STRUCTURE AND THE SEASONAL CHANGES OF THE MACROBENTHIC COMMUNITY IN RELATION TO THE HYDROGRAPHY OF A PRAWN FILTRATION POND

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Dedicated To
My Teachers and Friends

DECLARATION

I hereby declare that this thesis entitled **"STRUCTURE AND THE SEASONAL CHANGES OF THE MACROBENTHIC COMMUNITY IN RELATION TO THE HYDROGRAPHY OF A PRAWN FILTRATION POND"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, or other similar title, of any other University or Society.

Panangad, JAYASREE P.S
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CERTIFICATE

Certified that this thesis entitled **"STRUCTURE AND THE SEASONAL CHANGES OF THE MACROBENTHIC COMMUNITY IN RELATION TO THE HYDROGRAPHY OF A PRAWN FILTRATION POND"** is a record of research work done independently by **Smt. JAYASREE. P.S** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

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Introduction

1. INTRODUCTION

Aquaculture of prawns in coastal brackish water bodies has been recognized as one of the highly potential areas for increasing prawn production. The driving forces behind increased aquaculture production of shrimp are the continued market demand for prawn and the large profit margin between the cost of production through aquaculture and the world market price. Considering the landings in the last ten years, stagnation in the prawn landing could be seen despite the increased fishing effort. Thus the marine landing of prawns in India is not in a position to supply more quantity to meet the ever increasing world demand for prawns. Therefore, aquaculture of the prawns is the only alternative to augment the supply of prawns.

Brackishwater aquaculture is an area where the potential for increase in prawn production is high. India is bestowed with a vast coast line, mud flats, swamps, mangroves etc. and these water bodies could be utilised for prawn farming. However, we have not been able to achieve adequate progress in this field probably because of the lack of proper understanding of the productivity potential of these areas. Cochin backwater, with an extensive area of 12700 ha (Gopalan *et al.,* 1983), has about 18600 ha of adjacent low lying areas suitable for prawn farming (Anon, 1978).

Understanding of the environmental parameters and productivity of a biotope is a pre-requisite for the effective utilization of its fishery resources. Benthic organisms form the food for certain bottom dwelling fishes and the developmental stages of most of these organisms are pelagic, forming important components in the plankton community, which in turn are consumed by fish population (Murugan et al., 1980). Hence the growth of benthos is considered as the prerequisite for stocking a brackishwater pond and therefore soil fertilization, instead of water fertilization, is more effective in brackishwaterfarm (Mitra *et al*., 1992).

There are many barriers which the pelagic larvae of macrobenthic animals have to cross before they finally settle on the bottom. Each type of bottom deposit will attract a very limited and selected set of species (Thorson 1966). Such biotic interaction coupled with the extreme variability of environmental factors resulted in the evolution of benthic fauna.

Productivity of benthos is presumably related to the primary productivity of the overlying water column (Lie, 1968). Settling of products of primary production which are not consumed by pelagic herbivorous zooplankton (Inverson *et al.,* 1979) could enhance benthic secondary production in sediments directly. The importance of sediment nature for the benthic faunal distribution was emphasized by many workers (Sanders, 1960; Thorson, 1966; Kurian, 1967; Parulekar *et al.,* 1975).

The average number and weight of benthic organism has a correlation with climatic factors and demersal fish production. Relation between the benthic production and exploited demersal fishery resources has also been reported (Harkantra *et al.,* 1980). Damodaran (1973) had reported the dependence of shrimps on benthos and also about the relationship between benthos and prawn catch. An increase in prawn catch towards the southwest coast of India associated with an increase in benthic biomass and an analysis of the statewise benthic production showed a good relationship with the demersal fish catch (Harkantra *et al.,* 1980). A direct relationship was observed between benthic biomass and demersal fish catches along South Kanara Coast (Prabhu and Reddy, 1987). Such a correlation indicates the important role played by the benthic biomass in the dietary of demersal fish. Hence, quantitative data on benthos can be used as an efficient tool for stocking the pond.

Bottom fauna is roughly divided into **a)** animal that spend much of their lives in the upper layers of the water and descend to the bottom for breeding, feeding or resting as contrasted with **b)** animals that spend most of their lives on the bottom; and **c)** burrowers (Allee *et al.,* 1961). The first group includes bottom dwelling fishes, many crustaceans and other mobile invertebrates. The second and third categories correspond to Petersen’s epifauna and infauna respectively (Petersen, 1913).

For the ecological study of the bottom fauna it is necessary to consider two separate entities in the environment- the substratum and the water overlying it (Damodaran, 1973). For the first category of animals, the condition of the bottom water may be the most important factor. In the case of animals which live on the bottom and are constantly in contact with the bottom water (epifauna) for their feeding, respiration etc., the nature of the substratum as well as that of the overlying water are of equal importance. As far as the burrowers (infauna) which spend most of their life within the substratum are concerned, the physical and chemical nature of the sediment may be of greater significance than to the epifauna.

Benthic animals are divided into three categories according to size **1)** macrobenthos **2)** meiobenthos and **3)** microbenthos (Mare, 1942). Although the above terms are now in common use, the prefix *mega* (meaning large, great) is preferred to *macro* (meaning long, large), by some investigators (Carrikar, 1967)

As an understanding of the physico-chemical aspects of the environment is essential in order to obtain a true picture of the benthos, attempts were made in this direction. Hydrographical parameters such as salinity, water temperature, turbidity, pH, total alkalinity, hardness, nutrients, dissolved oxygen, primary production, chlorophyll-a and transparency were studied during the period of benthos investigation. The physico-chemical nature of the sediment was also studied. Influence of these ecological variables on the bottom fauna is discussed.

Review of Literature

2. REVIEW OF LITERATURE

2.1 BENTHOS

The study of benthos plays a major role in the formulation of strategy for bioconservation. Studying the benthos of an aquatic ecosystem is also useful for understanding changes in biological diversity. The study of benthos in aquatic ecological research and particularly evaluating marine pollution is especially effective in assessing long term changes (Datta and Sarangi, 1986). The benthos serves as useful indicators of health of estuaries and nearshore waters. Their life span is long enough to reflect the effects of environmental stresses (Anon, 2004).

Estuarine benthic fauna generally consists of marine, brackish water, 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 Cochin 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).

Kurian (1967) studied the benthos of the southwest coast of India and stated that apart from salinity, temperature and substratum ‘food supply’ or detritus plays an important role in benthic biomass. Panikkar (1969) reported partial or complete destruction of tropical estuarine fauna during the summer shower, followed by an annual repopulation of the estuaries and backwaters after the withdrawal of monsoon and the resulting salinity increase.

Desai and Krishnankutty (1969) compared the estuarine benthic fauna with marine benthic fauna and of the near shore regions of the Arabian Sea at Cochin 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 of Cochin back waters during the monsoon, which they attributed to the disappearance of transition from marine to freshwater conditions.

Benthos of the mud banks of the Kerala coast was studied by Damodaran (1973) and found that macrofauna consist mainly of polychaetes, crustaceans and molluscs.

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 of Vembanad Lake.

A progressive reduction in the faunal diversity and abundance with decreasing salinity from the lower reaches of Cochin backwater towards the upper reaches had 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 recolonisation of bottom fauna of Cochin back waters started during the beginning of the postmonsoon season and steadily increased and the maximum was recorded during the premonsoon season.

Gopalan *et al.* (1987) observed rich bottom fauna during the monsoon in the Vembanad estuary. Sunil Kumar (1998, 2002) observed rich bottom fauna in the prawn culture fields at Cochin. Jose *et al.* (1988) and Sunil Kumar (1998, 2002) also 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 connected to Cochin back waters.

The benthic fauna is mainly composed of polychaetes, molluscs and crustaceans in the order of abundance in the backwaters and in 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). Ansari (1974) found the occurrence of crustaceans throughout the Cochin estuary in all types of substrate and concluded that they were epibenthic in nature and had no substratum preference.

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, were distributed mainly in the sandy region of the estuary.

Pillai (1977) reported that polychaete fauna showed decrease in number during the monsoon and the maximum numbers were recorded during the premonsoon in the Cochin back waters.

Grizzle (1984) reported that macro benthic density was strongly correlated with dissolved oxygen and temperature in a sewage polluted, moderately enriched coastal lagoon namely Sykes creek at U.S.A.

Sunil Kumar (1995) reported that there was 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 around Cochin back waters 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 macro fauna and their seasonal distribution and abundance in perennial and seasonal culture systems of Cochin 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 of Panangad area of Cochin, meiofauna was mainly composed of nematodes and copepods and the macrobenthos was 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 had 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 adjacent to Cochin back waters and reported that there was 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%).

2.2 HYDROGRAPHICAL PARAMETERS

Sewell (1927) might be the first person to study about the water quality of a fish pond, when he studied the mortality of fish in a museum tank in Calcutta. Since then, many works have been carried out to understand the physico-chemical conditions of inland water either in connection with fish mortality or as a part of general hydrological study (Moyle, 1946; Ganapati, 1949; Mookherjee and Bhattacharya, 1949; Ganapati *et al.,* 1953, Chacko and Srinivasan*,* 1954 and Banerjee, 1967).

While studying the physico-chemical and biological condition of a pond in Calcutta, Saha *et al*. (1971) found considerable seasonal variations in water quality. Limnology of a temple tank at Thiruvananthapuram was studied by Anitha Kumari and Aziz (1989). Saha *et al*. (1990) studied ecological changes and its impact on fish yield of Kulis bed in Ganga basin. Impact of environmental stress on fresh water fishery resources was extensively studied by Jhingran (1991)

The hydrographic conditions of water bodies like rivers, lakes, backwaters and estuaries and their spatial and temporal changes were extensively studied (Balakrishnan, 1957; Ramamritham and Jayaraman, 1963; Cheriyan, 1967; Quasim and Gopinathan, 1969; Josinto, 1971; Sreedharan and Salih, 1974; Balakrishnan and Shynamma, 1976; Manoj Kumar, 1988; Varma *et al*., 2002;; Renjith *et al.,* 2004, Anon 2004, Renjith 2006).

The environmental condition of prawn filtration ponds was explained by several authors (Gopinathan *et al*., 1982; Singh, 1987; Mathew, 1987; Gopalakrishnan *et al*., 1988; Jose *et al*., 1988; Joseph *et al*., 1988; 1988; Nair *et al*., 1988, Balasubramanian *et al*., 1995; Ignatius, 1995; Venkatesan *et al*., 2001; Sudheer, 2003 and Susheela *et al*., 2006).

2.2.1 Salinity

Salinity is the master environmental factor affecting the physiological mechanisms of estuarine organisms (Kinne, 1971). The dominant feature of the estuarine environment is the fluctuations in salinity. Fresh water 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 (Ramamritham and Jayaraman, 1963; Quasim and Gopinathan, 1969). Sankaranarayanan and Quasim (1967) reported that salinity values were maximum in premonsoon months in Cochin backwaters. Stratification was reported during monsoon at lower reaches of estuary because of salt water intrusion (Balakrishnan and Shynamma, 1976; Ramaraju *et al*., 1979; Udayavarma et al., 1981; Sankaranarayanan *et al*., 1986, Joseph and Kurup, 1990). Ecology and productivity of prawn farms in central Kerala was studied by Ignatius (1995) and found that average salinity in ponds at Chellanam in Ernakulam District ranged between 16.94 ‰and 19.29 ‰and that of Poyya, Thrissur District ranged between 28.30 ‰ and 31.57 ‰. Varma *et al*. (2002) analysed long term daily variation of salinity at a station near Panangad jetty and noticed that salinity ranged between 0‰ - 32‰ with a bimodal variation. Salinity decreases during the monsoon season to reach the value 0‰. The premonsoon is the season of peak salinity in the area. These trends in the variations of salinity are same in the prawn culture fields adjacent to the Vembanad Lake (Gopinathan *et al*., 1982; Singh, 1987). During the active south west monsoon period

(June-September) the salinity remained less due to the inflow of large amount of fresh water into Cochin back waters (George, 1958). Gopinathan, 1982 and Venkatesan *et al*., 2001 observed the annual salinity range of 1‰-27‰ in seasonal and perennial prawn culture fields of Cochin estuarine system. Sudheer (2003) found that average salinity of an interior prawn filtration field in Cochin is around 15.2‰. The study conducted by Susheela *et al*., (2006) in the same field revealed that during pre-tsunami period (2003-04) the salinity range was 3.0‰-2.7‰ while after tsunami the salinity varied between 12.0‰ and 26.0‰.

2.2.2 Temperature

The variations in water temperature of the Vembanad Lake are not as high as salinity. 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 monsoon in Cochin backwaters. According to Kunjukrishnapillai *et al*., (1975) temperature ranged between 25°C to 33°C. Balakrishnan and Shynamma (1976) reported low values during July-August in Cochin harbour area. In the premonsoon period temperature was high at all depths. Sankaranarayanan *et al*. (1982) found that temperature values were low during the southwest monsoon in the culture field at Cochin. Singh (1987) reported that the temperature reached the peak during the premonsoon and showed a declining trend during monsoon months in seasonal and perennial fields. He observed that temperature values ranged between 24.5°C and 32.5°C. Nair *et al*. (1988) reported an annual variation in temperature in paddy-cum prawn culture fields of Cochin area was less. Temperature was low during December – February and showed an increasing trend afterwards. He also noted a decrease during monsoon months and again an increase during postmonsoon months. The variation in temperature in both surface and bottom waters of northern parts of Vembanad Lake during different seasons was related to the depth and location of stations (Batcha, 2000). Using daily temperature data for a long duration, Varma *et al*. (2002) observed a bimodal annual variation near Panangad Jetty. Anon (2004) reported that temperature did not show wide fluctuations in the Panangad region of Vembanad lake and ranged between 28.4°C and 33.5ºC, with a bimodal annual variation and the highest temperature was observed during the pre-monsoon months (March – April). Susheela *et al*. (2006) observed a temperature range of 29°C-32.5°C after tsunami and a range of 29.5°C-34°C before tsunami in an interior prawn filtration field in Cochin.

2.2.3 Turbidity

Turbidity is a measure of clarity of water. Anon (2004) reported that turbidity was an extremely important parameter for estuarine monitoring. Very high levels of turbidity of a short period of time may not have significant impact on ecology and may even be less of a problem than a lower level, which persists longer (Anon, 2004). In a turbidity range of 10 – 100 NTU for long hours, fishes start to show the stress. Anon (2004) recorded highest values during monsoon (range 0.49 –2.87) in Panangad region of Vembanad Lake.

2.2.4 pH

pH is a measure of hydrogen ion concentration and it indicates whether the water is alkaline or acidic. Brackish water is well buffered against wide variation in pH. Sankaranarayanan and Qasim (1969) reported that pH exhibited considerable fluctuations at the surface of Cochin backwater. They also found that during the period of freshwater discharge, the values at all depths decreased reaching a minimum during July and August. pH of the entire water column changed simultaneously. Sankaranarayanan *et al*. (1982) found that the pH values varied between 7.0 and 8.2 in some tidal pools of Ramanthuruthu Island (Cochin) and the higher values were recorded during the premonsoon season when the salinity was high. The coastal areas in many southeast Asian countries are acidic sulphate soils and becoming extremely acidic when reclaimed for shrimp ponds (Porter, 1976; Simpson and Pedini, 1985). Mortality of prawns was noticed by Mrithunjayan and Thampy (1986) in some cultured fields during first heavy monsoon rains as a result of reduction in pH from 7 to 4.5 due to leaching of acid sulphate soils from the bunds. Mathew (1987) reported that there were no seasonal trends in variation of pH and it fluctuated from 6.0 to 9.2 in perennial fields, from 6.7 to 8.2 in seasonal fields and from 6.1 to 8.3 in coconut grooves adjacent to Cochin backwaters. pH range between 6.5 and 9.0 is considered good for fish production in the culture ponds (Boyd, 1990; Venkatesan *et al*., 2001). Balasubramanian *et al*. (1995) found that pH, ranging between 7 and 8, was good for high primary production. Susheela *et al*. (2006) found a pH range of 7.0 – 8.5 during pre tsunami (2003 – 2004) and 6.0 -10.5 during post tsunami (2005) period in an interior prawn filtration field in Cochin.

2.2.5 Total Alkalinity

Total alkalinity of water refers to the total concentration of bases in water and is expressed in milligrams per litre of equivalent calcium carbonate. The variations in alkalinity in the Cochin backwater were less during the pre-monsoon months (Sankaranarayanan and Qasim, 1969). The alkalinity of water is a very important factor which influences the productivity of a pond ecosystem (Unnithan 1985). The alkalinity of brackish water shrimp ponds has been widely studied by Chakraborti et al., (1986). The ponds should be limed for good fertilization, when total alkalinity is less than 20 ppm (Pillai and Boyd, 1985). Mathew (1987) reported high total alkalinity with wide fluctuations in some prawn culture fields in Cochin. He also reported that the values ranged between 10 ppm and 130 ppm in perennial fields, between 22.5ppm and 111 ppm in seasonal fields and between 24 and 185 ppm in Coconut grooves. Higher values were recorded during pre-monsoon and lower values during monsoon months. Susheela et al. (2006) carried out a study in an interior prawn filtration field in Cochin and found that the total alkalinity was in the desirable range (25-75 ppm) during 2005 as against the minimum value of 15 ppm during 2003 – 2004.

2.2.6 Hardness

Total hardness of water refers to the total concentration of divalent cations in water and is also expressed in milligrams per litre of equivalent Calcium carbonate. Baticados *et al.* (1986) reported a total hardness of 3350 ppm-6567 ppm in brackish water ponds at Philippines. Ecological and productivity study of ponds in Chellanam area was conducted by Ignatius (1995) found that hardness was above 5000 ppm in January and it decreased to 2618 ppm during March.

2.2.7 Nutrients

Nutrients are functionally involved in the living process of organisms. Seasonal variations of nutrients in different parts of the Vembanad Lake were studied by very workers (Sankaranarayanan and Quasim, 1969; Reddy and Sankaranarayanan, 1972; Joseph, 1974; Manikoth and Salih, 1974; Anirudhan *et al*., 1987; Lakshmanan *et al.,* 1987; Nair *et al.,* 1988; Anirudhan and Nambisan, 1990). These studies had shown that the nutrient concentration in Vembanad Lake followed marked seasonal rhythm induced by local precipitation and land run off. They also reported large temporal variations in the nutrients between the premonsoon period when the system was predominantly marine and the nutrient concentration was low and southwest monsoon period when the nutrients was high due to the maximum influx of freshwater. Reddy and Sankaranarayanan (1972) suggested that the main reason for the spatial variation in nutrients in Cochin estuary might be due the variation in the regenerative property of the bottom sediments.

The amount of nitrate was low (1.5-5.5µg at/l) during monsoon in Cochin estuary and it suddenly increased to 25 – 30 5µg at/l, (Manikoth and Salih, 1974). Nitrate does not seem to be affected by the freshwater discharge in the Cochin back water and were mostly less than 1µg at/l (Sankaranarayanan and Quasim 1969). Joseph and Pillai (1975) observed that nitrite ranged between 0 and 6 µg at/l in the Cochin backwaters. A negative correlation was existed between salinity and silicate in an estuary (Sankaranarayanan *et al*., 1984; Anirudhan *et al*., 1987; Anirudhan and Nambisan, 1990). Anon (2004) found a negative correlation between phosphate, silicate and nitrate with salinity indicating their terrestrial origin.

Sankaranarayanan *et al*., (1982) reported that inorganic phosphate values were high throughout the year in the tidal ponds of Ramanthuruthu Island and nitrate values varied between <1 and 15µg at/l. Nitrate value showed a general decrease in September and October and the highest values were recorded during June to August period. Nair *et al*., (1988) reported that nitrate values in the culture fields showed an increasing trend during monsoon months due to freshwater discharge. The low nitrate content during remaining period was due to low land drainage and high primary production. The range of NO_3 – N, NO_2 – N and reactive Phosphorous in water during pre-monsoon months were found to be between 0.03 and 7.43 µg at/l, 0.01and 2.95 µg at/l, and 0.97 to 19.69 µg at/l respectively in certain selected prawn farming sites at Cochin (Venkatesan *et al.,*2001)

The range of Phosphate-P, Nitrate-N, Nitrite-N and Silicate-Si were below detectable level to 4.85µmol/l, 0.07 and 3.06µmol/l, 0 to 4.18µmol/l and 20.94 to 82.24µmol/l respectively during pre monsoon at Panangad region of Vembanad Lake (Anon, 2004). The range of Phosphate-P, Nitrate-N, Nitrite-N and Silicate-Si were from not detectable level to 17.3 µmol/l, 0.60 to 18.29 µmol/l, 0 to 3.24 µmol/l and 8.17 to 197.08 µmol/l respectively during southwest monsoon in the same area. During postmonsoon the above range were from not detected to 8.30 µmol/l, 0.40 to 20.40 µmol/l, 0 to 1.80 µmol/l and 3.02 to 130.15 µmol/l respectively in the same area (Anon,2004)

2.2.8 Dissolved oxygen

Three important kinetic processes influencing the dissolved oxygen status of aquatic systems are the exchange with atmosphere, respiration and photosynthetic production. Of these, photosynthesis by phytoplankton is the primary source (Hepher, 1963). The main loss of oxygen from a water body is caused by the respiration of organisms, decomposition of organic matter and by diffusion of dissolved oxygen to the air. The solubility of oxygen in water is mainly influenced by temperature and salinity (Weiss, 1970) and it decreases with increase in salinity and temperature.

Sankaranarayanan *et al*. (1982) observed high oxygen value (2 ppm-7 ppm) during the premonsoon months in tidal ponds of Ramanthuruthu Island whereas low values (<4 ppm) were observed during the southwest monsoon period.

