phosphate of the summer months to nearly nil values of the monsoon period to adsorption of phosphate by the silt brought in to the estuary by the freshwater discharge. Jitts (1959) reported that estuarine sediments can trap 80 to 90% of the phosphorus and Rochford (1951) suggested that sediments release phosphorus when the concentration in the overlying water is below 1 µg-at/l and absorb it when the concentration is above 3 µg-at/l.

Qasim and Sankaranarayanan (1969) also recorded relatively high values of phosphate concentration in this estuary during the pre-monsoon months and relatively low values during the monsoon months. Low to complete absence of inorganic phosphate recorded during the present investigation during the monsoon months may be due to the onset of monsoon and subsequent removal of phosphate from the solution by the silt brought into the estuary by rivers and land drainage and the biological removal of it by algal population. Qasim and Wyatt (1973) noted the highest algal population in the pre-monsoon period with a peak density of $1859x10^3$ cells/m^2 in May. Sankaranarayanan and Qasim (1969) indicated that in addition to the enrichment of phosphate by river run-off and land drainage, there might be some other mechanisms for its enrichment in the estuary. The interchange of phosphorus between the bottom and the overlying water may be another feature to be considered. According to Moore (1930) the phosphorus content of estuarine mud is 50 times greater than that of the water above and therefore, any stirring up of the sediment would greatly influence the concentration of phosphorus in the bottom layers. In estuaries the release of phosphorus from the silt occurs at a low oxygen concentration (Rochford, 1951) and at an increased pH (Carrit and Goodgal, 1954).

5.1.7.3 Silicate-Si

In both the culture field and the backwater silicate values remained low during the pre-monsoon and post-monsoon months (Table 1,2; Fig. 10). An inverse correlation was observed between salinity and silicate in the present investigation.

Sankaranarayanan and Qasim (1969) reported that silicon content of the backwater is generally high, and it is to be expected because of considerable freshwater discharge and land drainage. High silicate values are associated with low salinity of water and vice versa, indicating an inverse relationship between the two.

The behaviour of silicate-silicon in estuaries is the result of physical, chemical and biological processes taking place and it varies from one estuary to another (Kamatani and Takano, 1984). Anirudhan and Nambisan (1990) reported that silicate concentration in the estuary is largely dependent on external sources such as river discharge and land drainage. They found that intrusion of seawater also plays a decisive role in controlling the distribution of silicate-silicon in the estuary. They also observed that silicate values were high during monsoon and as the season advances to post-monsoon and pre-monsoon, a decrease in silicate-silicon is observed with an increase in salinity. They found that the coefficient of correlation and regression equations between salinity and silicate showed significant negative correlation during all the seasons, indicating that silicon behaves conservatively in this estuary.

5.1.8 Soil texture

In the culture field the substratum was generally sandy in nature (Table 3, 4; Fig. 11). During most of the months sand content was high with relatively low clay and silt fractions. The sand content was especially high during April and May reaching 84.2 and 94.2%, monsoon months of June, July in both places. Joseph (1988) has reported similar trends in zooplankton production of some culture fields of this region.

The abundance of total zooplankton does not show any significant correlation with the hydrographic parameters studied (Table 7). Even though salinity is considered to be the master factor in the estuarine environment its variations do not reflect in the abundance of zooplankton both in the culture field and open water (Fig. 18, 19). This may be due to the replacement of the organisms of the high salinity period (pre-monsoon) by fresh water organisms during the monsoon season as observed by Pillai *et al.* (1973). According to Silas and Pillai (1975) salinity acts on zooplankton in a different way affecting the nature and type of fauna and not on the biomass of zooplankton as a whole. Wellershaus (1974) also observed that there is no linear correlation existing between zooplankton abundance and salinity of the Cochin backwaters. The present observations agree with these findings (Table 7; Fig. 18, 19).