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

Nair *et al*., (1988) reported that dissolved oxygen varies widely with tides in the paddy-cum-prawn culture fields of Cochin back waters. 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.

Easwary and Bai (2002) observed high dissolved oxygen during premonsoon (4.74mg/l) and postmonsoon season (4.03 mg/l) at Adayar estuary. They reported that the dissolved oxygen content during monsoon season at Cooum estuary near Chennai, south east coast of India was 4.03 mg/l.

Panangad region of Vembanad Lake was found moderately oxygenated (Anon, 2004) and reported significant temporal and spatial variations. At lower salinity range (0ppt to 10ppt) dissolved oxygen had significant negative correlation with salinity, while for higher ranges of salinity (10ppt to 35ppt) it was poorly correlated.

2.2.9 Primary Production

Information on primary production is essential for assessing the fertility of aquatic systems (Anon, 2004) and predicting the potential of living resources. Primary production also gives valuable information about the fishery resources of the aquatic system. Organic production of Cochin backwaters was studied by Qasim (1973, 1979); Nair *et al.* (1975); Gopinathan *et al.* (1984), Sreekumar and Joseph (1997); Renjith *et al.* (2004). The estimated gross primary production (GPP) ranged from 272-293 $gC/m^2/yr$ and primary net production in Cochin backwaters was 193 $gC/m^2/yr$. Primary production showed considerable seasonal variation, with postmonsoon season recording the peak production. This may be due to optimum light intensity and effective utilization of nutrients (Menon *et al.,* 2000). Primary productivity of brackish water ponds near to Cochin estuarine system was well studied by Gopinathan *et al.* (1982), Devipriyan (1990) and Mathews (1992). The study conducted by Balasubramanian *et al.* (1995) shows that the GPP amounted to 5.68 $gC/m^2/day$ and 6.21 $gC/m^2/day$ for two ponds in Vallarpadam Island. GPP ranged between 0.57 and 16.339 $gC/m^2/day$ in a study conducted by Venkatesan *et al.* (2001) in Puduveypu and Valappu.

The monthly variation of primary production showed a trimodal pattern with maximum values during November, April, and July in the Panangad region of Vembanad Lake (Anon, 2004).

Primary production and fishery potential of the Panangad region were studied by Renjith *et al.* (2004) and observed maximum primary production during postmonsoon season and minimum during monsoon season.

2.2.10 Chlorophyll - a

Chlorophyll is probably the most-often used estimator of algal biomass and hence its measurement is an alternative approach to the estimation of primary production. Nair *et al.* (1975) reported an annual range of 2 to 21 mg/m^3 in the entire Vembanad Lake. Selvaraj *et al.* (2003) reported values of 6.14 mg/m^3, 4.93 mg/m^3 and 8.85mg/m^3 for premonsoon, monsoon and postmonsoon periods respectively near Thevara with an annual mean of 6.64 mg/m^3. Anon (2004), while studying about the circulation and mixing and their influence on productivity of Panangad region of Vembanad Lake found that Chlorophyll-a ranged between 1 mg/m^3 and 34.61 mg/m^3 and the average was 9.83$mg/m^{3.}$ The chlorophyll distribution followed the trend of primary production, showing a primary peak during postmonsoon and others during monsoon and premonsoon.

2.2.11 Transparency

In aquaculture ponds, turbidity from planktonic organism is often desirable, to a certain extend where as that caused by suspended particle is generally undesirable (McCombie, 1953).

Almost all problems related to dissolved oxygen in fish culture ponds are the consequences of heavy plankton blooms (Boyd *et al.,* 1978). Suitable plankton densities result in Secchi disc visibilities of 30 cm -60 cm. The probability of problems with low dissolved oxygen concentration increases as Secchi disc visibility decreases below 30cm. In ponds with Secchi disc visibilities of 10 cm – 20 cm, dissolved oxygen concentration may fall so low at night that fish are stressed ore even killed (Romaire and Boyd, 1978).

Das (2004) found higher values of transparency in a prawn filtration pond at Panangad area of Cochin during the south west monsoon where as a there was a gradual decrease in values from later part of southwest monsoon to till premonsoon period. Sudheer (2004) found that transparency values ranged between 30 and 38cm in an interior prawn filtration pond at Cochin.

2.3 SEDIMENTARY CHARACTERISTICS

Aquatic sediments are principally derived from weathering processes, with major transportation from terrestrial sources during high runoff and the land use. The geology and topography of the catchments determine the erosion and transport processes. In addition, discharges from urban, industrial and mining activities are potential sources of particulates. Anthropogenic contaminants, including metals, organics and nutrient elements are associated with particulate and dissolved inputs to natural waters. Typically, sediments are characterised as coarse material clay/silt and sand fractions. Higher fractions may consist of shells, rocks, wood, and other detrital materials, and are usually not a source of bioavailable contaminants (Mudroch *et al*., 1997). Sediment is transported as suspended load (silt and clay held in the water column above the bottom by turbulence), bed load (sand, gravel and coarser material moved by rolling, sliding, and bouncing along the streambed), and dissolved load (products of chemical weathering of rocks carried in solution). As earth material, sediment is obviously an important material affecting the physical, chemical and biological conditions of the environment (Renjith, 2006).

The character of sediments at any particular region is determined by (i) factors determining the source of supply of sedimentary material (ii) factors determining the transportation and (iii) factors determining the deposition (Nelson 1962). During the process of transportation and deposition sediments are subjected to physical and chemical adjustments which are reflected in the character. Thus the sediment of any particular region is a unique assemblage of matter retaining its own character and complexity (Nelson 1962).

Soil plays an important role on the balance of pond ecosystem and at the same time on the growth and survival of aquatic organisms. Soil is generally considered as the "laboratory of the pond" because many chemical reactions are governed by soil quality parameters (Hickling, 1971). According to Hickling (1971) soil quality is reported to play a more important role than the water quality does in brackish water productivity. Sediment has a considerable buffering capacity on the quality of the layer of water above it. It provides the water with nutrients and serves as a biological filter through the adsorption of the organic residues of food, body excretions and algal metabolites (Chien 1989).

pH is the most important soil quality parameter influencing the release of nutrients to the water body and decomposition rate of organic matter. Gopinathan *et al.* (1982) reported a wide range of soil pH of 3.5 to 7.0 with low values recorded at southern and northern parts and higher values in the middle region of Cochin estuarine system. Manoj Kumar (1988) reported that pH of sediment varied between 7.15 and 8.44 in some selected stations of Malpe estuary and observed that seasonal fluctuations were not considerable.

According to Boyd (1992) pH of shrimp pond soils vary greatly. Brackish water usually has a pH of 7.5 to 8 and such water buffers the soil. Acidic condition in soil hinders organic matter decomposition and recycling of nutrients which decrease the availability of phosphate. Acidic pH has direct inhibitory effects on benthos and shrimp.

Ignatius (1995) studied the soil pH of certain prawn filtration ponds at Chellanam and Poyya. Venkatesan *et al.* (2001) reported sediment pH range as 6.9 - 7.5 during pre monsoon in certain prawn filtration fields of Vypin Island of Cochin

Among the various soil quality parameters, organic carbon is of much importance. Organic carbon is an indication of the quantity of organic matter which enriches the soil with nutrients. Brackish water pond soil is considered to be poor in organic carbon contents (Chakraborti *et al.,* 1985). The organic matter content in bottom soils increases with increasing water depth (Boyd, 1977). According to Ting and Chen (1967), increasing organic carbon content increases the yield. Chakraborti *et al.* observed that brackish water soil with more than 1% organic carbon showed better production of prawns/unit area.

According to Gopinathan *et al*. (1982) Ramesan (1990), and Mathews (1992), organic carbon content in some of ponds nearer to the Cochin estuarine system ranged between 0.5 - 4.5%, 0.39 - 2.92% and 2.41 – 3.79 % respectively. On the other hand Easwaraprasad (1982) and Nasser (1986) recorded comparatively higher values of 1.12% – 6.48% and 2.47% – 8.85% respectively in some of the ponds of the same area.

Joseph (1998) studied the secondary production in the prawn field of the present study area and reported that percentage of organic carbon in the soil ranged from 0.50% – 1.72%. Venkatesan *et al.* (2001) stated total organic carbon as the most important determining fertility status of soil which ranged from 1.05% – 5.13% during premonsoon months in certain prawn filtration fields of Cochin.

Renjith (2006) reported that the percentage of organic carbon to total carbon did not show any seasonal trend and organic carbon values showed a clear spatial variation in the Panangad area of Vembanad Lake.

The significance of sediments in the distribution of faunal invertebrates has been recognised by several investigators (Thorson 1957, Thorson 1958, Sanders 1959, Brett 1963). The texture and content of dead organic matter in the substratum are undoubtedly the most important factors as far as the biota are concerned. Dora *et al.* (1968) had investigated the textural characteristics of Njarakkal mud bank sediments. The characteristics of the near shore sediments in the region off Neendakara, Kayamkulam coast and Ashtamudi and Vatta estuaries of Kerala have been studied by Rao (1968). Josanto (1971) studied the size distribution of sediments in the Cochin backwaters. Remani *et al.* (1981) reported that monsoon had a great effect on the sediments in the Cochin backwaters. Varshnay *et al.* (1981) in their study of benthos of Narmada estuary had reported that the sediments were largely muddy in the upper reaches and sandy in the lower reaches with varying proportions of silt and clay.

Joseph (1988) while studying the secondary production in brackish water culture fields at Cochin found that soil particles were constituted by sand (89%) silt (3%) and clay (8%). Manoj Kumar (1988) analysed sediment texture of Malpe estuary on a seasonal basis and observed a clear cut dominance of sand over silt and clay. However during the monsoon silt and clay together dominated the sand fraction. Sudheer (2003) analysed substratum of an interior prawn filtration pond at Panangad area of Cochin and found that it was sandy with low silt and clay fraction during most of the months.

Substratum of Panangad region of Vembanad Lake generally represented a combination of clay, sand, and silt and the composition of the sediments showed distinct spatial variation, but the seasonal variations were minimal (Renjith, 2006).

Materials and Methods

3. MATERIALS AND METHODS

3.1 SELECTION OF THE STUDY FIELD

A prawn filtration pond was selected in the campus of the College of Fisheries, Panangad, for the study. This is a perennial prawn filtration pond and prawn filtration is carried out throughout the year. The pond has an area of 0.75 ha and an average water depth of 50 cm. A sluice gate has been provided to connect the pond with Cochin backwater. The pond is situated near the eastern bank of Vembanad Lake.

3.2 SAMPLING FREQUENCY

The study was conducted during 3 seasons, viz. postmonsoon (October-January), and premonsoon (February-May) and southwest monsoon (June to September). Samples of water and sediments were collected fortnightly for estimation of hydrographical parameters and biological characteristics, from October 2007 to September 2008. Since the culture field was shallow, vertical variation in the hydrographical parameters were not considered significant as pointed out by Sankaranarayanan *et al*. (1982) and Nair *et al*. (1988). The methods used to collect the hydrographical, biological and sedimentary data for the present study are described below. Hourly meteorological data collected by Automatic Weather Station (AWS) was used to compute monthly averages of meteorological parameters.

3.3 SAMPLING METHODS

3.3.1 Macrobenthos

Macrobenthos samples were collected from the pond using a Van Veen grab having a biting area of 0.042 m^2. While collecting the grab 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 a bucket, sieved through a 500-μm mesh standard test sieve for separating the macrobenthos from the fine sediment particle, using filtered pond water. The contents of the sieve were transferred to plastic containers and preserved in 4% formalin for further analyses.

3.3.2 Hydrographical parameters

Surface water samples were collected from the pond to determine temperature, pH, turbidity, salinity, alkalinity, hardness, nutrients, dissolved oxygen, primary productivity and chlorophyll. For the estimation of dissolved oxygen and primary production water samples were collected in 125 ml dissolved oxygen bottles without entrapping air bubbles.

3.3.3 Sedimentary characteristics

Sediment samples were collected from the pond by using a Van Veen grab having a biting area of 0.042 m^2 to determine sediment pH, total organic carbon and soil texture.

The soil samples were sun dried. The samples were powdered using a mortar and pestle and stored in airtight self-sealing polythene covers to determine soil texture.

3.3.4 Meteorological parameters

Monthly mean values of meteorological parameters like maximum temperature, minimum temperature, rainfall and relative humidity were considered in the study. These values were computed from the hourly observation taken by an Automatic Weather Station (AWS) of EMCON make.

3.3.4.1 Maximum temperature

Maximum temperature is the highest air temperature attained by the air. It usually occurs in the early afternoons.

3.3.4.2 Minimum temperature

Minimum temperature is the lowest air temperature attained by the air .It usually occurs in the late nights.

3.3.4.3 Rainfall

Daily total rainfall data was computed from the hourly rainfall data collected by the AWS.

3.3.4.4 Relative humidity

Relative humidity is the ratio of the actual amount of water vapour present in unit volume of air to the water holding capacity of the air at that particular temperature expressed in percentage. Relative humidity recorded by the AWS at 9.00 a .m and 6.00 p. m was taken for the analysis.

3.4. METHODS OF ANALYSES

3.4.1 Macrobenthos

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

3.4.2 Hydrographical parameters

3.4.2.1 Water temperature

The temperature of the surface water was measured using a precision thermometer immediately after the sample collection.

3.4.2.2 pH

pH was determined within fifteen minutes using a digital pH meter (Systronics, MK IV). Each time prior to analysis, the instrument was calibrated using buffer tablets of pH 4 and 9.2.

3.4.2.3 Turbidity

Turbidity is the measure of clarity of water. Turbidity was measured using a digital nepheloturbidity meter immediately after the sample was brought to the laboratory. Calibration of instrument was done with standard formazine suspension prepared by mixing hydrazine sulphate and hexa methlyene tetramine (APHA, 1981)

3.4.2.4 Salinity

Moh-Knudsen titration method was used for the estimation of salinity (Grasshoff *et al.,* 1983). Standardization of the silver nitrate was done. Potassium dichromate was used as the indicator.

3.4.2.5 Total alkalinity

The amount of acid required to neutralize the base in water is a measure of alkalinity (APHA, 1981). Total alkalinity was determined by acidimetric titration following standard methods (Lenore *et al.,* 1998)

3.4.2.6 Total Hardness

The hardness of the sample was determined using complexometric titration (APHA, 1981). Eriochrome black T was used as the indicator

3.4.2.7 Nutrients

For the estimation of nutrients surface water samples were collected and stored in plastic bottles of 250 ml capacity. All these bottles were stored in an ice box and subsequently kept in a freezer to prevent the loss of nutrients during storage. The nutrients like Nitrate-N, Nitrite-N, Phosphate-P and Silicate-Si were estimated. Water samples collected in polythene bottles were analysed in the laboratory following standard photometric methods (Grasshoff *et al*., 1983) using UV-VIS spectrophotometer (JASCO, V-530). Phosphate and Reactive Silicon were estimated by standard molybdenum blue method. Nitrate was estimated by cadmium reduction followed by spectrophotometry (Grasshoff *et al*., 1983). Nitrite was estimated by photometric determination based on the reaction of nitrite with an aromatic amine leading to the formation of a diazonium compound which couples with a second aromatic amine to form an azo dye.

3.4.2.8 Gross Primary Productivity

Primary production was estimated using Gaarder and Graan's light and dark bottle method (Strickland and Parsons, 1972). Narrow mouthed 125ml bottles, one dark bottle and two light bottles, were filled with water samples collected, without trapping air bubbles. Oxygen in one of the light bottles was fixed immediately. The second light and dark bottles were incubated in water for 4 hours by putting the bottles in a deep tray containing water. After the incubation period the dissolved oxygen bottles were taken out and the dissolved oxygen was fixed. The dissolved oxygen content of the two bottles was determined using Winklers'method (Strickland and Parson, 1972). The difference in the oxygen content between light and dark bottle was taken for estimating the gross primary productivity.

3.4.2.9 Dissolved oxygen

The dissolved oxygen was determined following Winklers' method as described by Strickland and Parsons (1972). Surface water samples were collected *insitu* in oxygen bottles of 125 ml capacity. Fixing of dissolved oxygen was done immediately after the collection of sample using Winklers' reagents.

3.4.2.10 Chlorophyll-a

Estimation of chlorophyll-a was done by spectrophotometry method (Strickland and Parsons, 1972). About one litre of sample was filtered through 0.45μ GF/C filter paper and extracted by keeping in 90% acetone at 4°C overnight.

3.4.2.11 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 centimetres.

3.4.3 Soil quality parameters

3.4.3.1 pH

Sediment pH was determined within fifteen minutes using a digital pH meter (Systronics, MK IV). Each time prior to analysis, the instrument was calibrated using buffer tablets of pH 4 and 9.2.

3.4.3.2 Total organic carbon

Total organic carbon was determined by back titration method (Gaudette and Flight, 1974).

3.4.3.3 Soil Texture

Sediment samples collected were weighed and wet sieved through ASTM 230 mesh sieve (mesh size 63μ) to separate the sand from the fine fractions of the sediment. The percentage of silt and clay was determined by pipette analysis (Krumbein and Pettijohn, 1938

3.5 STATISTICAL ANALYSIS

Correlation of total number of macrobenthos and individual groups with hydrographical and biological parameters and also with sedimentary characteristics was estimated (Snedecor and Cochran, 1968). Seasonal variation between postmonsoon and premonsoon was studied using t- test. (Snedecor and Cochran, 1968).

Plate 1 Automatic Weather Station Installed in the campus

Plate 2 Experimental Prawn Filtration Pond

Results

4. RESULTS

Structure and seasonal variations in the abundance of macrobenthos in the hydrographical parameters and in the seasonal variation in sedimentary characteristics are studied. Fortnightly data of macrobenthos, hydrographical parameters and sedimentary characteristics are given in tables 1, 2, and 3 respectively. Seasonal average values of abundance of macrobenthos, hydrographical parameters and sedimentary characteristics are given in tables 4, 5 and 6 respectively. Correlation of seasonal averages of hydrographical, biological and sedimentary parameters of the study area is given in table 7. Monthly variations of meteorological parameters in the study area are given in table 8.

4.1 MACROBENTHOS

The abundance of macrobenthos expressed in no. /m^2 in the prawn filtration pond is given in table 1.

The macrobenthic groups obtained during the present investigation were polychaetes, tanaids, amphipods, bivalves and gastropods (Fig.66, 67, 68, and 69). Prawn juveniles and cumaceans were encountered very rarely during the study period and these were grouped as 'others'.

In the culture field macrobenthic population showed wide variations in their abundance in different months. It varied between 84 no. /m^2 and 1632 no. /m^2 during the period of investigation. The benthic populations were high during the postmonsoon months and it gradually decreased during the premonsoon period. But towards the end of premonsoon period a moderate increase was noticed followed by a drastic decrease with the onset of monsoon(Table 6a, 6b, Fig.1). Gastropods were the most prominent group with a fortnightly average value of 292 no. /m^2 forming 47% of macrobenthos. Percentage abundance of gastropods during postmonsoon, premonsoon and monsoon period were 20, 80 and 51, respectively. (Table 6b, Fig.

67, 68 and 69).They showed maximum abundance during second half of May and second maximum was during first half of December. Tanaids were the second major group with a fortnightly average of 184 no. /m^2 which is 29% of the macrobenthos. Percentage abundance of Tanaids during postmonsoon, premonsoon and monsoon period were 54, 2 and 12, respectively. (Table 6b, Fig. 67, 68 and 69). They showed maximum abundance during first half of November (1429 no. /m^2). Polychaetes were the third major group with an average of 115 no. /m^2 which is 18% of the macrobenthos. Percentage abundance of polychaetes during postmonsoon, premonsoon and monsoon period were 17 13 and 35, respectively. (Table 6b, Fig. 67, 68 and 69). Maximum abundance was during first half of September. Amphipods contributed 25 no. /m^2 on average which is 4% of the macrobenthos. Percentage abundance of gastropods during postmonsoon, premonsoon and monsoon period were 6, 2 and 2, respectively. (Table 6b, Fig. 67, 68 and 69). They were maximum during postmonsoon months and showed a decreasing trend and were completely absent during February and June. Presence of bivalves was on average, 8 no. /m^2 which was 1.2% of macrobenthos. Percentage abundance of bivalves during postmonsoon, premonsoon and monsoon period were 2, 1 and 0 respectively. (Table 6b, Fig. 67, 68 and 69). They were maximum during postmonsoon months and were completely absent during the monsoon period. Prawn larvae and cumaceans together grouped under 'others' were also seen during premonsoon and postmonsoon with an average of 6 no. /m^2 which was 0.9% of the macrobenthos. Percentage abundance of 'others' during postmonsoon, premonsoon and monsoon period were 1, 2 and 0, respectively. (Table 6b, Fig. 67, 68 and 69). They were completely absent during the monsoon period.

The abundance of macrobenthos showed no significant difference between postmonsoon and premonsoon on t-test. The abundance of macrobenthos showed a significant negative correlation (r= -0.463**) with percentage of sand and a significant positive correlation (r= 0.402*) with percentage of clay and gastropods (r=

0.430*). Polychaetes showed positive correlation with sediment pH (r= 0.420*), sand (r= 0.580**) tanaids (0.415*), amphipods (r= 0.537**), and bivalves (r= 0.513*) and negative correlation with silt (r= -0.514**) and clay(r= -0.406*). Tanaids showed positive correlation with polychaetes (r= 0.415*) and amphipods (r= 0.503**) and negative correlation with clay(r= -0.426*). Amphipods showed positive correlation with sediment pH (r=0.367*), sand (r= 0.388*) and polychaetes (0.537**) and negative correlation with clay (r= -0.385*). Bivalves showed positive correlation with sand (r= 0.362*) and polychaetes (r= 0.513**) and negative correlation with silt (r= -0.466**). Gastropods showed positive correlation with silt(r= 0.497**) and total macrobenthic abundance (r= 0.430*) while it showed a negative correlation with sand (r= -0.450*).