As stated in the previous chapter crustacean larvae, copepods, tintinnids, nematodes, veliger larvae of molluscs and rotifers were the conspicuous constituents of the zooplankton. In general, the relative abundance of these groups varied according to the hydrographical conditions in different seasons (Fig. 20, 21). In both the culture field and the open water crustacean larvae and copepods were the dominant groups and were present throughout the period of observation in varying numbers.

Crustacean larvae constituted 42, 37 and 42% of the zooplankton during the post-monsoon, pre-monsoon and monsoon seasons, respectively in the culture field (Fig. 16). They dominated the zooplankton of the culture field during the three seasons and did not show any correlation with the environmental factors (Table 7; Fig. 20).

In the backwater, they constituted 28, 46, and 53% of the zooplankton during the post-monsoon, pre-monsoon and monsoon seasons, respectively (Fig. 17). They dominated the zooplankton during the pre-monsoon and monsoon seasons and have not shown significant correlation with the hydrographic parameters observed (Table 7; Fig. 21). Nair and Tranter (1971), Menon *et al.* (1971), Silas and Pillai (1975) and Antony (1991) have studied the distribution of crustacean larvae in the Cochin backwaters. According to their observations brachyuran larvae occur throughout the year while copepod larvae were more during November-April. Antony (1991) observed high abundance of crustacean larvae in the Cochin harbour area during the onset of the monsoon and attributed the increase to the sudden change in salinity, which triggered the spawning of the decapods. She also observed that the decrease in the abundance of the larvae in the subsequent months might be due to heavy mortality caused by drop in the salinity. No such decrease was observed during the present study. An increase in the abundance of crustacean larvae during the post-monsoon period can be attributed to the increase in salinity and temperature favouring the multiplication of brackishwater forms.

Copepods were the second major constituents of the zooplankton in the culture field as well as in the open water. They were present throughout the period of observation in varying intensities (Table 5, 6; Fig. 14, 15). In the culture field the maximum number was recorded in July when the salinity was the lowest. This may be duc to the dominance of cyclopoids of freshwater origin. In the culture field they constituted 23, 22 and 55 per cent of the total zooplankton during the post-monsoon, pre-monsoon and monsoon, respectively. They dominated the zooplankton during the monsoon season (Fig. 16). In the backwater the copepods formed 33, 32 and 35 per cent of the total zooplankton, respectively, during the post-monsoon, pre-monsoon and monsoon

(Fig. 17). However seasonal variations were not pronounced in copepod abundance in the present study area. Studies by George (1958) and Silas and Pillai (1975) also have shown that copepods dominated the zooplankton of the Cochin backwaters both in number and variety of species throughout the year. Nair and Tranter (1971) and Antony (1991) have reported that copepods were more during the post-monsoon period and succession of species in response to seasonal variations in salinity is responsible for their abundance throughout the year. George (1958) has observed that there are several species of copepods, which are euryhaline occurring in the region in all the seasons.

Antony (1991) observed that variations in environmental factors like temperature and dissolved oxygen in the Cochin backwaters do not have a direct relationship with the fluctuations in the abundance of copepods. According to her factors like the availability of food, species composition and reproductive potential of the species may affect the populations.

Pillai (1972) found a positive correlation between salinity and the distribution of copepods in the estuary. However, a negative correlation was observed during the present study but the correlation coefficients were not statistically significant (Table 7). This negative correlation may also be due to the anomalous salinity values observed during pre-monsoon months (March, April and May) because of the pre-monsoon showers. During most of the months the salinity of the area was below 20 ‰ and freshwater conditions prevailed during the monsoon season (Table 1, 2; Fig. 3). These observations point to the probability of the copepods being highly euryhaline and proliferating in low salinities in the culture field and adjacent backwater.

Tintinnids were observed during the high saline period and their number gradually decreased with decreasing salinity (Table 5, 6; Fig. 14, 15). They are generally marine in origin and are found during the pre-monsoon period when the salinity is high in the estuary. Positive correlation was observed between tintinnids and salinity but it was not significant statistically. This indicates that they prefer high salinity. The tintinnids were abundant constituting 27% of the total zooplankton during the pre-monsoon period while their number decreased forming only 5% of the total zooplankton during the monsoon and post-monsoon seasons (Fig. 16). In the backwater they formed 9% of the total during the pre-monsoon season. During the monsoon season their number decreased to 5% of the total and they were not noticed during the post-monsoon season. An unusually large number of them was observed in March.

Nematodes though benthic in nature were observed in the plankton during the present investigation. In both the culture field and backwater they showed higher abundance in March. They were either absent or very few in numbers in the other months and did not show significant correlation with any of the hydrographic parameters (Table 7; Fig. 20, 21). In the culture field the number of nematodes was more in the pre-monsoon season forming 9% of the total zooplankton. They formed only 3% during the post-monsoon season and were absent during the monsoon season (Fig. 16). In the backwater they were noticed only during the pre-monsoon season constituting 6% of the total zooplankton (Fig. 17).

Rotifers were present in the culture field in November and July and in the backwater during November, May and June. They were present in the samples when salinity values were low. They showed negative correlation with salinity, though not significant. Rotifers were present in small numbers in the culture field forming 8% and 3%, respectively, during the post-monsoon and monsoon seasons, while they were not observed during the pre-monsoon season (Fig. 16). In the backwater they constituted 2, 3 and 7 % of the total zooplankton during the post-monsoon, pre-monsoon and monsoon seasons, respectively (Fig. 17).

Veliger larvae of gastropods and lamellibranchs were observed in the culture field during December and February. They were 8% and 3% of the zooplankton during post-monsoon and pre-monsoon seasons, respectively in the culture field and were absent during monsoon season (Fig. 16). However they were not present in samples from the backwater. George (1958) and Nair and Tranter (1971) recorded the presence of veliger larvae belonging to *Thais sp.* and *Neritina sp.* during both pre-monsoon and post-monsoon periods, whereas Silas and Pillai (1975) recorded their maximum during the post-monsoon period from the Cochin backwater.

Rao *et al.* (1975) observed that the species diversity of zooplankton is high during the high salinity regime at the mouth region of the estuary and there is a progressive diminution towards the head. In the present investigation it was observed that the number of groups contributing to the zooplankton was high during the high salinity regime and it gradually decreased with decreasing salinity in the study area.

The total zooplankton have not shown significant correlation with the nutrient concentration in the present study. It is well known that nutrients do not have direct relation with zooplankton, but they influence them indirectly by influencing the primary production. Zooplankton graze upon the phytoplankters, abundance of which is dependent on the availability of nutrients. Studies have shown that the availability of food in the form of phytoplankton for the zooplankton is never a limiting factor in the Cochin backwaters (Madhupratap and Haridas, 1977).

The above results of statistical analysis for the influence of hydrographic parameters like pH, transparency, temperature, dissolved oxygen, salinity, total alkalinity, nitrate, phosphate and silicate on the zooplankton abundance showed that none of these had significant influence independently. However, the variations in the zooplankton abundance may be due to the combined effect of all these factors.

In brief, the present studies reveal that there is no significant variation in the total zooplankton abundance in relation to seasonal changes in the hydrographical conditions in the area. However, there are variations in the abundance of individual groups constituting the zooplankton and these may be due to the seasonal changes in the hydrographic parameters to some extent.

5.3 MACROBENTHOS

Since prawns are primarily inhabitants of the benthic region and obtaining food from the bottom, the distribution and abundance of benthic populations are of great significance. It is well known that benthic populations represent an important link in the trophic cycle of aquatic ecosystems. The importance of benthic fauna as food of brackishwater fishes and prawns has been studied by several workers (Gopalakrishnan, 1952; Pillai, 1954; George, 1958). The role of benthic fauna as food of cultivable species has been emphasized by William (1958) and Marte (1980). The brackishwater ponds usually support a rich fauna of molluscs, polychaete worms and smaller crustaceans like copepods, amphipods, isopods, tanaidaceans *etc.* (Jhingran, 1975).