4.2 HYDROGRAPHICAL PARAMETERS

4.2.1 Salinity

Salinity of the prawn filtration pond ranged between 0.05‰ and 30.63‰ and showed wide fluctuations in the prawn filtration pond during the study period (Table 2, Fig.2). It showed an increasing trend in the postmonsoon period (average 14.34‰) and reached maximum in the first half of February (30.63‰) but experienced considerable reduction during March to May due to premonsoon showers(Table 4, Fig.40). With the onset of monsoon salinity further decreased (average 3.25‰). The range of salinity estimated for the three seasons are given below

Postmonsoon	:	0.36‰-27.5‰
Premonsoon	:	8.5‰-30.63‰
Monsoon	:	0.05‰-9.37‰

Statistical analysis for understanding the characteristics of the seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. Salinity showed positive correlation with pH (r= 0.652**) alkalinity

(0.723**), hardness (r= 0.682**) and nitrite-N (r= 0.608**) and negative correlation with dissolved oxygen (r= -0.556**).

4.2.2 Water temperature

The highest temperature (32.5°c) was estimated during the first half of May and the lowest temperature (26°c) was estimated during the first half of January (Table 2, Fig.3). Seasonal variation in water temperature is presented in Table 4, Fig.41. The ranges estimated for three seasons are given below.

Postmonsoon : 26°c-29°c

Premonsoon : 28°c-32.5°c

Monsoon : 26.75°c-30.25°c

Significant difference between postmonsoon and premonsoon was estimated by t-test. Water temperature showed significant positive correlation with turbidity (r= 0.381*), primary production (r=0.592**), chlorophyll (r= 0.477**) and sediment pH (r= 0.476**).

4.2.3 pH

pH showed an increasing trend in the postmonsoon season with an average of 7.92 and the increasing trend continued in the premonsoon with an average of 8.73 (Table 4, Fig.42). The highest peak of 9.6 was estimated in the last half of June and the lowest value (6.5) was estimated in the second half of September (Table 2, Fig.4). The average value estimated during monsoon was 8.34. The ranges estimated for three seasons are given below.

Postmonsoon : 7.0-8.2

Premonsoon : 8.1-9.2

Monsoon : 6.5-9.6

Statistical analysis of seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. pH showed positive correlation with salinity (r= 0.652**), alkalinity (r= 0.800**), hardness (r= 0.464**), chlorophyll (r= 0.361*) and nitrite-N (r= 0.477**). It showed a negative correlation with nitrate-N (r= -0.573**) and total organic carbon (r= -0.415*).

4.2.4 Total Alkalinity

Generally alkalinity showed an increasing trend during the postmonsoon with an average of 134.29 mg $CaCo_3$/l and a decreasing trend during monsoon with an average of 156.25 mg CaC_3/l (Table 4, Fig.43). Maximum alkalinity (250 mg $CaCo_3$/l) was estimated during the first half of February and minimum was estimated during the second half of October (Table 2, Fig.5). Average alkalinity during premonsoon period was 182.81 mg $CaCo_3$/l. The range estimated for three seasons are given below.

Postmonsoon : 50 mg $CaCo_3$/l -225 mg $CaCo_3$/l

Premonsoon : 125 mg $CaCo_3$/l -250 mg $CaCo_3$/l

Monsoon : 150 mg $CaCo_3$/l -175 mg $CaCo_3$/l

The t-test on alkalinity showed no significant difference between postmonsoon and premonsoon. Alkalinity showed a positive correlation with salinity (r= 0.723**), pH (r= 0.800**), hardness (r= 0.639**), nitrite-N (r= 0.539**) and chlorophyll (r= 0.449*). It showed a negative correlation with nitrate-N (r= -0.416*).

4.2.5 Hardness

Hardness showed an increasing trend during postmonsoon and the increasing trend continued till the first half of February to reach the highest value of 796 mg $CaCo_3$/l (Table 2, Fig.6). Premonsoon experienced a gradual reduction in hardness due to occasional premonsoon showers where as a drastic reduction was noticed during monsoon (Table 4, Fig.44). Lowest value of hardness (19 mg $CaCo_3$/l) was estimated during the first half of September. Average value of hardness during postmonsoon premonsoon and monsoon were 490.96 mg $CaCo_3$/l, 623.44 mg

$CaCo_3$/l and 130.78 mg $CaCo_3$/l respectively. The ranges of hardness for three seasons are given below.

Postmonsoon : 41.25 mg $CaCo_3$/l- 758.0 mg $CaCo_3$/l

Premonsoon : 455 mg $CaCo_3$/l- 796 mg $CaCo_3$/l

Monsoon : 19.0 mg $CaCo_3$/l- 468 mg $CaCo_3$/l

Statistical analysis of the seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. It showed a positive correlation with salinity (r= 0.682**), p^H (r= 0.464**), alkalinity (r= 0.639**) and nitrite-N (r= 0.539**). It showed a negative correlation with nitrate-N (r= -0.575**) and dissolved oxygen (r= -0.466**).

4.2.6 Nutrients

4.2.6.1Nitrate- Nitrogen

Higher values were estimated during postmonsoon and monsoon whereas lower values were estimated during premonsoon (Table 4, Fig.45). Maximum value (12.12µg at/l) was estimated during October while the minimum 3.0µg at/l) were estimated during the first half of March (Table 2, Fig.7). The average values for postmonsoon, premonsoon and monsoon were 6.03µg at/l, 3.77µg at/l and 6.95µg at/l respectively. The ranges estimated for three seasons are given below.

Postmonsoon : 3.50 µg at/l-12.12 µg at/l

Premonsoon : 3.00 µg at/l- 4.70 µg at/l

Monsoon : 3.42 µg at/l-10.30 µg at/l

The t-test on Nitrate- N showed no significant difference between postmonsoon and premonsoon. It showed a positive correlation with total organic carbon (r= 0.483**) and a negative correlation with sediment pH (r= -0.417*), water pH (r= -0.573**) alkalinity (r= -0.416*) and hardness (r= -0.575**).

4.2.6.2 Nitrite-Nitrogen

Nitrite-N value ranged between 0.4 µgm atom/l to 3.01 µg at/l, during the study period (Table 2, Fig.7). Seasonal variation of nitrite was not pronounced in the study period. The maximum value was estimated during the second half of February and a minimum value was in second half of October. Average values for postmonsoon, premonsoon and monsoon were 1.02 µg at/l. 1.21 µg at/l and 1.33 µg at/l respectively (Table 4, Fig.46). The ranges estimated for three seasons are given below.

Postmonsoon : 0.4 µg at/l - 1.31 µg at/l

Premonsoon : 0.64 µg at/l -3.01 µg at/l

Monsoon : 0.89 µg at/l r-2.0 µg at/l

Statistical analysis of seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. It showed a positive correlation with salinity (r= 0.608**), pH (r= 0.477**), alkalinity (r= 0.399*) and hardness (r= 0.539**) and a negative correlation with total organic carbon (r= -0.477**).

4.2.6.2 Phosphate-Phosphorous

Higher values were estimated during monsoon and lower values during premonsoon (Table 4, Fig.47). Maximum value (16.3 µg at/l) was estimated during last half of September and minimum value (3.05µg at/l) was estimated during the second half of November (Table 2, Fig.9). Average values for postmonsoon, premonsoon and monsoon were 6.36 µg at/l, 7.01 µg µat/l and 10.08µg at/l respectively. The ranges estimated for three seasons are given below.

Postmonsoon : 3.05 µg at/l 11.59 µg at/l

Premonsoon : 3.78 µg at/l -7.83 µg at/l

Monsoon : 4.73 µg at/l -16.3 µg at/l

Statistical analysis of seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. It showed a positive correlation with silicate (r= 0.394*).

4.2.6.3 Silicate-Silicon

Silicate showed large fluctuations during the study period and presented manifold increase during monsoon. The highest value (134.2 µg at/l) was estimated during the second half of September and the minimum value (4.81 µg at/l) was estimated during October (Table 2, Fig.10). Average value for postmonsoon, premonsoon and monsoon were 43.17 µg at/l, 28.46µg at/l and 78.76µg at/l respectively (Table 4, Fig.48). The ranges estimated for three seasons are given below.

Postmonsoon : 4.81 µg at/l -116.43 µg at/l

Premonsoon : 8.92 µg at/l -43.92 µg at/l

Monsoon : 31.96 µg at/l -134.2 µg at/l

Statistical analysis of seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. It showed a positive correlation with phosphate (r= 0.394*).

4.2.7 Dissolved Oxygen

In the premonsoon period, when the study field was under predominant influence of marine conditions the levels of dissolved oxygen were comparatively low. The estimated average value of dissolved oxygen during postmonsoon was 3.57mg/l which increased to 5.86mg/l. With the onset of monsoon the average value of dissolved oxygen further increased to 8.41mg/l (Table 4, Fig.49). The maximum dissolved oxygen (10.4 mg/l) was estimated during the second half of June and the minimum (1.5 mg/l) was estimated during the fist half of February (Table 2, Fig.11). The ranges estimated for three seasons are given below.

Postmonsoon : 2.0 mg/l -7.40 mg/l

Premonsoon : 1.5 mg/l -8.5 mg/l

Monsoon : 7.0 mg/l -10.4 mg/l

No significant difference between postmonsoon and premonsoon were estimated by t-test. It showed a positive correlation with primary production (r= 0.487**) and a negative correlation with salinity (r= -0.556**) and hardness (r= -0.466*).

4.2.8 Turbidity

Turbidity ranged between 9.3 NTU and 38.95 NTU. The maximum was recorded during the second half of July and the minimum was during the second half of November (Table 2, Fig.12). The average value of turbidity during postmonsoon, premonsoon and monsoon were 17.16 NTU, 21.17 NTU and 21.71 NTU respectively (Table 4, Fig.50). The ranges estimated for three seasons are given below.

Postmonsoon : 9.3 NTU- 26.85 NTU

Premonsoon : 14.8 NTU- 30.85 NTU

Monsoon : 13.7 NTU- 38.95 NTU

Statistical analysis of seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. Turbidity was positively correlated with temperature(r= 0.381*)

4.2.9 Transparency

Transparency values did not show much variation during the study period and it varied between 30.0cm 46.0cm. The maximum value was estimated in the second half of November and the minimum value was during the second half of June (Table 2, Fig.13). The average value of transparency during postmonsoon, premonsoon and monsoon were 36.57cm, 36.86cm and 36.75cm respectively (Table 4, Fig.51). The ranges estimated for three seasons are given below.

Postmonsoon : 34.0 cm - 46.0 cm

Premonsoon : 34.0 cm – 40.0 cm

Monsoon : 30.0 cm- 44.0 cm

No significant difference between postmonsoon and premonsoon were estimated by statistical analysis of seasonal variation.

4.2.10 Primary production

Primary production ranged between 37.5 $mgC/m^3/day$ and 3900 $mgC/m^3/day$. The maximum was recorded during the second half of June and the minimum was recorded in the first half of September (Table 2, Fig.14). The average value of primary production increased from 698.02 $mgC/m^3/day$ during postmonsoon to 2458.54 $mgC/m^3/day$ during premonsoon but further decreased to 1206.22 $mgC/m^3/day$ during south west monsoon (Table 4, Fig.52). The ranges estimated for three seasons are given below.

Postmonsoon : 300 $mgC/m^3/day$ - 1575 $mgC/m^3/day$

Premonsoon : 900 $mgC/m^3/h$ - 3904 $mgC/m^3/day$

Monsoon : 37.5 $mgC/m^3/h$ - 3900 $mgC/m^3/day$

Statistical analysis of seasonal variation by t-test showed significant difference between postmonsoon and premonsoon. It showed a positive correlation with dissolved oxygen (r= 0.487**), temperature (r= 0.592**), chlorophyll (r= 0.692**) and sediment pH (r= 0.574**).

4.2.11 Chlorophyll-a

Chlorophyll values ranged between 3.30 mg/m^3 and 62.70 mg/m^3. The highest value was observed during the second half of July and the minimum was observed during second half of October (Table 2, Fig.15). The average values of chlorophyll for postmonsoon, premonsoon and monsoon were 8.81 mg/m^3, 20.23

mg/m^3 and 29.66 mg/m^3, respectively (Table 4, Fig.53). The ranges estimated for three seasons are given below.

Postmonsoon : 3.30 mg/m^3- 14.95 mg/m^3

Premonsoon : 10.60 mg/m^3- 36.50 mg/m^3

Monsoon : 6.10 mg/m^3- 62.70 mg/m^3

The t-test on chlorophyll showed significant difference between postmonsoon and premonsoon. Chlorophyll showed a positive correlation with sediment pH (r= 0.645**), temperature (r= 0.477**), pH (r= 0.361*), alkalinity (r= 0.449*) and primary production (r= 0.692**).

4.3 SEDIMENTARY CHARACTERISTICS

4.3.1 Sediment pH

Values of sediment pH ranged between 7.58 and 9.78 (Table 3, 4, Fig.16, 57). The average values of sediment pH increased from postmonsoon season (8.23) till premonsoon season (9.14), but showed a decrease during south west monsoon (8.44). The highest value was estimated during the first half of April and the lowest during the second half of October. The ranges estimated for three seasons are given below.

Postmonsoon : 7.58 – 8.64

Premonsoon : 8.42- 9.78

Monsoon : 8.24- 9.00

Statistical analysis of seasonal variation by t-test showed significant difference between postmonsoon and premonsoon. Sediment pH showed a positive correlation with temperature (r= 0.476**), primary production (r= 0.574**) chlorophyll (r= 0.645**) and amphipods (r= 0.367*). It showed a negative correlation with nitrate-N (r= -0.417*).

4.3.2 Total organic carbon

The total organic carbon values ranged between 4.75% and 9.15%. The highest value was estimated during the second half of March and the lowest value was during the second half of February (Table 3, Fig.17). The average values of total organic carbon for the postmonsoon, premonsoon and monsoon were 6.97%, 6.90% and 6.32%, respectively (Table 5, Fig.58). The ranges estimated for three seasons are given below.

Postmonsoon : 5.55%- 8.44%

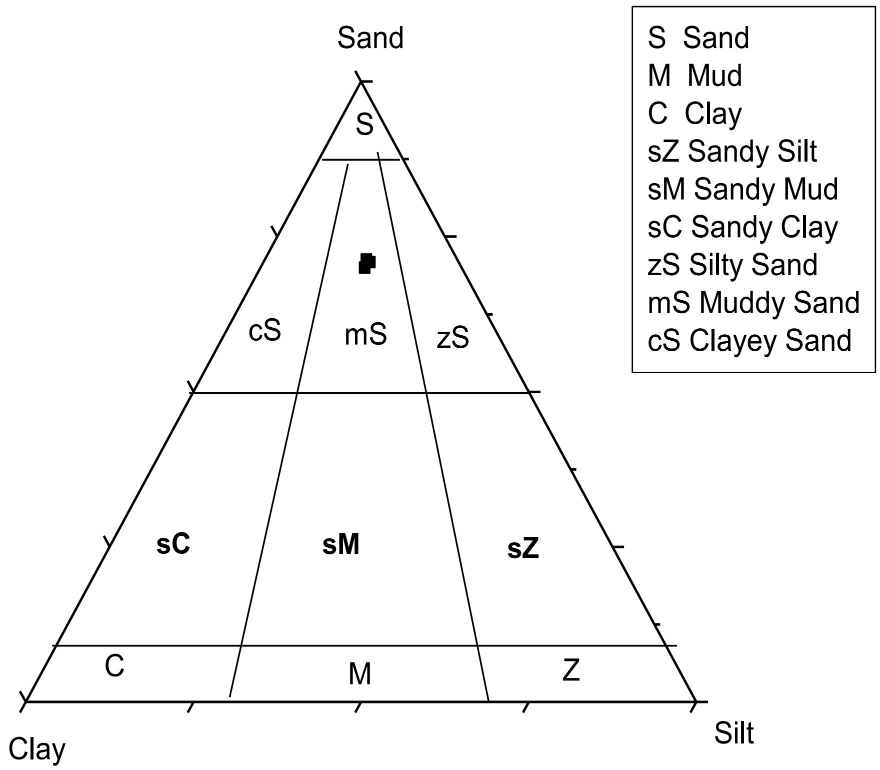
Premonsoon : 4.75%- 9.15%

Monsoon : 6.05%- 7.00%

Statistical analysis of seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. Total organic carbon showed a positive correlation with nitrate-N (r= 0.483**) and a negative correlation with nitrite-N (r= -0.477**) and water pH (r= -0.415*).

4.3.3 Soil Texture

The result of the analysis revealed that sediment of the prawn filtration pond is muddy sand by applying Folk (1974) classification and no seasonal variations were observed. (See Ternary diagram shown below). During postmonsoon, the average values of textural pattern of the sediment were estimated as sand 76.66%, silt 15.76% and clay 13.57%. During premonsoon, the average values of textural pattern were sand 71.33%, silt 15.16% and clay 13.52%. During monsoon the values were 70.12%, 15.93% and 13.28%, respectively. (Table 3 and 5, Fig. 18, 19, 20, 54, 55 and 56)



Ternary diagram showing the grain size distribution in the surficial sediment- Sediment nomenclature after (Folk, 1974)

Statistical analysis of seasonal variation by t-test showed no significant difference between postmonsoon and premonsoon. Percentage of sand showed a negative correlation with silt (r= -0.500**), clay (r= -0.855**), total macrobenthic abundance (r= -0.463**), gastropods (-0.450*). Percentage of sand showed a positive correlation with polychaetes (r= 0.580**), amphipods (r= 0.388*), and bivalves(r= 0.362*). Silt showed a negative correlation with sand(r= -0.500*), polychaetes (r=-0.514**) and bivalves(r=-0.466**), while it showed a positive correlation with gastropods (r= 0.497**). Clay showed a positive correlation with total benthic abundance (r= 0.402*) and negative correlation with sand(r=-0.855**), polychaetes (r= -0.406*), tanaids(r= -0.426*),and amphipods (r= -0.385*).

4.4 METEOROLOGICAL PARAMETERS

4.4.1 Maximum temperature

The highest temperature recorded during the study period was 35.06°C (February). During postmonsoon period the mean maximum temperature recorded was 34.24°C (December), which increased to 35.06°C in the premonsoon period and with the onset of monsoon it further decreased to 32.82°C (June).

4.4.2 Minimum temperature

The mean minimum temperature recorded during postmonsoon was 16.42°C (December) and during premonsoon it increased to 19.15°C (March). During south west monsoon it further increased to 21.37°C (August). The lowest temperature recorded during the study period was 16.42°C (December).

4.4.3 Total rainfall

The highest monthly total rainfall was received in the month of June (156.15mm) followed by July (131.85mm). It was also observed that there was no rainfall received in the month of January. Total rain fall recorded during postmonsoon, premonsoon and monsoon were 86.50mm 138.42mm and 416.72 mm, respectively

4.4.4 Relative humidity

Analysis of relative humidity values showed that the mean maximum relative humidity during postmonsoon season was 82.91% in the evening hours and the mean minimum (71.32%) was experienced in December in the morning hours. During premonsoon months the mean maximum relative humidity (96.28%) in April was in the morning hours and the lowest (73.93%) was in the evening hours of February. During monsoon the highest relative humidity (98.82%) was recorded in the evening hours of September and the lowest (70.83%) was recorded in the evening hours of August.