Tanaidaceans, polychaetes, amphipods, gastropods, bivalves, isopods and chironomid larvae were the major benthic groups obtained during the present investigation.

In the culture field benthic populations were maximum during the post-monsoon months and showed a decreasing trend during the pre-monsoon and were absent in May. The populations showed an increasing trend with the onset of monsoon. Maximum abundance was observed during November and December in the culture field. Joseph (1988) reported high benthic populations during November and March from the culture fields of this region. However, no macrobenthos were observed in May in the culture field. This may be due to the high content (94.2 %) of sand in the bottom coupled with changes in the hydrographical conditions due to the sudden rains during the month.

In the backwater maximum number was observed in January and minimum in July. Relatively more macrobenthos were observed during January and February when high salinity prevailed. They gradually decreased from March onwards reaching the minimum in July.

Pillai (1977) observed fairly rich benthic fauna during pre- and post-monsoon periods and complete absence during the monsoon from the Cochin backwaters. Desai and Krishnankutty (1967) also reported a marked decline of macrofauna during the southwest monsoon in the Cochin backwaters.

Gastropods constituted 30, 50, and 33% of the total macrobenthos in the culture field, respectively during the post-monsoon, pre-monsoon and monsoon seasons (Fig. 25). In the backwater respective percentages were 44, 71 and 86 (Fig. 26). They dominated the macrobenthos during all the three seasons in the backwater while in the culture field their dominance was during the pre-monsoon period only.

In the culture field the tanaidaceans formed 47, 11 and 3% of the macrobenthos during the post-monsoon, pre-monsoon and monsoon, respectively while in the backwater the percentages were 15, 9 and 9 during the same periods (Fig. 25, 26). In both places they were more in number during the post-monsoon season and in the culture field they were the dominant group in that period.

The polychaetes constituted 6, 27 and 59% of the total macrobenthos during the post-monsoon, pre-monsoon and monsoon seasons, respectively in the culture field. The percentages for the three seasons in the backwater were 19, 9 and 1, respectively (Fig. 25, 26). In the culture field their number increased in the monsoon season while it decreased in the backwater in the same period.

Amphipods were 7, 8 and 1 per cent of the total during the post-monsoon, pre-monsoon and monsoon seasons, respectively in the culture field while they formed 3, 9 and 1 per cent, respectively during the same periods (Fig. 25, 26). In both places the amphipods showed maximum intensity during the pre-monsoon.

Bivalves were not noticed during the monsoon period in the culture field and during post-monsoon and pre-monsoon periods they constituted 7 and 3%, respectively (Fig. 25). In the backwater the percentages were 19, 2 and 3, respectively for the post-, pre- and monsoon seasons. Their number was more during the post-monsoon season in both places.

In the culture field chironomid larvae were observed during November, December and July. The highest number was observed during November and they were absent during the following months. They reappeared in July. Joseph (1988) recorded the presence of chironomid larvae in the culture fields of this region during the early monsoon period and they were absent in the later months. Consumption by predators as reported by Gundermann and Popper (1977) from the prawn fields of Fiji Island and increase in the salinity as observed by Saraladevi and Venugopal (1989) from the Cochin backwaters may be the reasons for the disappearance of chironomid larvae during the later months.

In the culture field the bottom was mainly sandy in nature, while in the backwater it was silty sand (Table 3, 4; Fig. 11, 12). The correlation coefficients between textural composition of the sediment *viz.* sand, silt and clay and the total benthic abundance, though not significant statistically, showed a direct relationship with the clay and silt fractions of the sediment (Table 10). It showed an inverse relationship with the sand content in the culture field. Relatively high benthic abundance was observed during the post-monsoon and monsoon months when clay and silt fractions in the sediment were relatively high with considerable amounts of sand. During the pre-monsoon when the sand fraction of the sediment showed high values, especially during April and May the macrobenthos were very few or completely absent. Sand content of the sediment in the culture field increased from post-monsoon to pre-monsoon, while the benthic population showed a decreasing trend. However, it was found that polychaetes were not influenced by the variations in the textural composition of the sediment (Fig. 27, 29).

In the backwater benthic abundance showed strong inverse relationship with the silt fraction of the sediment, whereas it showed direct relationship with sand and clay even though not significant statistically. All the groups except bivalves showed inverse relationship with silt but 'r' values were not significant statistically. Bivalves showed inverse relation with the sand and direct relation with clay which are statistically significant indicating that their abundance in the backwater is influenced by the variations in the sand and clay fractions of the sediment (Table 10; Fig. 28, 30).

The relationship between the nature of the substratum and the occurrence and abundance of the benthos has been well established by several workers (Jones, 1950; Sanders, 1958; Kurian, 1967; Bloom, 1972; Parulekar *et al.,* 1975; Murugan *et al.,* 1980; Varshney, 1981). Seasonal fluctuations in the characteristics of the substratum have been found to influence the qualitative and quantitative composition of the benthic fauna in the backwater as well as in the culture fields adjacent to it (Saraladevi and Venugopal, 1989; Aravindakshan *et al.,* 1992). In the present investigation also the variations in the benthic fauna were found to be affected by the variations in the sediment characteristics especially in the culture field.

Joseph (1988) while studying the bottom characteristics of the fish culture ponds of this region found that the substratum was generally sandy and the faunal variations are not related to the nature of the soil. However, during the present investigation soil texture in the culture field showed variations in different months and this could be one of the reasons for the variations in the benthic fauna (Fig. 27, 29).

Russels (1950) has observed close association of organic content with clay content of the sediment. According to him the area with high fraction of clay supported high proportion of organic matter. Murthy and Veerayya (1972) while studying the sediments of the Vembanad Lake found the same relationship between organic matter and grain size. Singh (1987) also observed that sediment with high clay content supported high organic carbon and reported that benthic biomass was closely related to organic carbon content. Kurian (1972) suggested that high benthic productivity in estuaries is due to the high organic carbon content which indicates the availability of detritus in the sediment. Harkantra *et al.* (1980) found the dominance of detritus feeders like crustaceans in the shallow regions and in the mouth of the estuaries and related it to the availability of detritus. During the present investigation sand fraction with low clay content was found in the culture field during the pre-monsoon period indicating low organic content (Fig. 11). This may be the possible reason for the paucity of fauna in such soils.

Pillai (1977) observed that in the Cochin backwaters dominance of sand fraction supported dense and varied benthic population. Panikkar and Aiyar (1937) observed absence of animals in thick clayey substratum and abundance of fauna in loose substratum. Harkantra and Parulekar (1987) reported that rich fauna occurred in clayey sand and sandy substrates whereas clayey substrate supported a poor fauna.

Kurian (1967) and Ansari (1977) observed that sandy deposits have a high abundance of benthos at some places while at others it was low. This suggests that the type of substratum cannot be considered independently as a major ecological factor determining the distribution and abundance of benthic fauna. Similar observations were made in the backwater during the present investigation also.

Singh (1987) and Sunil Kumar (1998, 2002) reported that maximum biomass was associated with fine sand with equal admixture of clay and silt. During the present investigation higher abundance of macrobenthos was observed during the months when sediment contained sand-silt-clay fractions in more or less equal proportions. It was also found that high sand content supported poor fauna in the prawn filtration field (Fig. 27, 29). In the backwater high sand content supported a rich fauna whereas high clay and silt fractions in the sediment supported a poor fauna (Fig. 28, 30).

Aravindakshan *et al.* (1992) observed that in the prawn culture fields of Cochin backwater, substratum with more sand and clay was more conducive for faunal production. Substratum with more sand content provides more interstices, permeability and microhabitats, so that food particles can move through it and permanent burrows can exist there (Sunil Kumar, 1995). In general, the pattern of community structure was related to the nature of substratum and availability of food. A direct relationship between benthic production and demersal fishery resources has also been reported by Harkantra *et al.* (1980) and Prabhu and Reddy (1987).