Period	Polychaetes	Tanaids	Amphipods	Bivalves	Gastropods	Others	Total
Oct II-07	95	857	72	0	0	0	1024
Nov I-07	179	1429	0	24	0	0	1632
Nov II-07	191	1036	119	0	0	0	1346
Dec I-07	203	108	119	36	929	0	1395
Dec II-07	202	155	36	48	477	0	918
Jan I-08	179	131	72	12	12	36	442
Jan II-08	155	143	0	0	12	12	322
Feb I-08	0	0	0	0	774	12	786
Feb II-08	0	0	0	0	667	24	691
Mar I-08	84	24	36	12	476	12	644
Mar II-08	84	36	12	12	286	12	442
Apr I-08	83	12	12	0	262	0	369
Apr II-08	155	12	12	12	0	12	203
May I-08	214	12	24	24	572	12	858
May II-08	60	0	12	0	119	0	1191
June I-08	48	0	0	0	238	0	286
June II-08	60	12	0	0	12	0	84
July I-08	96	24	0	0	24	0	144
July II-08	155	48	12	0	24	0	239
Aug I-08	24	12	12	0	48	0	96
Aug II-08	143	0	12	0	60	0	215
Sept I-08	227	12	0	0	643	0	882
Sept II-08	12	167	12	0	72	0	263
Total	**2649**	**4230**	**574**	**180**	**6707**	**132**	**14472**
Average	**115.1**	**183.9**	**24.9**	**7.8**	**291.6**	**5.7**	**629.2**
%	**18.2%**	**29.2%**	**3.9%**	**1.2%**	**47.3%**	**0.9%**	**100%**

Table 1-Fortnightly abundance of macrobenthos (no. /m^2) in the prawn filtration pond

Period	Salinity (‰)	Temp(°C)	pH	Alkalinity (mg $CaCO_3$/l)	Hardness (mg$CaCO_3$/l)
Oct II-07	0.36	7.4	7	50	41.25
Nov I-07	4.85	30	7.4	65	150
Nov II-07	6.96	28.5	7.7	75	560
Dec I-07	16.14	28.5	7.6	125	685
Dec II-07	19.55	29	8	200	758
Jan I-08	24.97	27	8.1	225	623
Jan II-08	27.5	26	8.2	200	620
Feb I-08	30.63	27	8.5	250	796
Feb II-08	20.02	28	8.1	175	756
Mar I-08	11.05	29.75	8.8	175	791
Mar II-08	10.45	29	8.7	163	625
Apr I-08	9.98	28	8.5	125	604
Apr II-08	8.5	31	9	150	473
May I-08	9.9	32.5	9.2	225	488
May II-08	9.45	30.5	9.2	200	455
June I-08	9.37	30	9.3	150	468
Jun II-08	7.33	30.25	9.6	175	173
July I-08	4.8	26.75	8.6	150	175
July II-08	1.88	27	9	175	85
Aug I-08	1.6	27	8	150	70
Aug II-08	0.85	28	8	150	35
Sept I-08	0.15	29	7.9	150	19
Sept II-08	0.05	29.25	6.5	150	23

Table 2-Fortnightly variations of hydrographical parameters

Period	NO_3 – N (µg at/l)	NO_2-N (µg at/l)	PO_4-P (µg at/l)	SiO_4-Si (µg at/l)
Oct II-07	12.12	0.4	3.87	4.81
Nov I-07	9025	0.65	3.25	33.5
Nov II-07	3.56	0.87	3.05	37.31
Dec I-07	3.61	1.31	9.57	16.87
Dec II-07	4.03	1.27	9.19	64.45
Jan I-08	3.64	1.4	11.59	116.43
Jan II-08	3.5	1.25	4	28.83
Feb I-08	3.9	1.8	3.78	31.34
Feb II-08	4.7	3.01	6.45	21.3
Mar I-08	3	0.81	7.55	8.9
Mar II-08	3.1	0.64	7.83	10.5
Apr I-08	4.5	1.14	15	43.92
Apr II-08	4	1.06	5.96	34.44
May I-08	3.7	1.06	5	40
May II-08	3.4	0.85	4.6	37.32
June I-08	3.4	0.98	5.95	36.6
Jun II-08	5.4	0.89	4.73	35.74
July I-08	6	1.43	5.3	82.85
July II-08	5.6	1.37	5.85	31.96
Aug I-08	6.8	1.15	13.6	102.05
Aug II-08	8.5	1.15	13	105.6
Sept I-08	9.7	1.7	16	102.1
Sept II-08	10.3	2	16.3	134.2

Table 2 contd. Fortnightly variations of hydrographical parameters

Period	DO (mg/l)	Turbidity (NTU)	Transparency (cms)	Pri.production $mgC/m^3/h$	Chlorophyll mg/m^3
Oct II-07	7.4	22.15	36	1575	3.3
Nov I-07	5.5	15	38	300	5
Nov II-07	3.8	9.3	46	359	6.2
Dec I-07	2.0	26.85	34	788	14.95
Dec II-07	2.75	11.85	34	824	14.15
Jan I-08	3.3	19	40	503	9.2
Jan II-08	3.25	16	38	538	8.9
Feb I-08	1.5	30.85	38	900	10.96
Feb II-08	8.5	24.2	36	2550	12.3
Mar I-08	4.3	12.55	36	3600	26.25
Mar II-08	4.9	14.8	40	2748	17.5
Apr I-08	5.2	20.7	36	1976	16.55
Apr II-08	8.1	18.15	38	2250	10.6
May I-08	7.3	20.65	36	3904	31.2
May II-08	7.1	22.06	34	2995	36.5
June I-08	8.8	14.5	38	417	43.5
Jun II-08	10.4	15.05	30	3900	50.2
July I-08	7.6	31.6	38	1500	24.4
July II-08	7.5	38.95	32	187.2	62.7
Aug I-08	8.35	25	34	1035	15.2
Aug II-08	8.0	20	34	664	27.9
Sept I-08	9.6	14.85	44	37.5	6.1
Sept II-08	7.0	13.7	44	225	7.3

Table 2 contd. -Fortnightly variations of hydrographical parameters

Period	Sed. pH	TOC (%)	Sand (%)	Silt (%)	Clay (%)
Oct II-07	7.58	8.44	69.25	16.55	14.20
Nov I-07	8.10	8.05	69.10	15.05	15.85
Nov II-07	8.64	8.01	70.10	15.60	14.30
Dec I-07	8.41	5.85	70.50	16.50	13.00
Dec II-07	8.20	6.90	73.15	14.60	12.25
Jan I-08	8.36	5.55	72.30	15.05	12.65
Jan II-08	8.35	6.00	70.25	17.00	12.75
Feb I-08	8.44	5.90	70.15	16.40	13.45
Feb II-08	8.42	4.75	70.20	15.90	13.90
Mar I-08	8.85	6.60	70.30	16.55	13.15
Mar II-08	9.43	9.15	70.95	16.35	12.70
Apr I-08	9.78	8.30	73.60	12.25	14.15
Apr II-08	9.28	6.85	72.00	13.10	14.90
May I-08	9.54	6.60	75.15	11.40	13.45
May II-08	9.40	7.30	68.25	19.35	12.40
June I-08	9.00	6.15	70.20	17.35	12.45
Jun II-08	8.50	6.05	71.35	17.15	11.50
July I-08	8.35	7.00	70.70	16.30	13.00
July II-08	8.45	6.25	70.70	15.25	14.05
Aug I-08	8.35	6.20	71.70	13.10	15.40
Aug II-08	8.30	6.30	71.25	16.50	12.25
Sept I-08	8.24	6.20	70.50	16.25	14.25
Sept II-08	8.37	6.15	70.95	15.55	13.50

Table 3 - Fortnightly variations of sedimentary characteristics

Parameters	Postmonsoon	Premonsoon	monsoon
Salinity(‰)	14.335	13.75	3.25
Water temp(°C)	28	29.72	28.41
pH	7.92	8.73	8.34
Alkalinity(mg CaCo3/l)	134.29	182.81	156.25
Hardness (mg CaCo3/l)	490.96	623.44	130.78
NO_3-N (µg at/l)	6.03	3.77	6.95
NO_2-N(µg at/l)	1.02	1.21	1.33
PO_4-P(µg at/l)	6.36	7.01	10.08
SiO_4_Si(µg at/l)	43.17	28.46	78.76
Dissolved oxygen(mg/l)	3.57	5.86	8.41
Turbidity(NTU)	17.16	21.17	21.71
Transparency(cms)	36.57	36.86	36.75
Prim.productivity(mgC/m^3/day)	698.02	2458.84	1206.22
Chlorophyll(mg/m^3)	8.81	20.23	29.66

Table 4 - Seasonal variations in hydrographical parameters in prawn filtration pond

Sedimentary characteristics	postmonsoon	premonsoon	monsoon
Sand (%)	70.66	71.33	70.92
Silt (%)	15.76	15.16	15.93
Clay (%)	14.57	13.52	13.28
Sediment p^H	8.23	9.14	8.44
Total organic carbon (%)	6.97	6.90	6.32

Table 5 - Seasonal variations in sedimentary characteristics in the culture pond

Season	Polychaetes (no. /m^2)	Tanaids (no. /m^2)	Amphipods (no. /m^2)	Bivalves (no. /m^2)	Gastropods (no. /m^2)	Others (no. /m^2)	Total (no. /m^2)
Postmonsoon	172	551.29	59.71	17.14	204.29	6.86	1011.29
Premonsoon	85	12	13.5	7.5	519.50	10.50	655.50
Monsoon	95.63	34.38	6.00	0	140.13	0	311.25

Table 6a - Seasonal variations in the abundance of macrobenthos in the culture pond

Season	Polychaetes (%)	Tanaids (%)	Amphipods (%)	Bivalves (%)	Gastropods (%)	Others (%)	Total (%)
Postmonsoon	17	54	6	2	20	1	100
Premonsoon	13	2	2	1	80	2	100
Monsoon	35	12	2	0	51	0	100

Table 6b - Seasonal variations in the abundance of macrobenthos in the culture pond (in %)

Month/Parameters	**Mean maximum temp(°C)**	**Highest temp(°C)**	**Mean minimum temp(°C)**	**Lowest temp(°C)**	**Total Rainfall (mm)**	**Relative Humidity (%) 9.00 am**	**6.00 pm**
October	30.94	32.57	21.80	20.79	45.90	77.59	82.91
November	31.50	33.78	21.45	17.55	37.90	74.33	78.45
December	32.19	34.24	20.79	16.42	2.70	71.32	74.02
January	32.08	33.78	19.57	16.69	0.00	73.5	68.37
February	32.07	35.06	22.20	20.79	7.38	79.68	73.93
March	32.17	34.89	22.18	19.15	43.74	88.65	85.28
April	32.36	34.29	23.27	20.40	43.56	96.28	93.75
May	32.13	33.01	23.34	22.34	43.74	91.73	88.45
June	30.80	32.82	22.53	21.35	156.15	97.17	94.58
July	29.17	31.49	22.16	20.69	131.85	97.28	97.35
August	28.94	31.49	22.23	21.37	97.13	94.10	70.83
September	29.66	30.79	22.53	21.01	31.59	95.50	98.82

Table 7 – Monthly variations of meteorological parameters

	Salinity	Temperature	Turbidity	pH	Alkalinity	Hardness	NO_3	NO_2	PO_4	SiO_4	DO	Primary Productivity	Chlorophyll
Salinity	1	-.537**	.241	.652**	.723**	.682**	-.337	.608**	.185	.356	-.556**	-.294	-.082
Temperature	-.537**	1	.381*	-.099	-.174	-.269	.060	-.064	-.085	-.296	.605**	.592**	.477**
Turbidity	.241	.381*	1	.277	.224	.001	-.008	.307	.148	.001	.073	.058	.102
pH	.652**	-.099	.277	1	.800**	.464**	-.573**	.477**	-.044	.331	-.155	.037	.361*
Alklinity	.723	-.174	.224	.800**	1	.639**	-.416*	.399*	.123	.322	-.256	.235	.449*
Hardness	.682**	-.269	.001	.464**	.639**	1	-.575**	.539**	.246	.129	-.466**	.119	.291
NO_3	-.337	.060	-.008	-.573**	-.416*	-.575**	1	-.319	-.167	-.244	.138	.025	-.318
NO_2	.608	-.064	.307	.477**	.399*	.539**	-.319	1	.162	.134	.046	-.058	-.074
PO_4	.185	-.085	.148	-.044	.123	.246	-.167	.162	1	.394*	-.133	-.136	.035
SiO_4	.356	-.296	.001	.331	.322	.129	-.244	.134	.394*	1	-.192	-.316	-.062
DO	-.556	.605**	.073	-.155	-.256	-.466**	.138	.046	-.133	-.192	1	.487**	.224
Primary Productivity	-.294	.592**	.058	.037	.235	.119	.025	-.058	-.136	-.316	.487**	1	.692**
Chlorophyll	-.082	.477**	.102	.361*	.44*	.291	-.318	-.074	.035	-.062	.224	.692**	1
Sediment pH	-.171	.476**	.037	.199	.277	.255	.417*	-.094	.129	-.010	.247	.574**	.645**
TOC	-.357	.066	-.134	-.415*	-.232	-.299	.483**	-.477**	-.168	-.305	-.094	.126	-.182
Sand	.039	.063	-.013	.133	.066	.079	-.301	-.007	.037	.134	.075	.088	.039
Silt	.036	.012	.157	.230	.161	.007	-.021	-.051	-.343	-.244	-.137	.062	.203
Clay	-.104	.051	.043	-.170	-.093	-.121	.336	.038	.131	-.016	.015	-.026	-.083
Benthos	-.207	.043	.027	-.077	-.182	-.259	.020	-.010	-.088	-.171	-.077	-.285	-.075
Polychaets	-.101	.128	-.033	.058	.149	.040	-.258	-.138	.465**	.134	.160	.149	.247
Tanaids	-.332	.030	-.209	-.179	-.197	-.238	-.135	-.334	.028	-.274	.094	.091	-.079
Amphipods	-.224	.189	-.024	-.197	-.054	-.085	-.143	-.205	.234	-.155	.166	.039	.023
Bivalves	-.169	.136	-.199	-.061	-.037	.008	-.117	-.019	.173	-.079	.082	.042	.002
Gastropods	-.030	.303	.245	.160	.165	.047	-.024	.148	.000	-.152	-.031	.154	.232

Table 8 – Correlation Table

	Sediment pH	TOC	Sand	Silt	Clay	Benthos	Polychaets	Tanaids	Amphipod	Bivalve	Gastropod
Salinity	-.171	-.357	.039	.036		-.207	-.101	-.332	-.224	-.169	-.030
Temperature	.476**	.066	.063	.012		.043	.128	.030	.189	.136	.303
Turbidity	.037	-.134	-.013	.157		.027	-.033	-.209	-.024	-.199	.245
pH	.199	-.415*	.133	.230		-.077	.058	-.179	-.197	-.061	.160
Alklinity	.277	-.232	.066	.161		-.182	.149	-.197	-.054	-.037	.165
Hardness	.255	-.299	.079	.007		-.259	.040	-.238	-.085	.008	.047
NO_3	-.417*	.483**	-.301	-.021		.020	-.258	-.135	-.143	-.117	-.024
NO_2	-.094	-.477**	-.007	-.051		-.010	-.138	-.334	-.205	-.019	.148
PO_4	.129	-.168	.037	-.343		-.088	.465**	.028	.234	.173	.000
SiO_4	-.010	-.305	.134	-.244		-.171	.134	-.274	-.155	-.079	-.152
DO	.247	-.094	.075	-.137		-.077	.160	.094	.166	.082	.031
Primary Productivity	.574**	.126	.088	.062		-.285	.149	.091	.039	.042	.154
Chlorophyll	.645**	-.182	.039	.203		-.075	.247	-.079	.023	.002	.232
Sediment pH	1	.072	.211	-.118		-.280	.420*	.017	.367*	.305	.290
TOC	.072	1	-.135	.124		.173	-.135	.117	.154	.116	.310
Sand	.211	-.135	1	-.500**		-.463**	.580**	.353	.388*	.362*	-.450*
Silt	-.118	.124	-.500**	1		.318	-.514**	-.020	-.135	-.466**	.497**
Clay	-.084	.128	-.855**	.103		.402	-.460*	-.426*	-.385*	-.106	.338
Benthos	-.280	.173	-.463**	.318		1	.269*	.019	-.189	-.071	.430*
Polychaets	.420*	-.135	.580**	-.514**		-.269	1	.415*	.537**	.513**	-.259
Tanaids	-.017	.117	.353	-.020		.019	.415*	1	.503**	.034	-.266
Amphipods	.367*	.154	.383*	-.135		-.189	.537**	.503**	1	.355	.011
Bivalves	.305	.116	.362*	-.466**		-.71	.513**	.034	.355	1	.135
Gastropods	.290	.310	-.450*	.497**		.430*	-.259	-.266	.011	.135	1