In both the culture field and backwater though significant correlation was not observed between salinity and total macrobenthic abundance an inverse relation was observed in the culture field, whereas a direct relation was seen in the backwater. In the backwater amphipods showed a statistically significant positive correlation with salinity (Table 10; Fig. 30).

The effect of salinity on benthic macrofauna in the Cochin backwaters has been studied by Desai and Krishnankutty (1967), Kurian (1967), Pillai (1977) and Ansari (1977). A progressive reduction in faunal diversity and abundance with decreasing salinity from the lower reaches of the backwater towards the upper reaches has been observed by Ansari (1974, 1977), Saraladevi and Venugopal (1989) and Sunil Kumar (1995). Pillai (1977) reported a decrease in bottom fauna during the monsoon months probably due to the fall in salinity. He observed that the recolonization of bottom fauna started during the beginning of the post-monsoon season reaching the maximum in the pre-monsoon season. Devassy and Gopinathan (1970) reported that there was an increase in the benthic biomass from marine to freshwater region during the monsoon, which they attributed to the disappearance of transition from marine to freshwater conditions. Srinivasan (1982) and Sugunan (1983) observed a gradual decrease in biomass in perennial and seasonal fields and coconut groves with the onset of monsoon. Singh (1987) reported that the correlation between the biomass and salinity showed that the 'r' values were not significant in backwater as well as seasonal fields, whereas in perennial fields this relationship was highly significant. Aravindakshan *et al.* (1992) found that the benthic abundance is not supported by high salinity conditions in the prawn culture fields in and around Cochin backwaters. Gopalan *et al.* (1987) and Aravindakshan *et al.* (1992) have observed that in the distribution of tanaidaceans, salinity does not seem to be a major factor. Sunil Kumar (1998, 2002) has stated that the drastic change in salinity in the southwest monsoon does not affect the benthic productivity in the culture fields. The results of the present study also agree with these observations.

pH showed variations in the culture field and open water during the present study. The values were low during post-monsoon and high during the pre-monsoon. There was a sudden drop with the onset of the monsoon. The correlation between pH and the benthic population was not significant statistically in both the culture field and backwater. Though the correlation was not significant statistically an inverse relation was observed in the culture field as well as in the backwater. Among individual groups some showed a direct relation (Table 10; Fig. 27, 28, 29, 30). Singh (1987) observed significant negative correlation between benthic biomass and pH and stated that alkaline medium was unfavourable for the growth of macrobenthic fauna, especially in the perennial culture fields where the values were high. During the present investigation also high pH values and low benthic abundance were recorded in the culture field during the pre-monsoon (Fig. 27). Srinivasan (1982) and Sugunan (1983) also have reported the disappearance of benthic fauna during the regime of high pH in the perennial culture fields adjacent to the Cochin backwater.

In the present investigation both the culture field and the backwater showed comparatively low oxygen values during the pre-monsoon and high values during the monsoon months (Fig. 6). However, dissolved oxygen content was never below 2 ml/l in both places. The correlation between benthic populations and dissolved oxygen content was not significant statistically, but an inverse relationship was observed in both the culture field and backwater (Table 10). Similar findings have been reported by Singh (1987) from the perennial fields. Ansari (1974) and Kurian *et al.* (1975) have reported that because of constant water flow and relative shallowness of the lake, dissolved oxygen might not be a limiting factor for the bottom fauna in the Cochin backwaters.

Singh (1987) found that species diversity and population density in culture fields were low compared to the backwater. He reported that the distribution and abundance of macrofauna in the perennial culture fields were primarily influenced by pH, dissolved oxygen and organic carbon whereas, in the seasonal fields the biomass was primarily affected by organic carbon and salinity played only a secondary role. The nature of the substratum also plays a vital role in the distribution and abundance of benthic fauna. Aravindakshan *et al.* (1992) reported that sand, silt, clay, organic matter and salinity were found to be relatively important factors controlling the benthic biomass in the culture fields adjacent to Cochin backwaters. The present study reveals that the population density in culture field was low compared to that in the backwater. The abundance of macrobenthos in the culture field is controlled by several factors instead of a single factor and the nature of the substratum and pH are more important in this respect. In the backwater salinity is also a major factor.

Gopinathan *et al.* (1982) while studying the environmental characteristics of the seasonal and perennial culture fields in the estuarine system of Cochin classified the culture fields based on productivity. They found that the culture fields located in the immediate vicinity of Cochin barmouth are highly productive, while those away from the bar mouth are less productive. This is probably because of the incursion of nutrient laden waters being highly restricted in this zone.

The area of the present study is away from the bar mouth and the nutrient levels especially phosphate are low in the culture field. This may be limiting the primary productivity of the area leading to low secondary production in terms of zooplankton and macrobenthos in the culture field. The high pH noticed in the field may be another reason for the low productivity.

Summary

6. SUMMARY

1. The present study was carried out to find out the faunal variations of zooplankton and macrobenthos of a brackishwater prawn culture field adjacent to the Vembanad Lake, to correlate them with the variations in hydrographical conditions and to compare the results with those obtained from observations in the adjacent lake.
2. Monthly samples for hydrographical and biological studies were collected during the period from November 2002 to July 2003. Hydrographical factors like temperature, salinity, transparency, pH, total alkalinity, dissolved oxygen, nitrate-N, phosphate-P and silicate-Si were observed. Zooplankton samples were collected using a plankton net. Bottom samples for macrobenthos and soil texture were taken using a Van Veen grab.
3. To study the relationship between the zooplankton and different hydrographic parameters, linear correlation coefficients (r) were worked out. In the case of macrobenthos, correlations of total number with sediment texture (sand, silt and clay), salinity, dissolved oxygen and pH were estimated.
4. In both the culture field and backwater temperature showed peak values during pre-monsoon period and with the onset of monsoon the values decreased.
5. Salinity showed wide variations and ranged between 0.51 and 27.37‰ in the culture field and between 0.38 and 28.78‰ in the backwater. A sudden drop in salinity was observed from both places during March and May due to pre-monsoon showers.
6. Transparency values ranged between 30 and 31 cm in the culture field and between 30 and 35 cm in the backwater.

7. In both places high pH (>9) values were observed during late post-monsoon (December and January) and pre-monsoon period (February and May) and with the onset of monsoon the values decreased.
8. Dissolved oxygen showed low values during the pre-monsoon period whereas during the monsoon period relatively high values were obtained in both the culture field and backwater.
9. In both places, relatively high total alkalinity values were observed during pre- and post-monsoon months and the values decreased with the onset of monsoon.
10. Both nitrate and silicate showed high concentrations during monsoon period and low concentration during pre-monsoon period in the culture field and backwater. Phosphate was relatively low in both places and showed comparatively high values during the pre-monsoon months.
11. In the culture field substratum was sandy with low silt and clay fractions during most of the months. In the backwater the substratum was silty sand in nature.
12. The major zooplankton groups obtained were crustacean larvae, copepods, tintinnids, nematodes, rotifers and veliger larvae of molluscs. Among these crustacean larvae and copepods were the predominant groups in both places and were found during all the months.
13. Crustacean larvae dominated the zooplankton of the culture field during all the three seasons *viz.* pre-, post- and monsoon season, while in the backwater they were dominant during the pre-monsoon and monsoon seasons.

14. Copepods were the second major constituents of the zooplankton in both places. They dominated the zooplankton of the culture field during monsoon season. However, seasonal variations were not pronounced in copepod abundance in the present study area.
15. In both places tintinnids and nematodes were observed during the saline period and their number decreased with decreasing salinity. Rotifers were recorded during low saline period only. Veliger larvae were recorded during December and February in the culture field whereas they were not present in the samples from the backwater.
16. In the present study significant variation was not observed in the total zooplankton abundance in relation to seasonal changes in hydrographic conditions in the area. However, there were variations in the abundance of individual groups constituting the zooplankton and these may be due to the seasonal changes in the hydrographic parameters, to some extent.
17. Tanaidaceans, polychaetes, amphipods, gastropods, bivalves, isopods and chironomid larvae were the benthic groups obtained during the present investigation.
18. Gastropods dominated the macrobenthos during all the three seasons in the backwater while in the culture field they were dominant during the pre-monsoon period only.
19. In both places tanaidaceans were more in number during the post-monsoon season and in the culture field they were the dominant group in that period.
20. In the culture field polychaetes showed increasing trend from post-monsoon to monsoon period whereas in the backwater they showed decreasing trend in the same period.