Table 8 – Correlation Table ………. continued

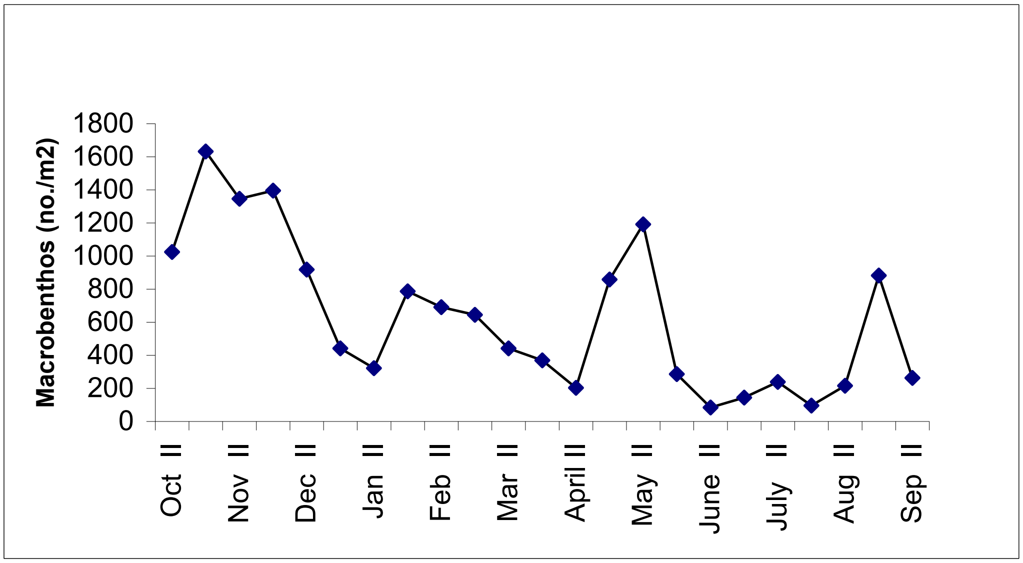


Fig.1 Fortnightly variations in macrobenthos

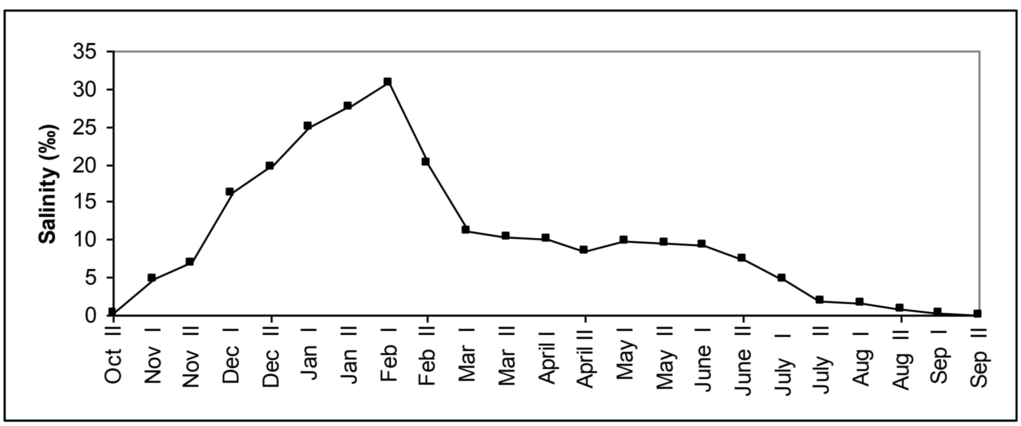


Fig.2 Fortnightly variations in salinity

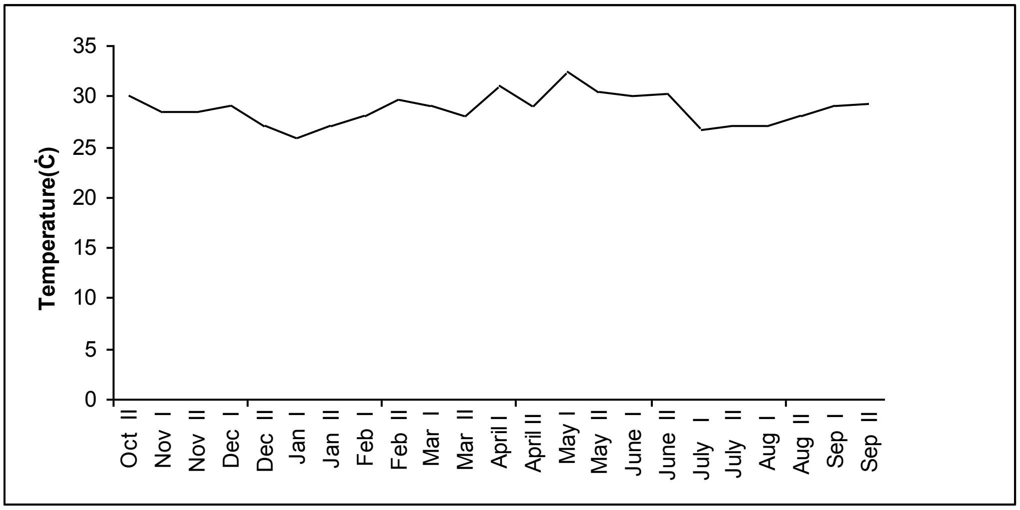


Fig.3 Fortnightly variations in temperature

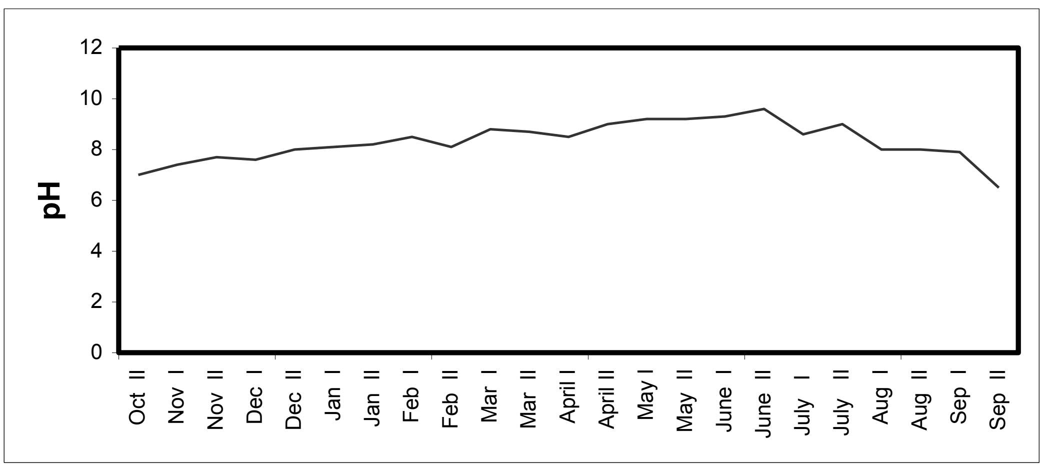


Fig.4 Fortnightly variations in pH

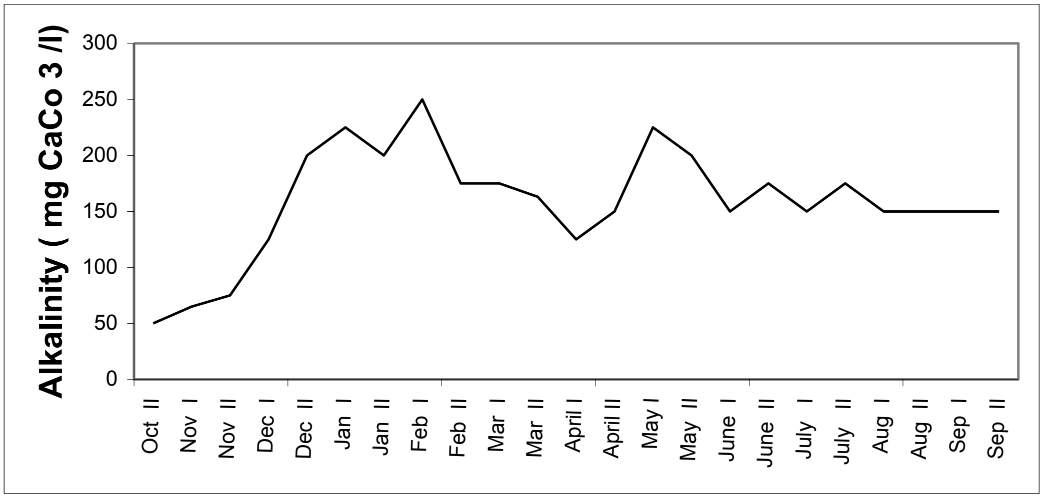


Fig.5 Fortnightly variations in alkalinity

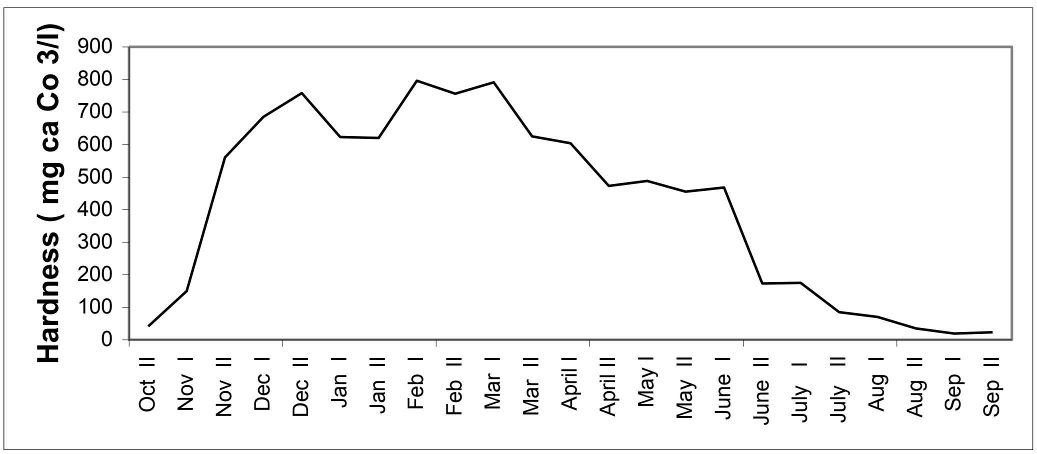


Fig.6 Fortnightly variations in hardness

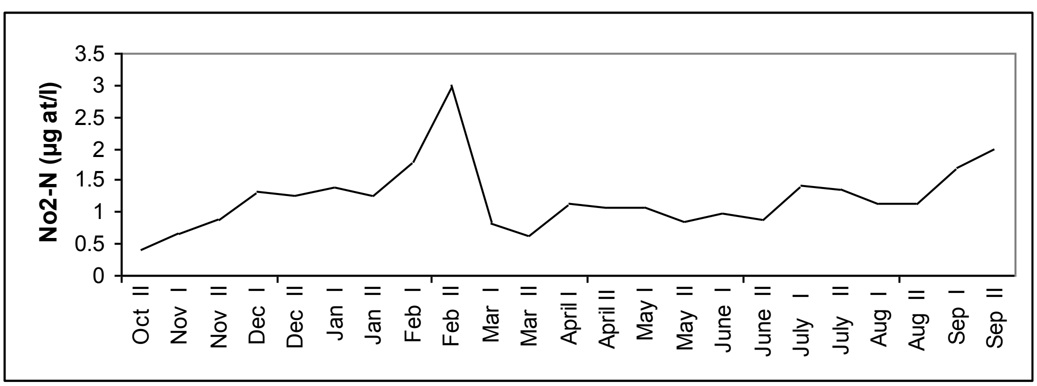


Fig.7 Fortnightly variations in No_2-N

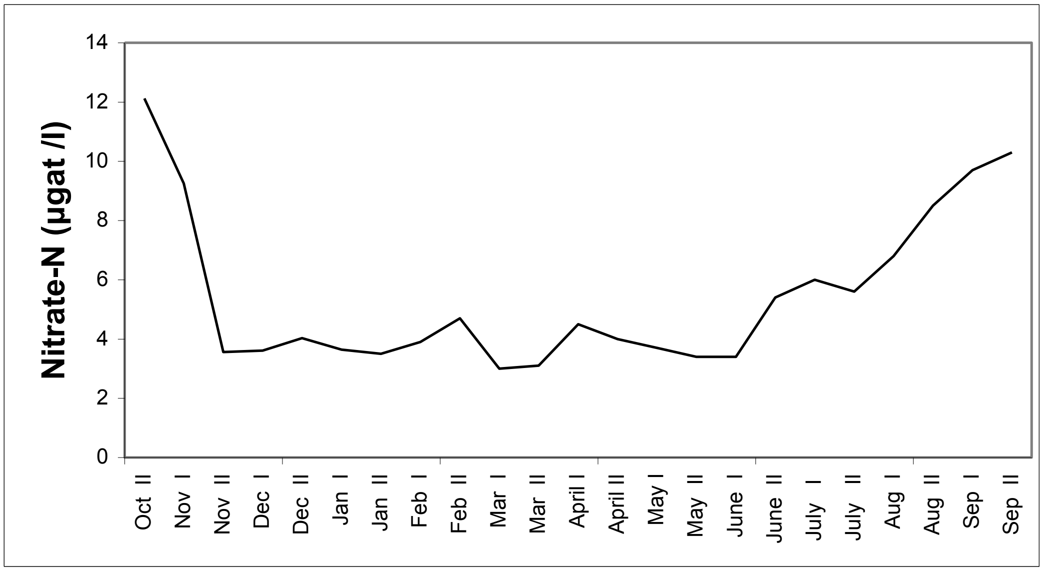


Fig.8 Fortnightly variations in No3-N

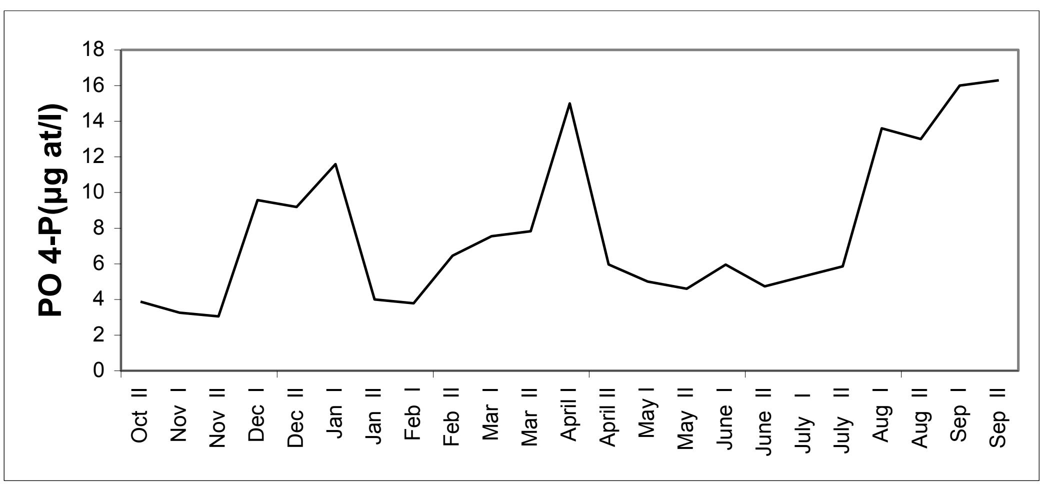


Fig.9 Fortnightly variations in PO_4-P

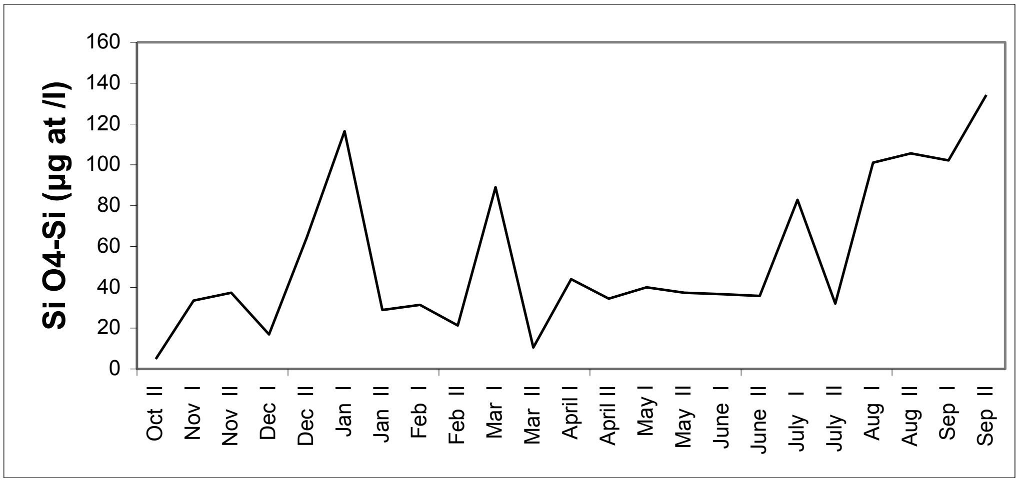


Fig.10 Fortnightly variations in SiO_4-Si

Fig.11 Fortnightly variations in Dissolved Oxygen

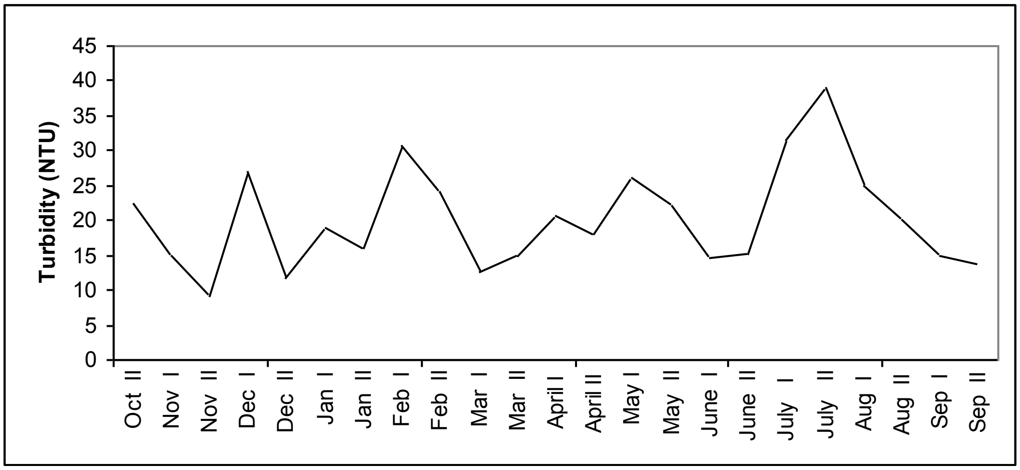