21. Amphipods showed maximum abundance during pre-monsoon period in both places.
22. Bivalves were recorded in all the three seasons in the backwater whereas in the culture field they were not present in the samples during the monsoon period. In both places their number was more during the post-monsoon season.
23. Chironomid larvae were observed from the culture field only. They are freshwater forms and observed during low saline period only.
24. The benthic abundance was low in the culture field compared to the backwater.
25. In the culture field benthic populations were maximum during the post-monsoon months and showed a decreasing trend during the pre-monsoon. With the onset of monsoon they showed an increasing trend. In the backwater high benthic abundance was observed during January and February when high salinity conditions prevailed and gradually decreased from March on wards reaching the minimum in July.
26. In the culture field benthic abundance was mainly influenced by substratum characteristics and pH, whereas in the backwater salinity also was a major factor.
27. The area of the present study is away from the barmouth and the nutrient levels especially phosphate is low in the culture field. This may be limiting the primary productivity of the area leading to low secondary production in terms of zooplankton and macrobenthos in the culture field. The high pH noticed in the culture field may be another reason for the low productivity.

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COMMUNITY CHANGES IN ZOOPLANKTON AND MACROBENTHOS OF A PRAWN CULTURE FIELD IN RELATION TO HYDROGRAPHICAL CONDITIONS

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study was carried out in the prawn filtration field of the College of Fisheries at Panangad adjacent to the Cochin backwater system to find out the faunal variations of zooplankton and macrobenthos and to correlate them with the variations in hydrographic conditions and compare the results with those obtained from the observations in the adjacent lake. Monthly samples for hydrographical and biological studies were collected during the period from November 2002 to July 2003 from the culture field and adjacent backwater. Hydrographical features like temperature, salinity, transparency, pH, total alkalinity, dissolved oxygen, nitrate-N, phosphate-P, silicate-Si were observed. Crustacean larvae, copepods, tintinnids, nematodes, rotifers and veliger larvae of molluscs were the zooplankton groups obtained in the present study. Crustacean larvae and copepods were the dominant groups in both places and were found during all the months whereas tintinnids and nematodes were observed during saline period and their number decreased with decreasing salinity. Rotifers were recorded during low saline period only. Veliger larvae were recorded during December and February in the culture field, whereas, they were not present in the samples form the adjacent backwater. Statistical analysis for the influence of hydrographical parameters on the zooplankton showed that none of these had significant influence independently and the variations in the zooplankton abundance may be due to the combined effect of all these factors. Even though the seasonal changes in the total zooplankton were not pronounced the per cent composition of different groups showed fluctuation.

Tanaidaceans, gastropods, polychaetes, amphipods, bivalves, isopods and chironomid larvae were the benthic groups obtained. Among these

gastropods, tanaidaceans and polychaetes were the dominant forms. In the culture field benthic populations were maximum during the post-monsoon months and a showed a decreasing trend during pre-monsoon. With the onset of the monsoon they showed an increasing trend. In the backwater high benthic abundance was observed during January and February when high salinity prevailed and gradually decreased from March onwards reaching the minimum in July. In the culture field benthic abundance was mainly influenced by substratum characteristics and pH, whereas in the adjacent backwater salinity also played a role.

The area of the present study is away from the barmouth and the nutrient levels especially phosphate is low in the culture field. This may be limiting the primary productivity of the area leading to low secondary production in terms of zooplankton and macrobenthos in the culture field. The high pH noticed in the culture field may be another reason for the low productivity.