Fig.12 Fortnightly variations in turbidity

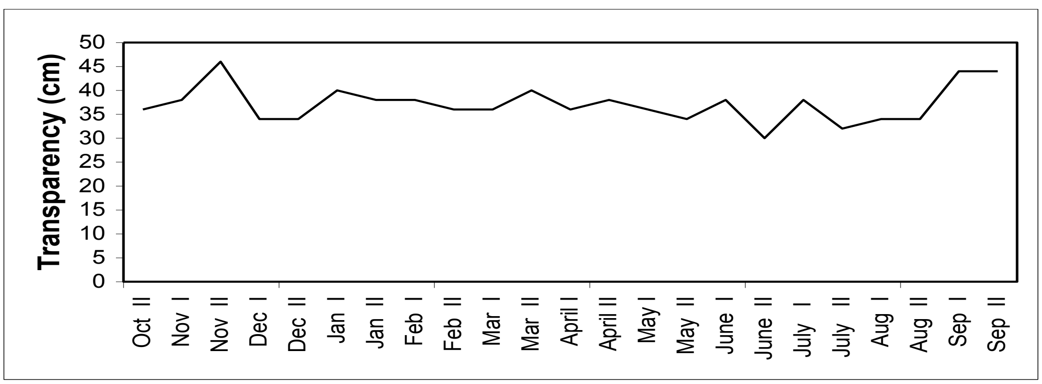


Fig.13 Fortnightly variations in transparency

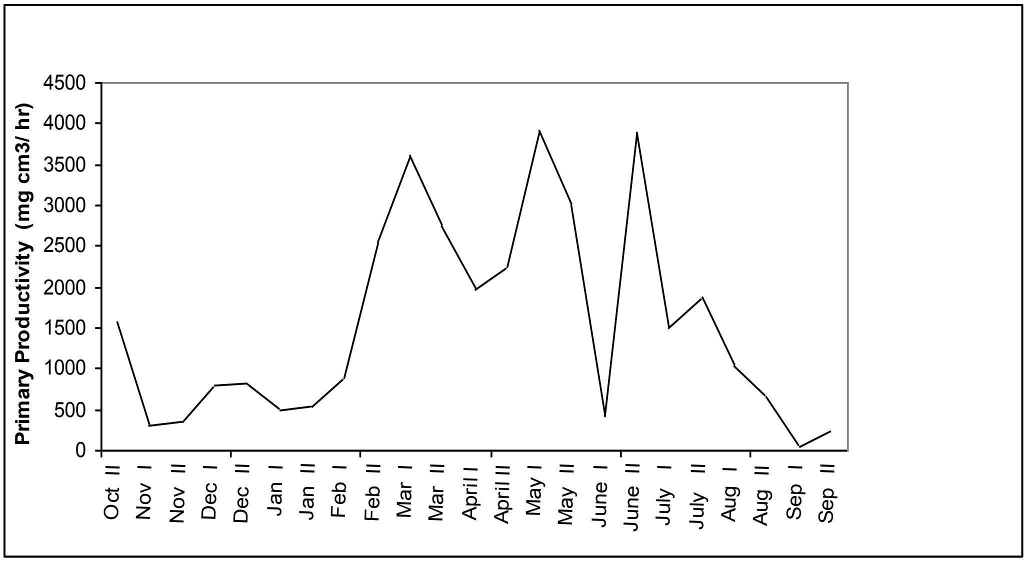


Fig.14 Fortnightly variations in primary productivity

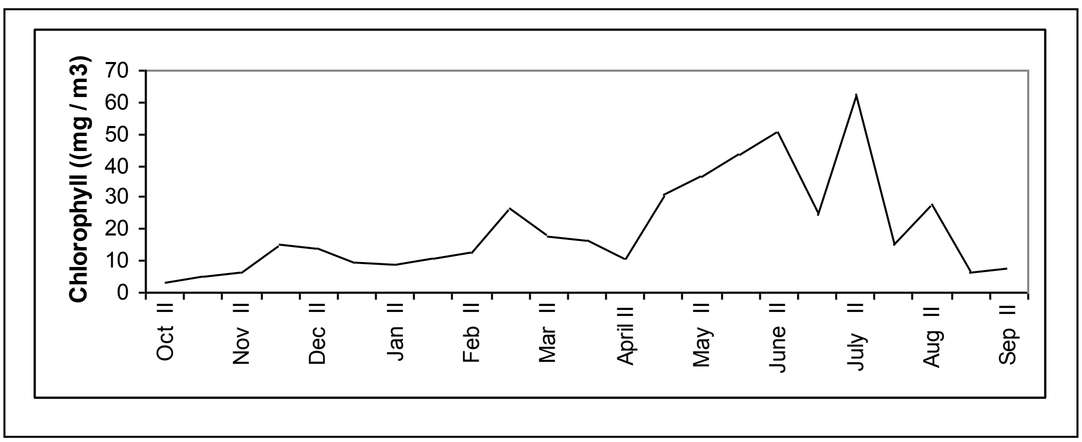


Fig.15 Fortnightly variations in chlorophyll

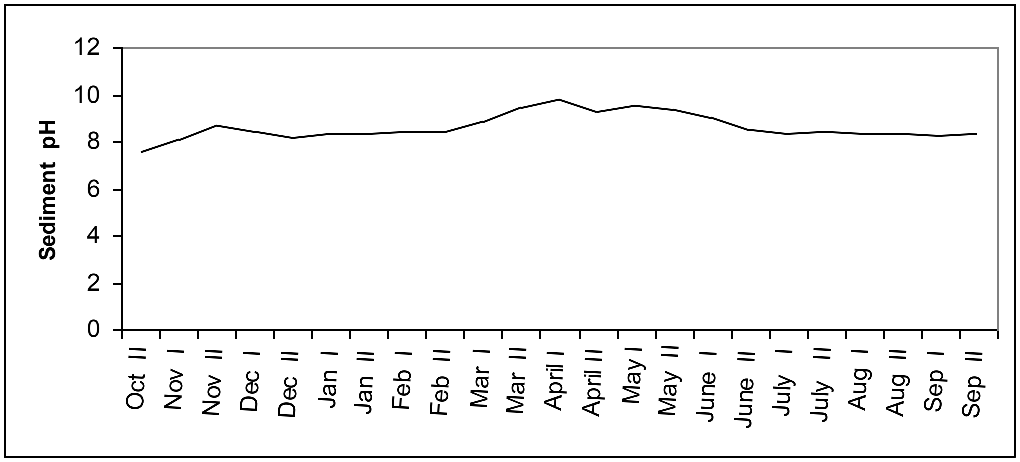


Fig.16 Fortnightly variations in Sediment pH

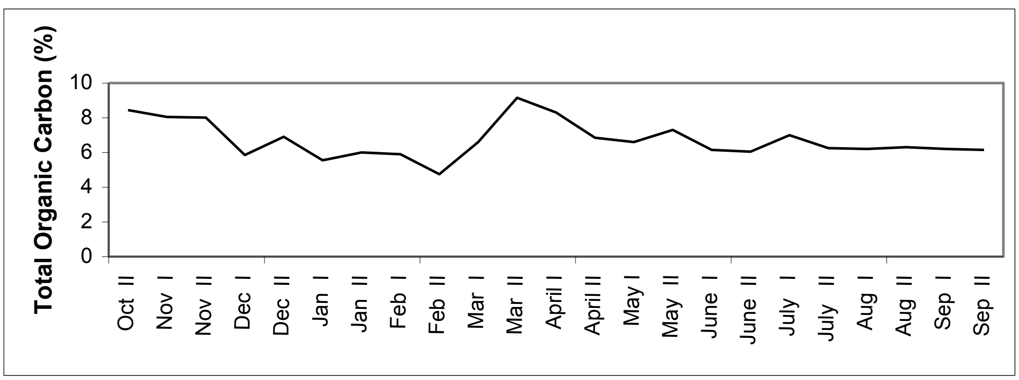


Fig.17 Fortnightly variations in total organic carbon

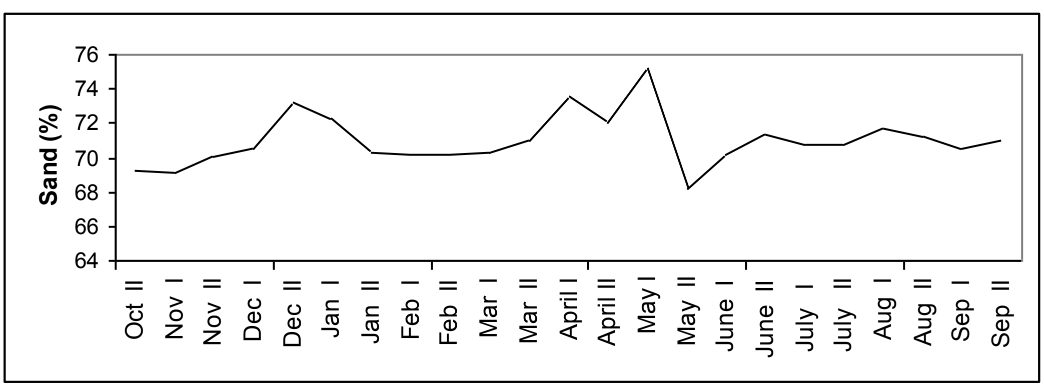


Fig.18 Fortnightly variations in Sand

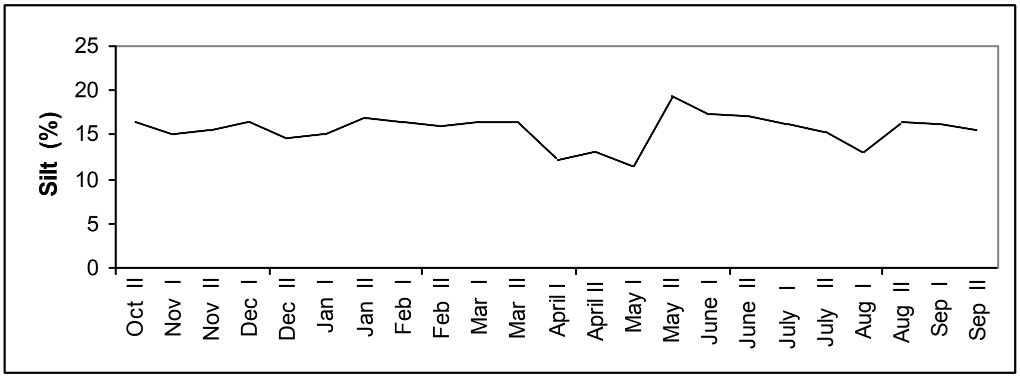


Fig.19 Fortnightly variations in Silt

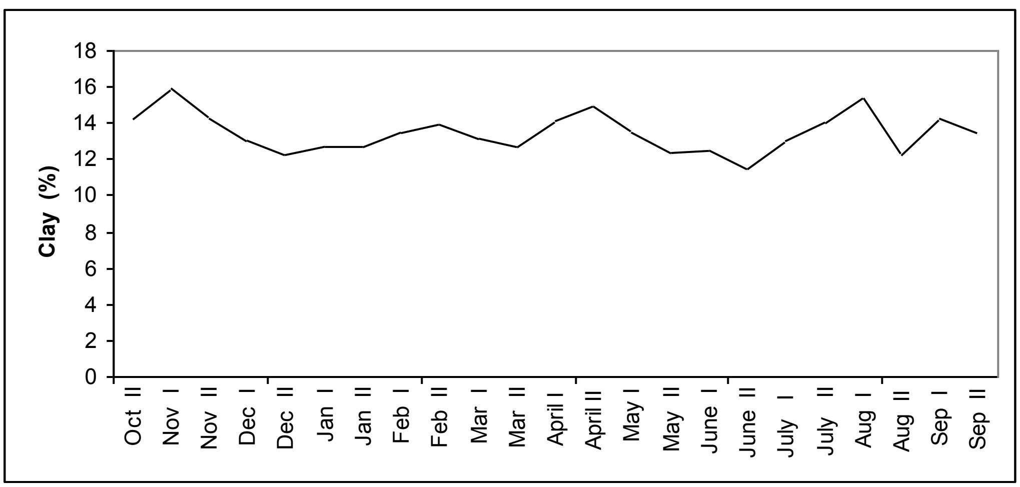


Fig.20 Fortnightly variations in clay

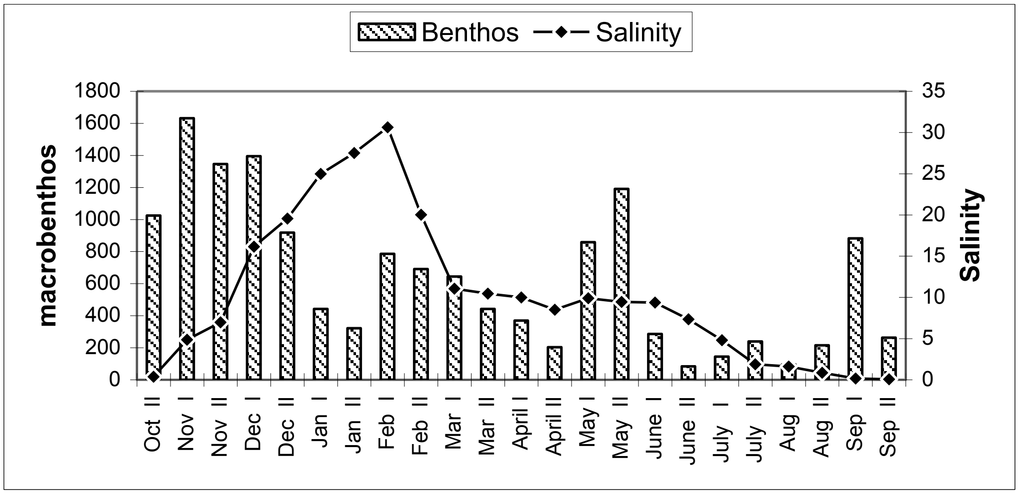


Fig.21 Fortnightly variations in macrobenthos in relation to salinity

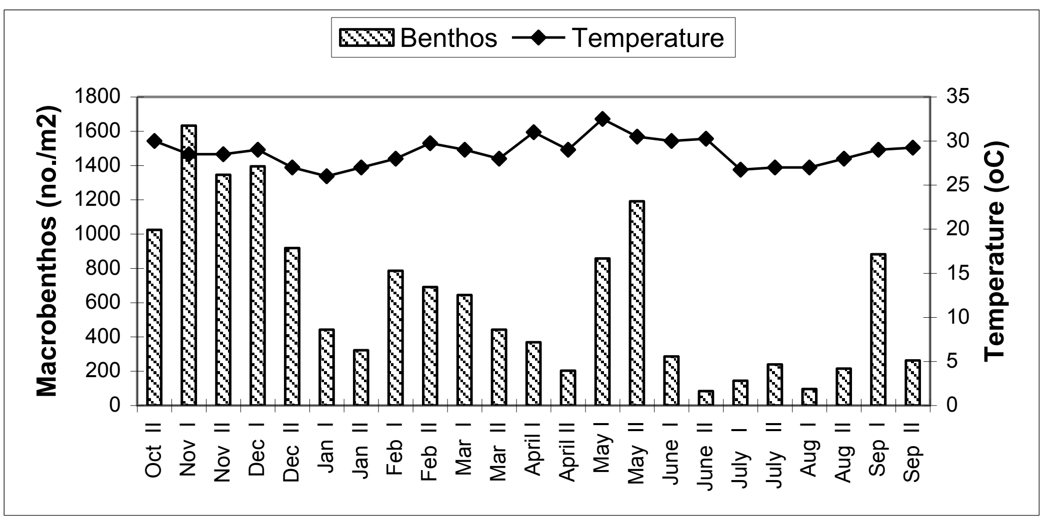


Fig.22 Fortnightly variations in macrobenthos in relation to temperature.

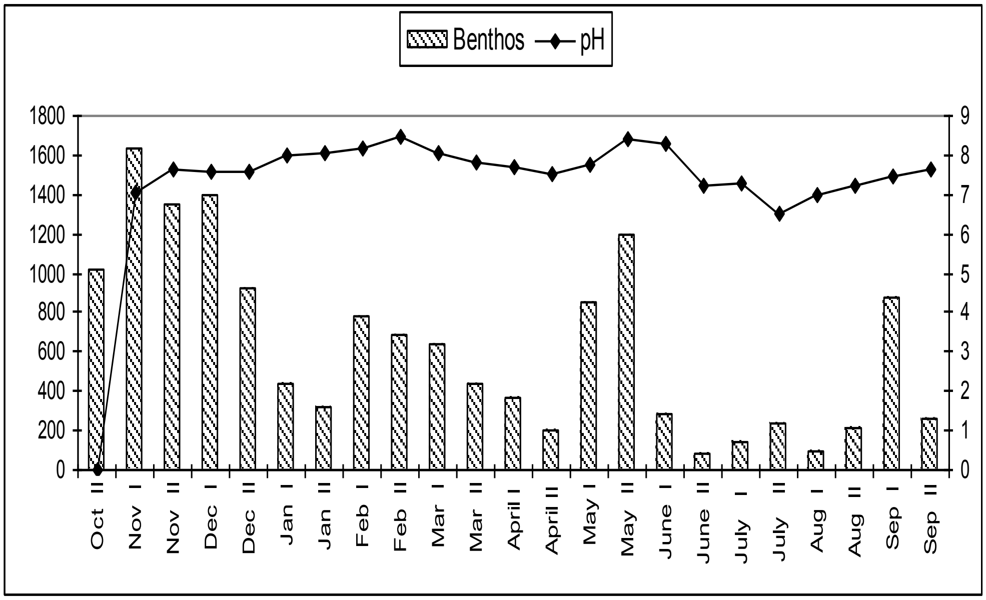


Fig.23 Fortnightly variations in macrobenthos in relation to pH

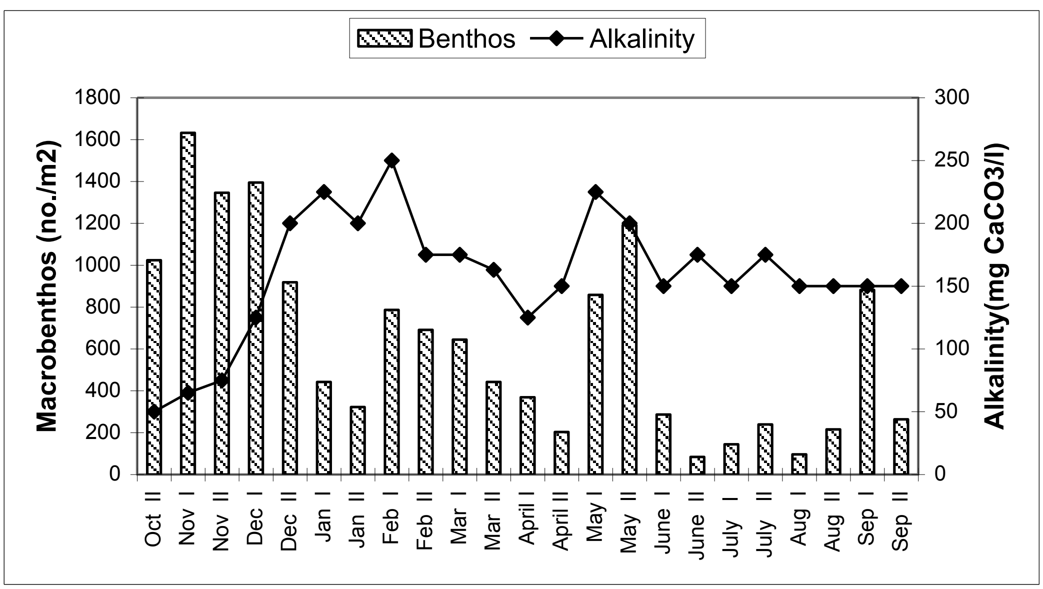


Fig.24 Fortnightly variations in macrobenthos in relation to alkalinity

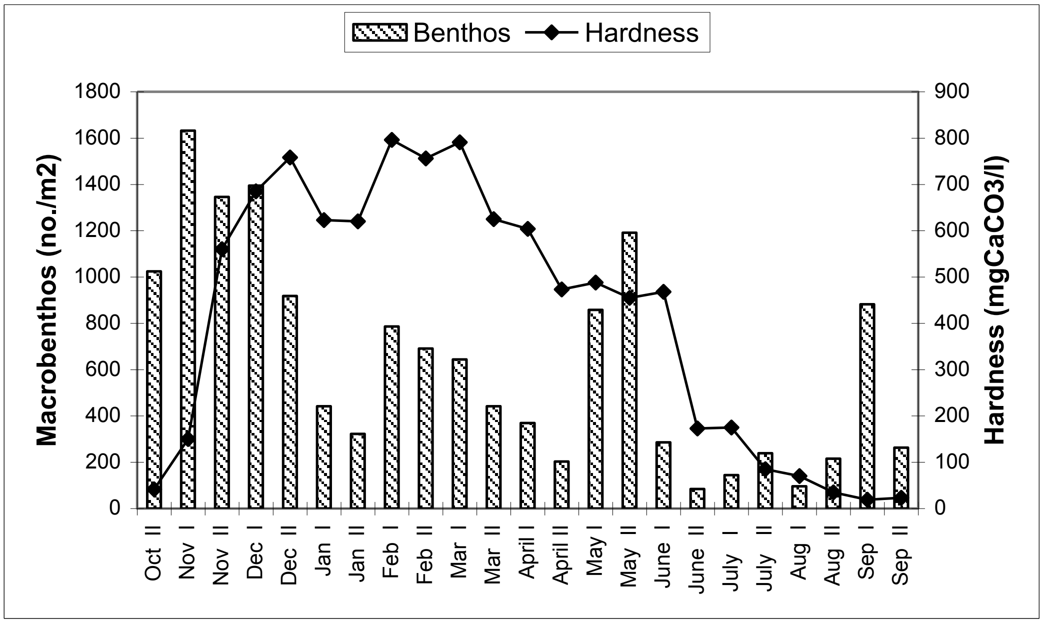


Fig.25 Fortnightly variations in macrobenthos in relation to hardness

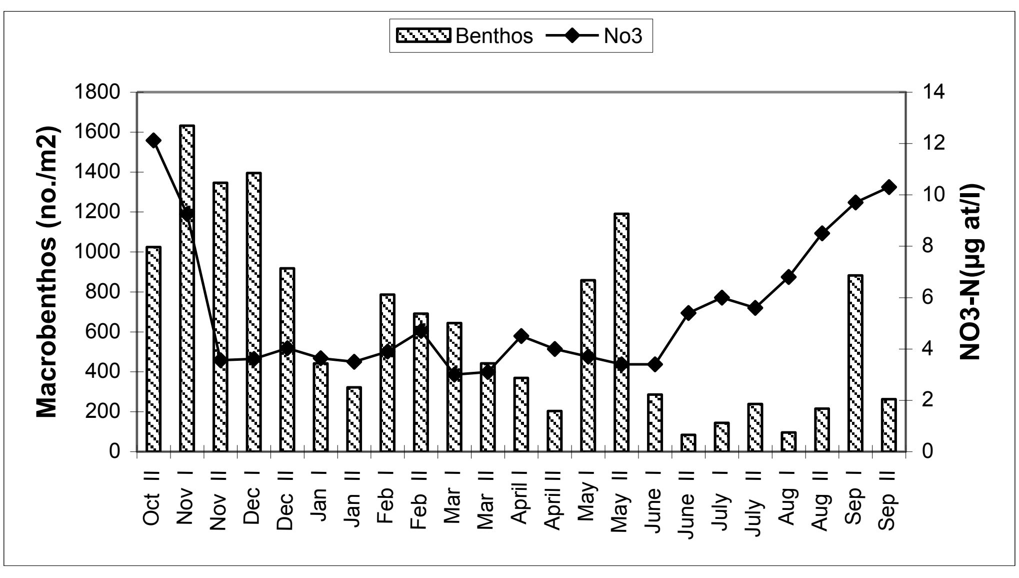


Fig.26 Fortnightly variations in macrobenthos in relation to no3-N

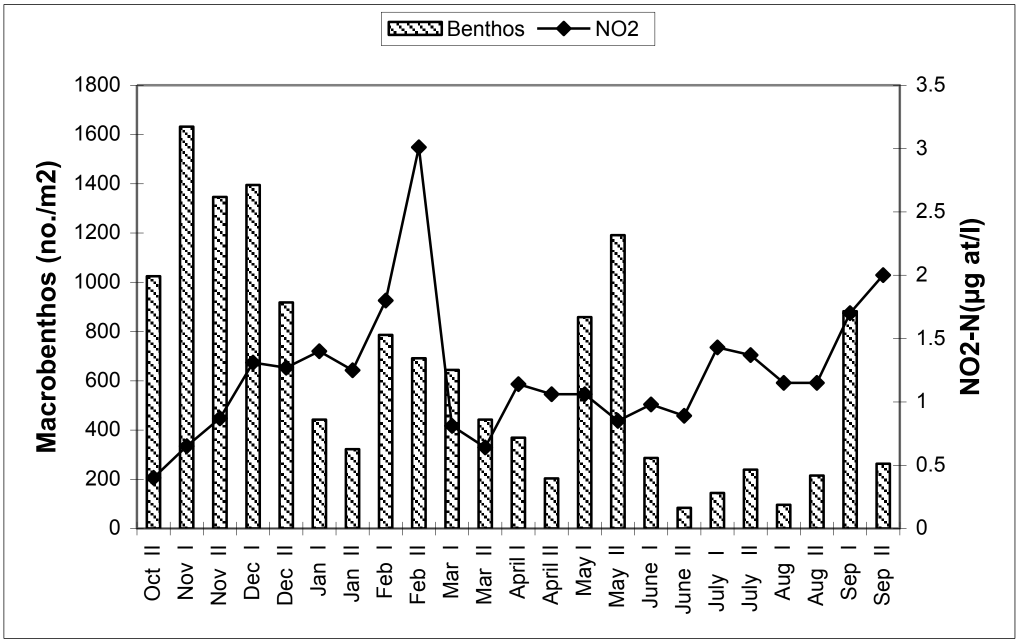


Fig.27 Fortnightly variations in macrobenthos in relation to no2-N

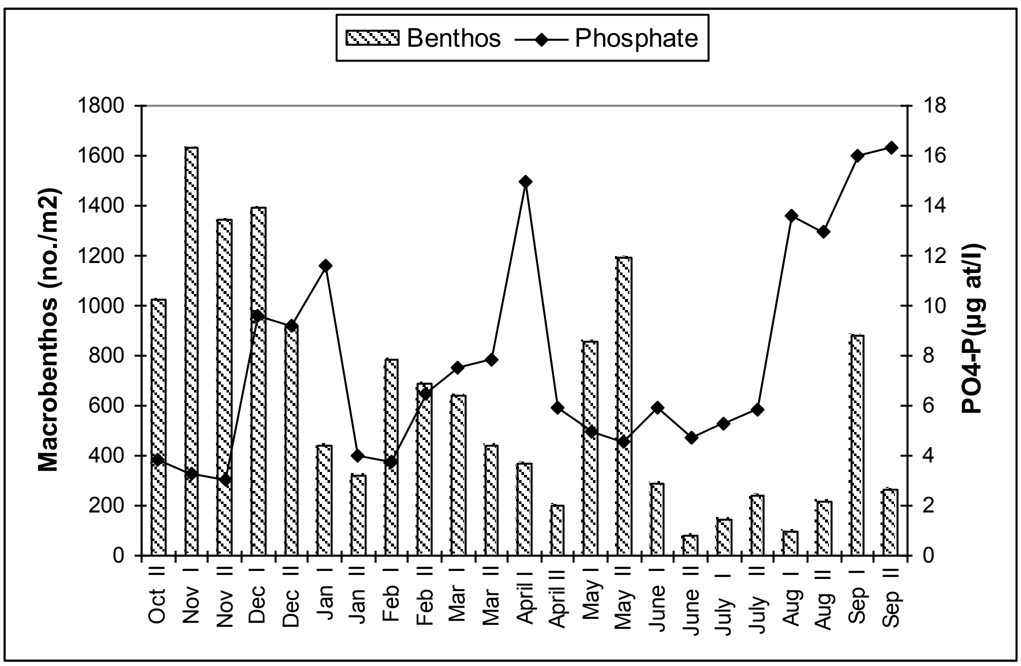


Fig.28 Fortnightly variations in macrobenthos in relation to po4-P

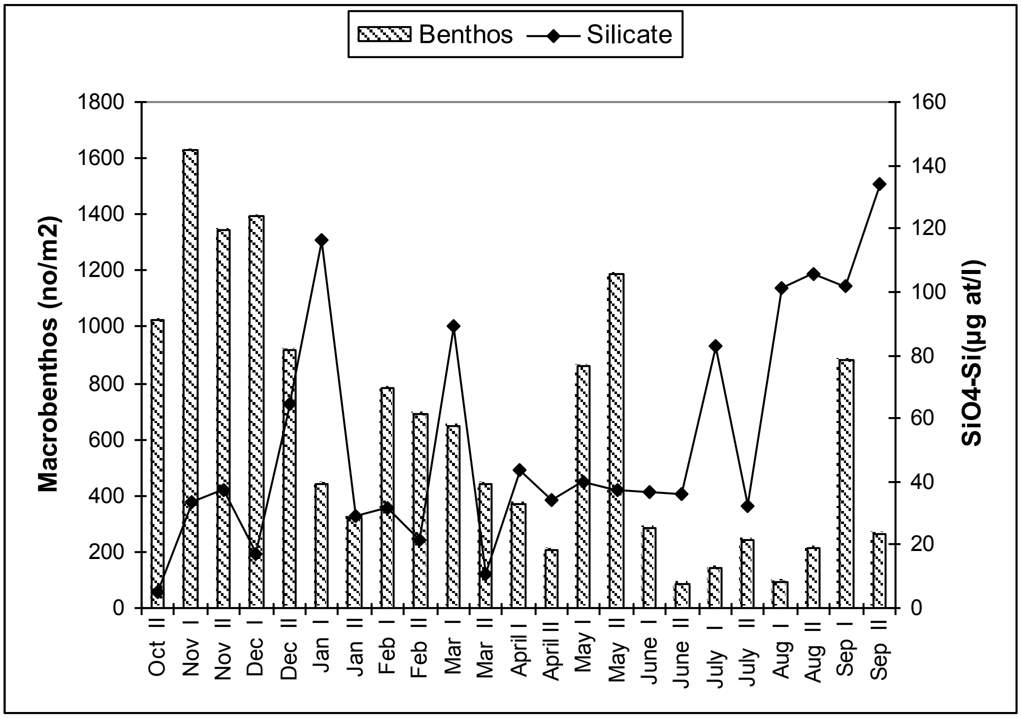


Fig.29 Fortnightly variations in Macrobenthos in relation to sio4-S

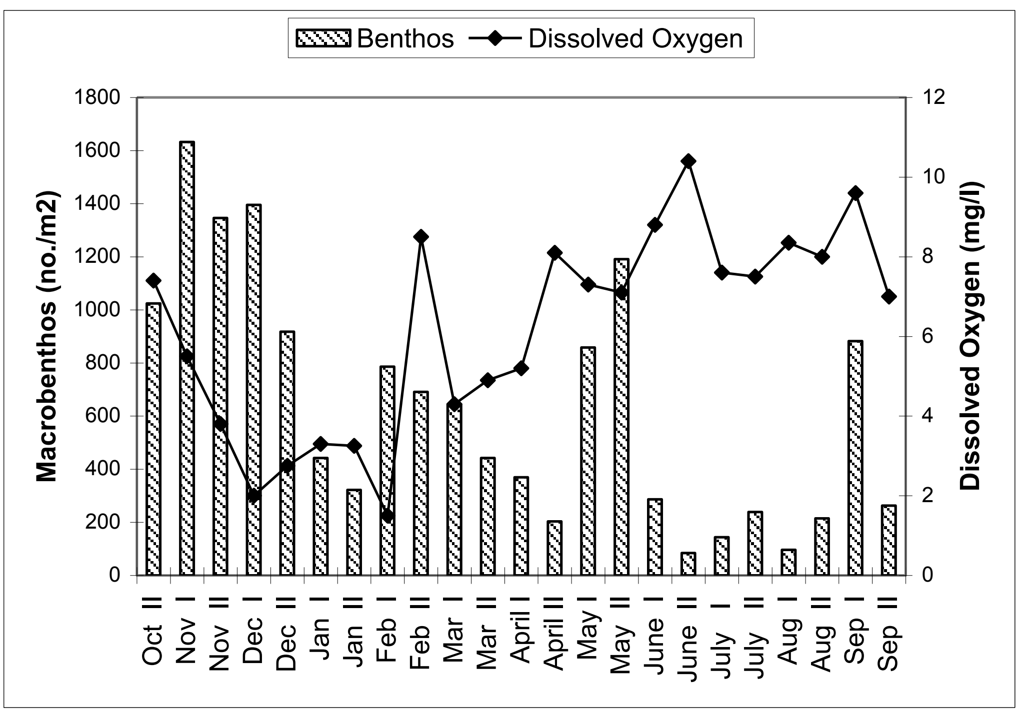


Fig.30 Fortnightly variations in macrobenthos in relation to dissolved oxygen

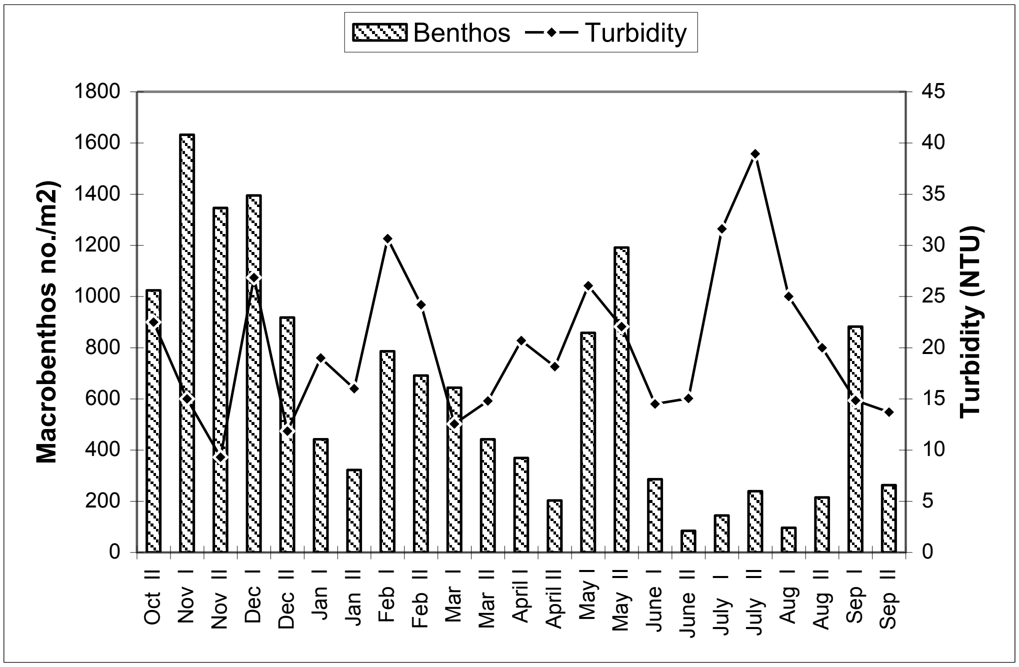


Fig.31 Fortnightly variations in macrobenthos in relation to turbidity

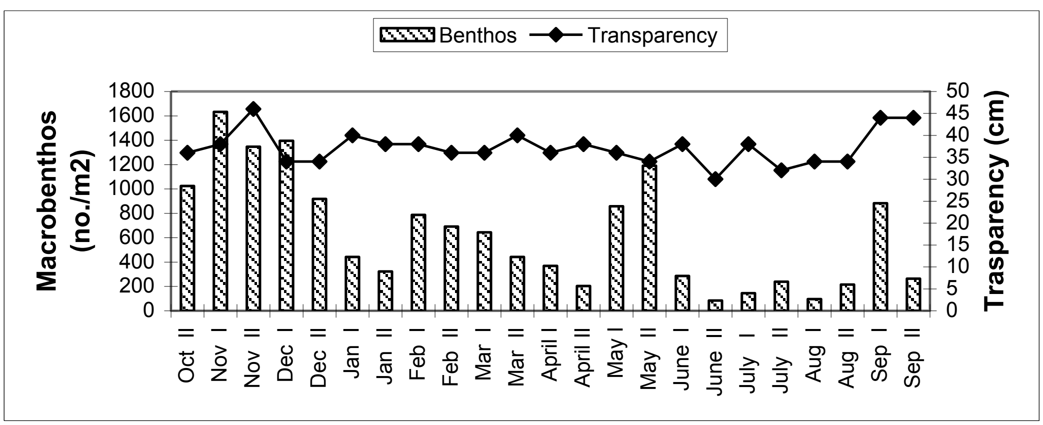


Fig.32 Fortnightly variations in macrobenthos in relation to transparency

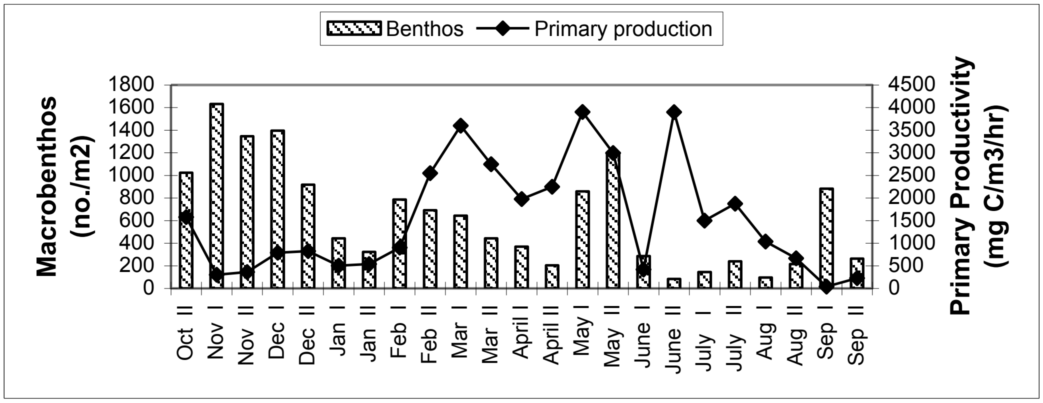


Fig.33 Fortnightly variations in macrobenthos in relation to primary production.

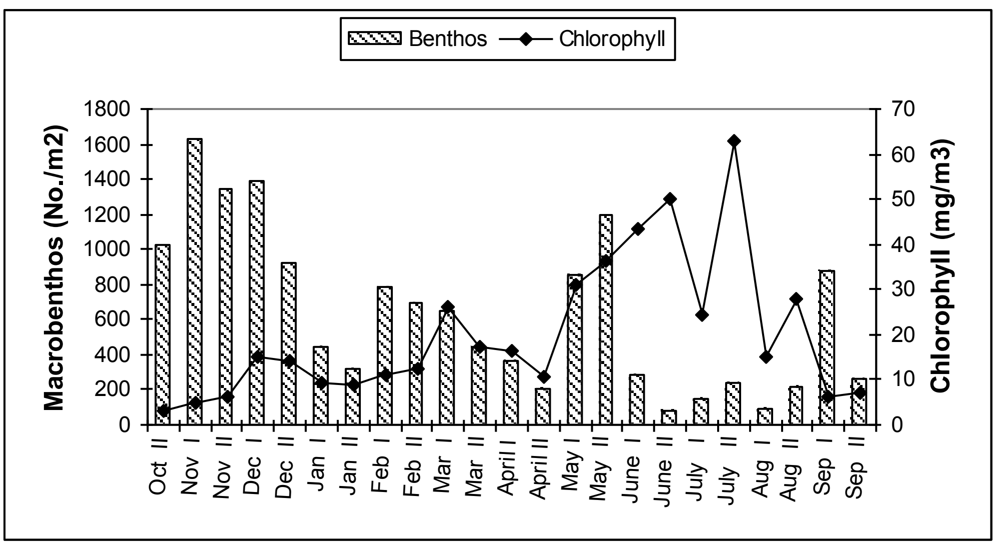


Fig.34 Fortnightly variations in macrobenthos in relation to chlorophyll

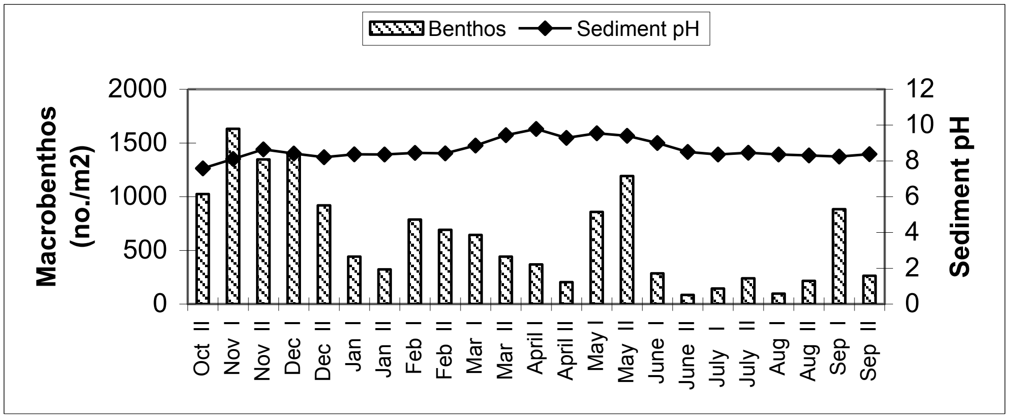


Fig.35 Fortnightly variations in macrobenthos in relation to sediment

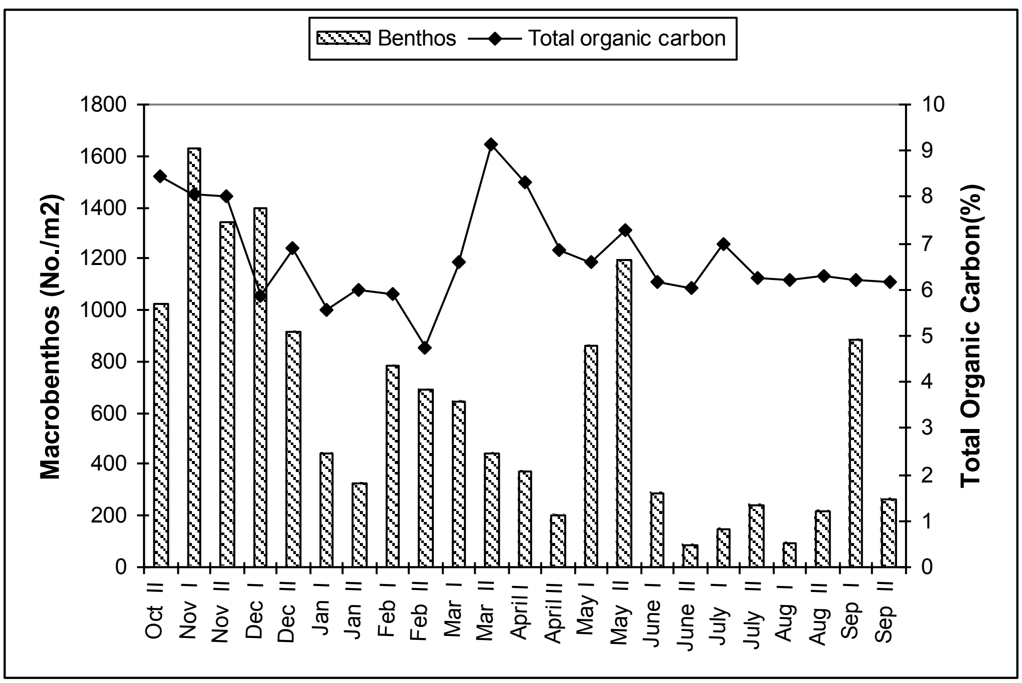


Fig.36 Fortnightly variations in macrobenthos in relation to total organic carbon

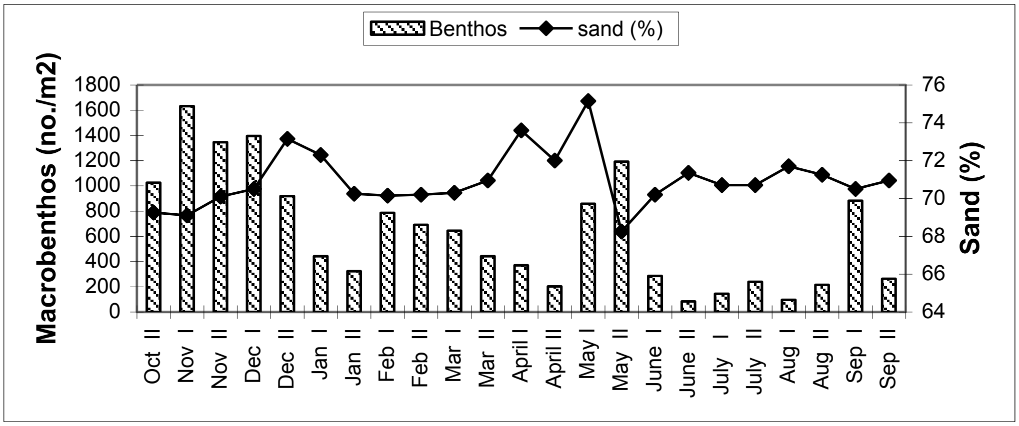


Fig.37 Fortnightly variations in macrobenthos in relation to sand

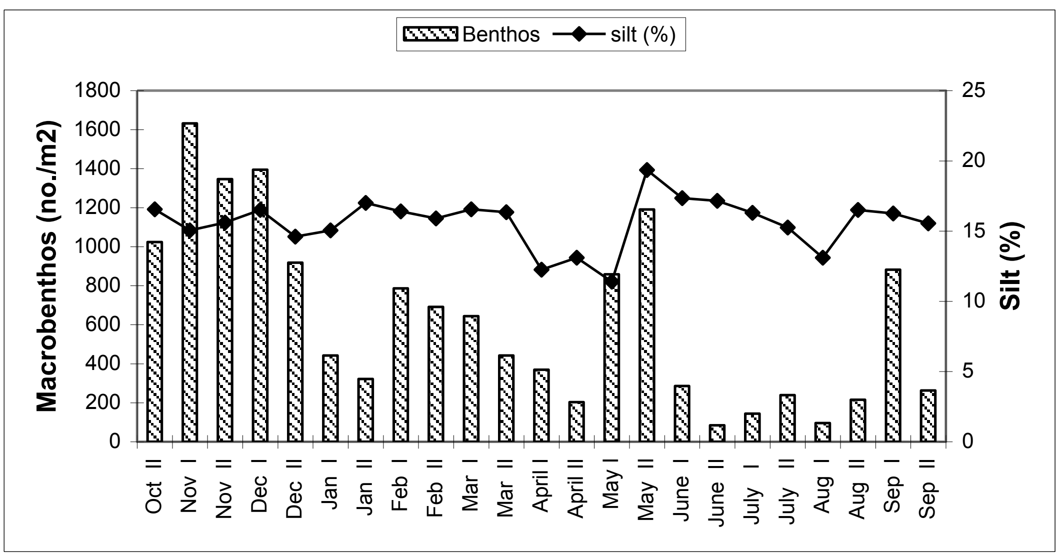


Fig.38 Fortnightly variations in macrobenthos in relation to silt

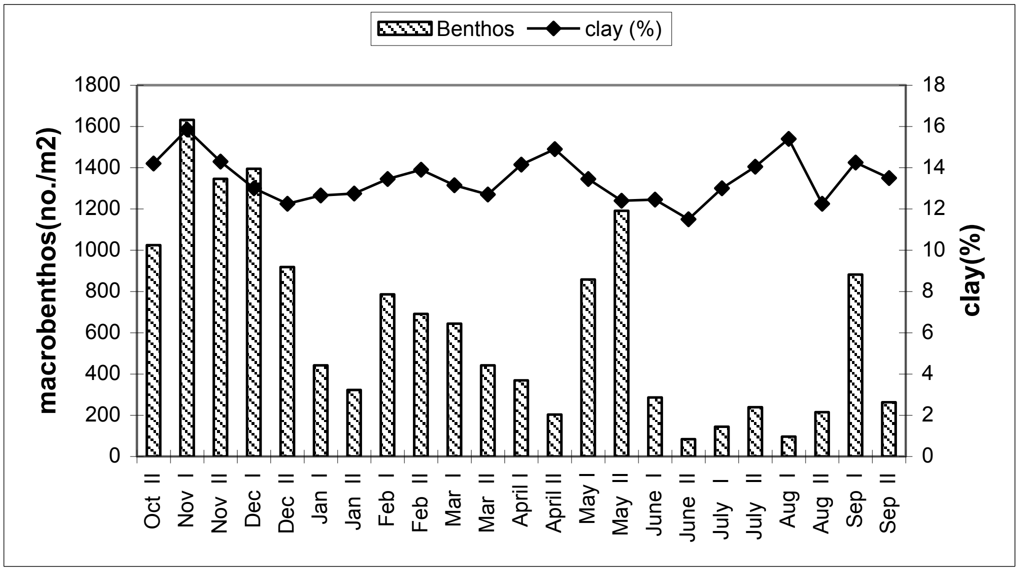


Fig.39 Fortnightly variations in macrobenthos in relation to clay

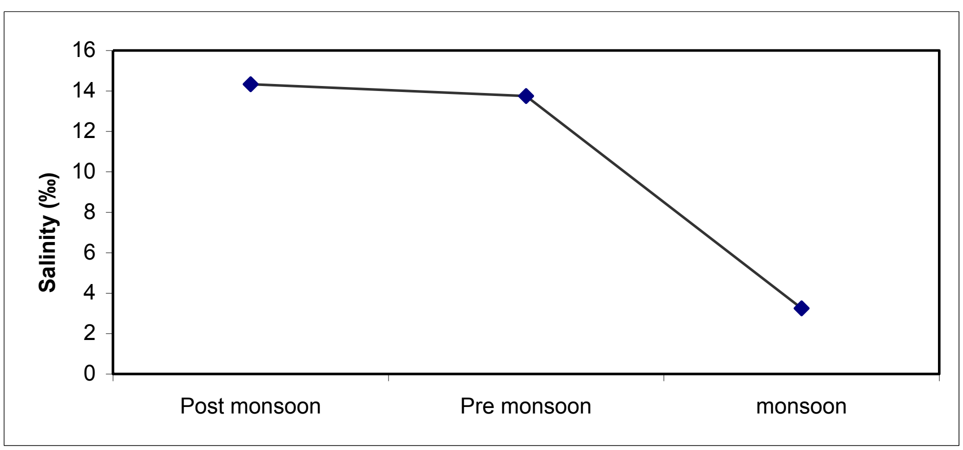


Fig. 40 Seasonal variation in salinity

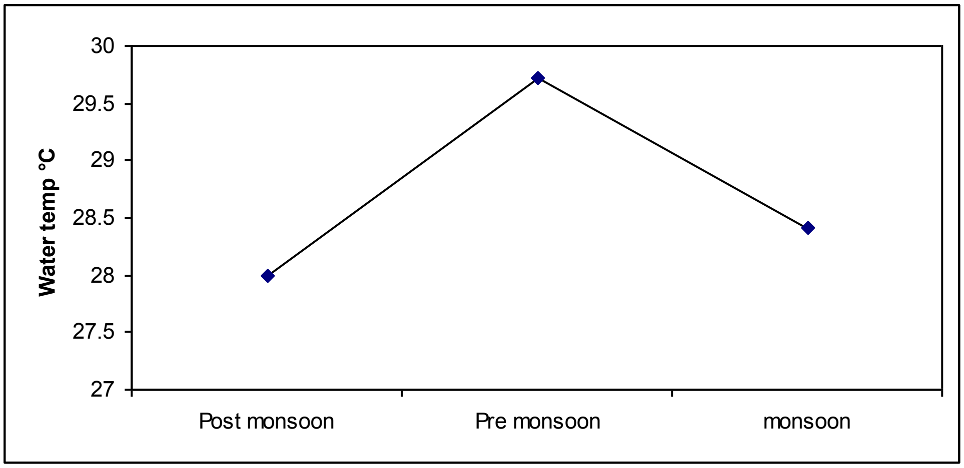


Fig. 41 Seasonal variation in water temperature

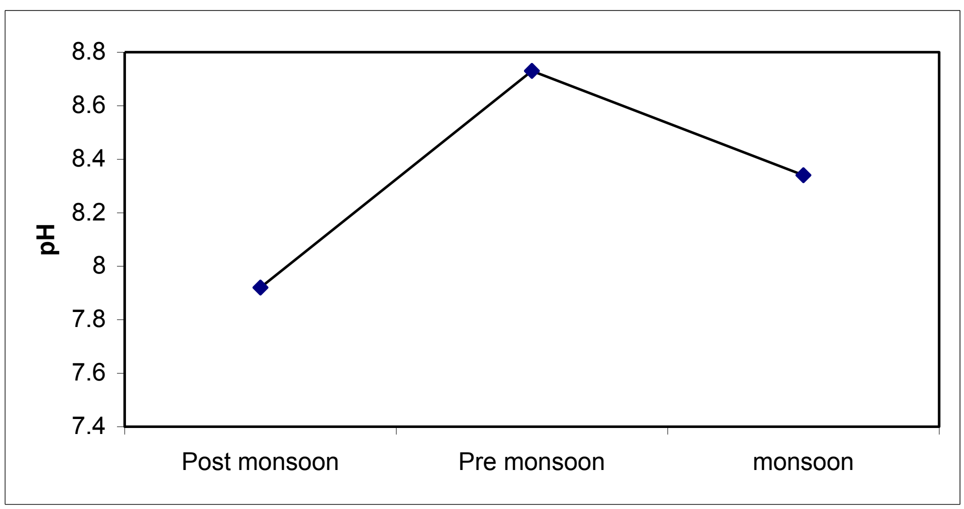


Fig. 42 Seasonal variation in pH

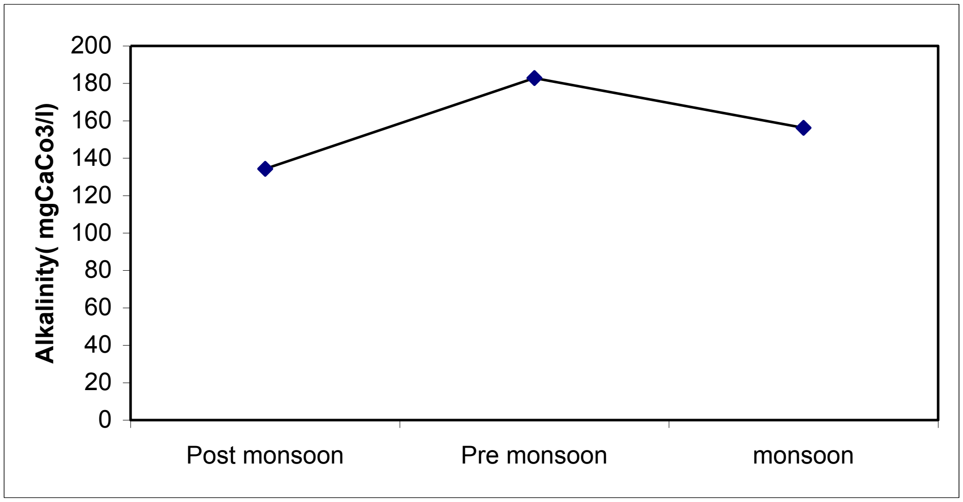


Fig. 43 Seasonal variation in alkalinity

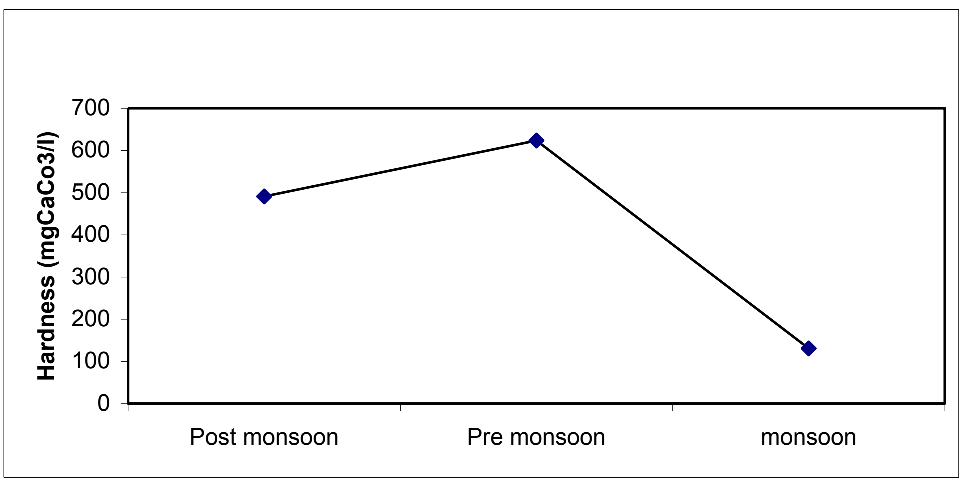


Fig. 44 Seasonal variation in hardness

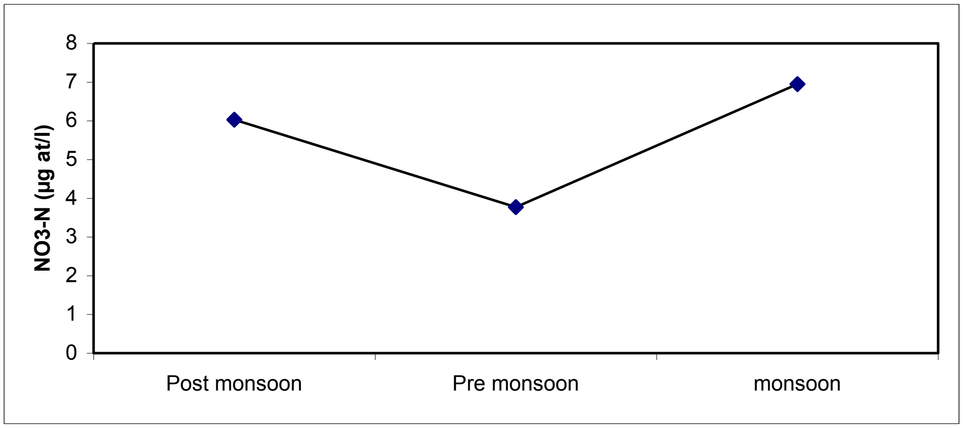


Fig. 45 Seasonal variation in NO_3-N

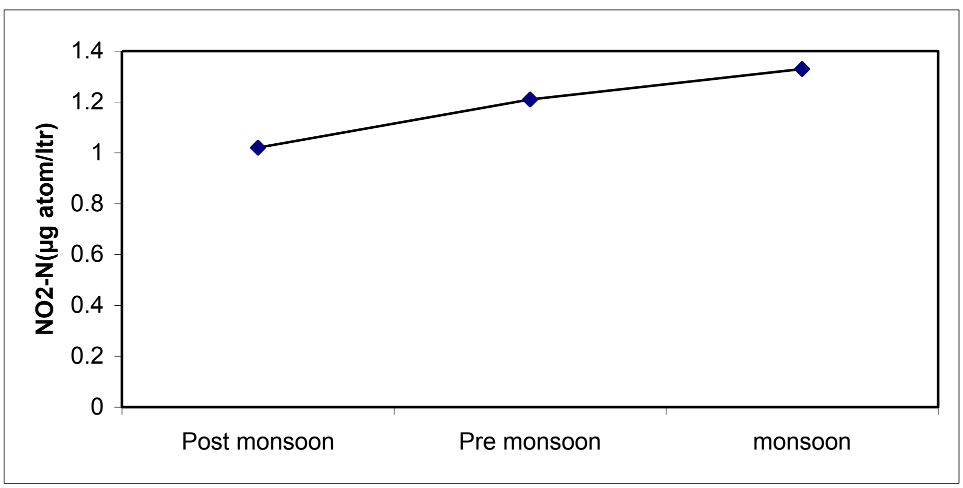


Fig. 46 Seasonal variation in NO_2-N

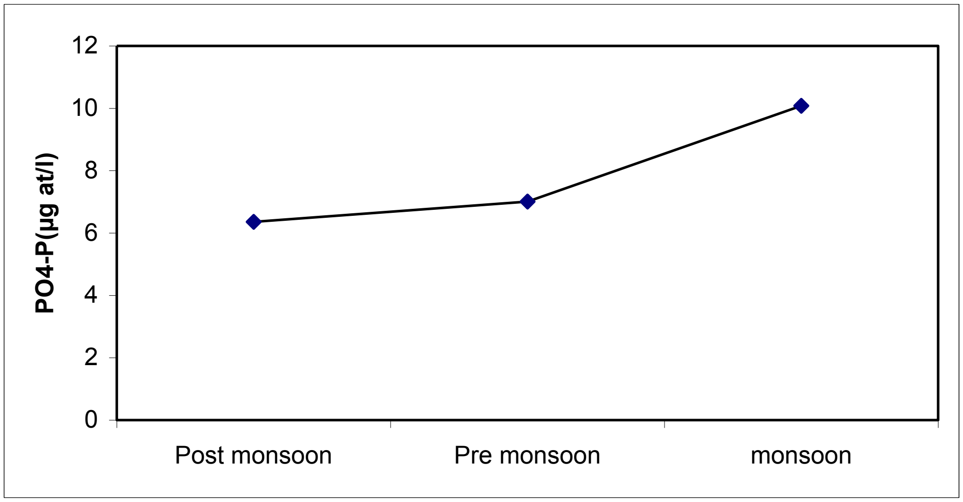


Fig. 47 Seasonal variation in PO_4-P

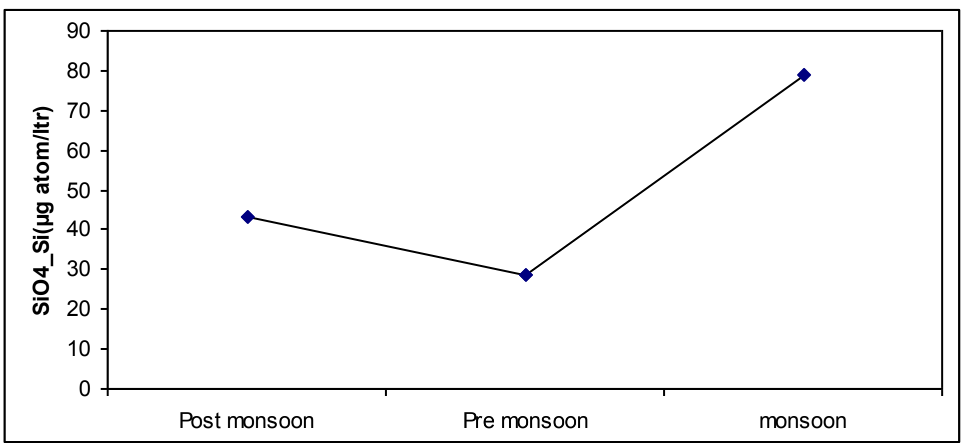


Fig. 48 Seasonal variation in SiO_4-Si

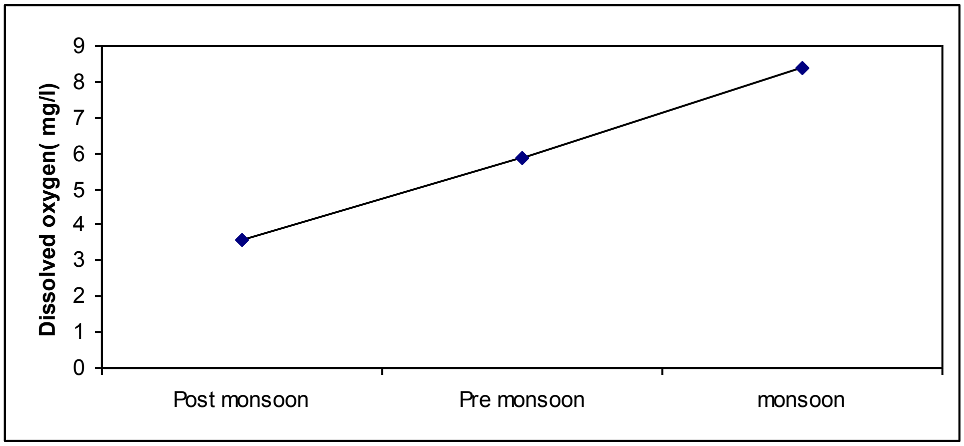


Fig. 49 Seasonal variation in dissolved oxygen

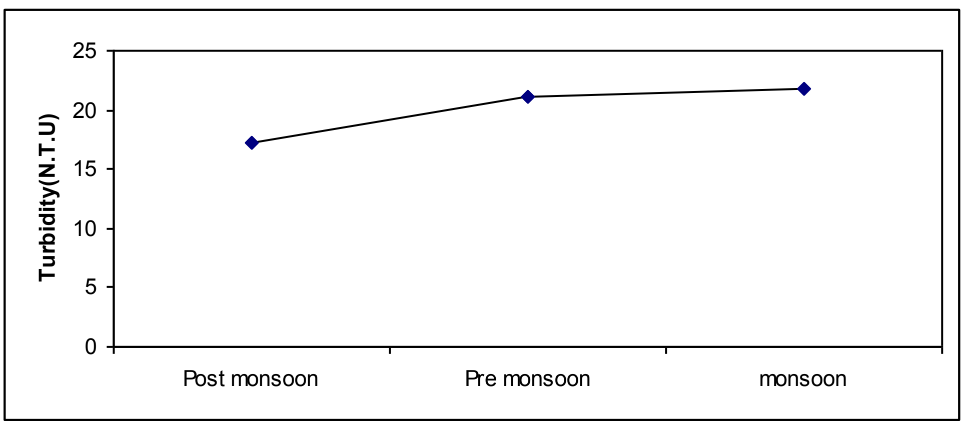


Fig. 50 Seasonal variation in turbidity

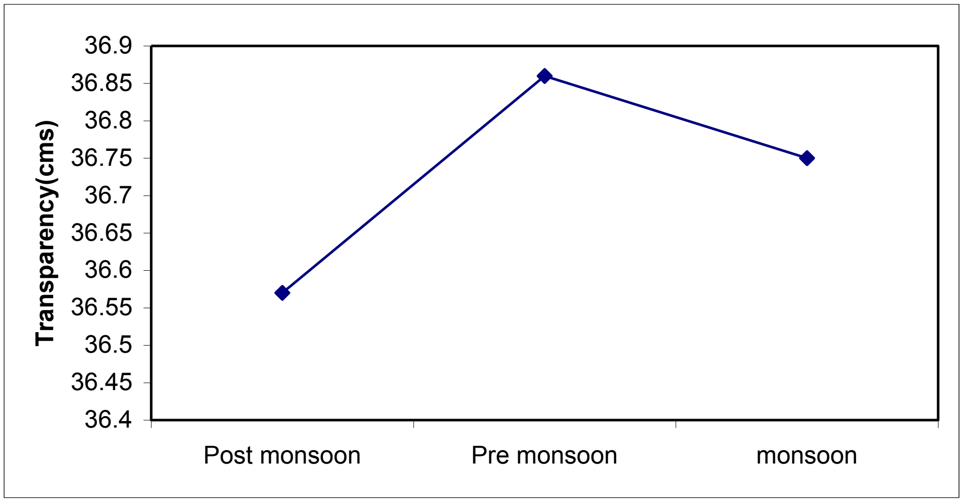


Fig. 51 Seasonal variation in transparency

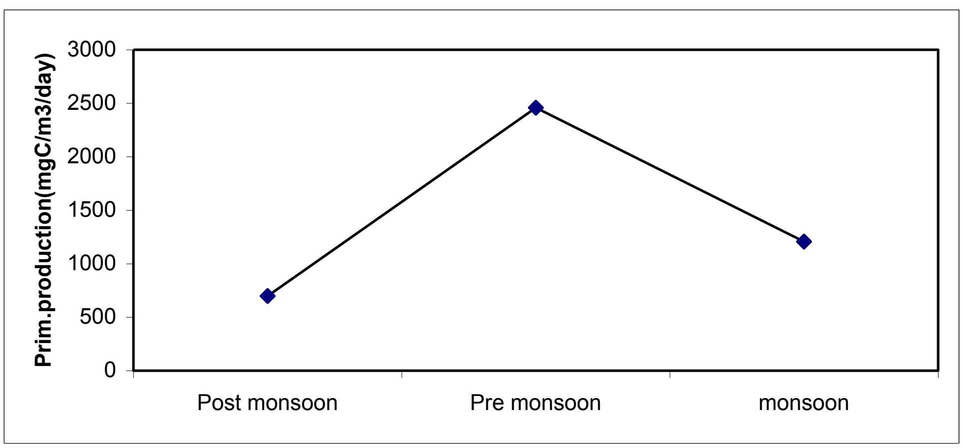


Fig. 52 Seasonal variation in primary productivity i

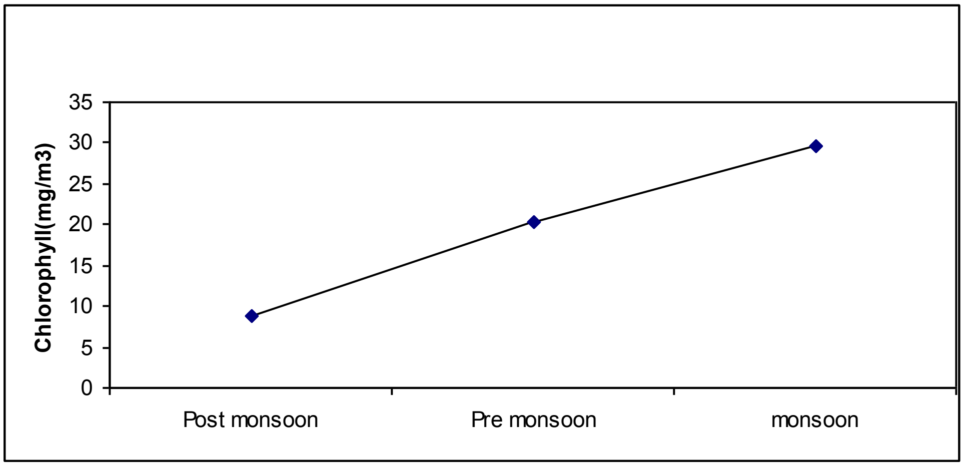


Fig. 53 Seasonal variation in chlorophyll

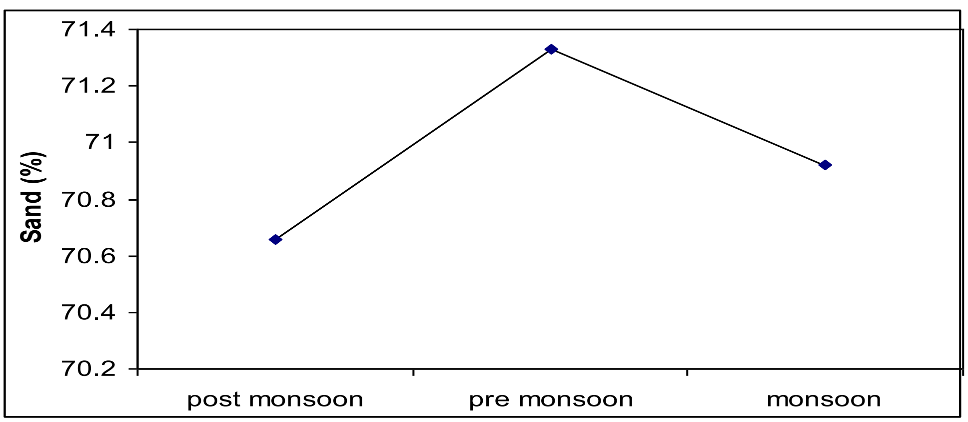


Fig. 54 Seasonal variation in sand

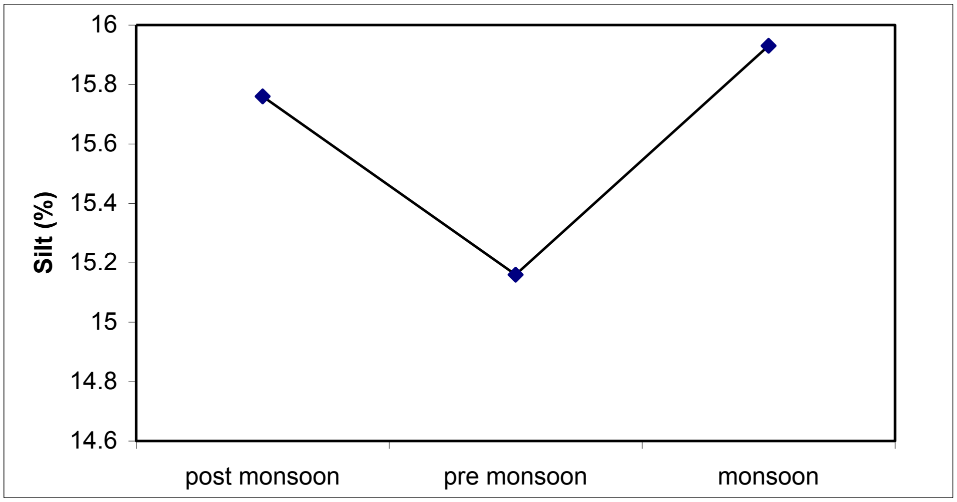


Fig. 55 Seasonal variation in silt

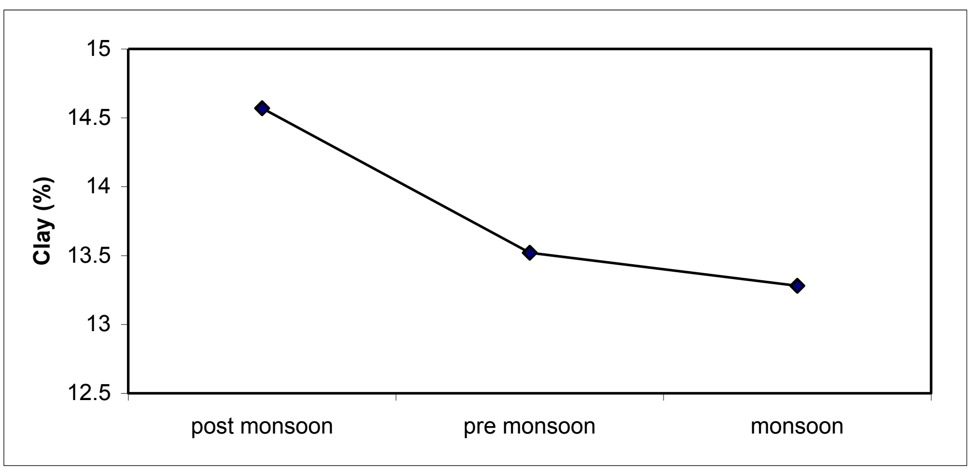


Fig. 56 Seasonal variation in clay

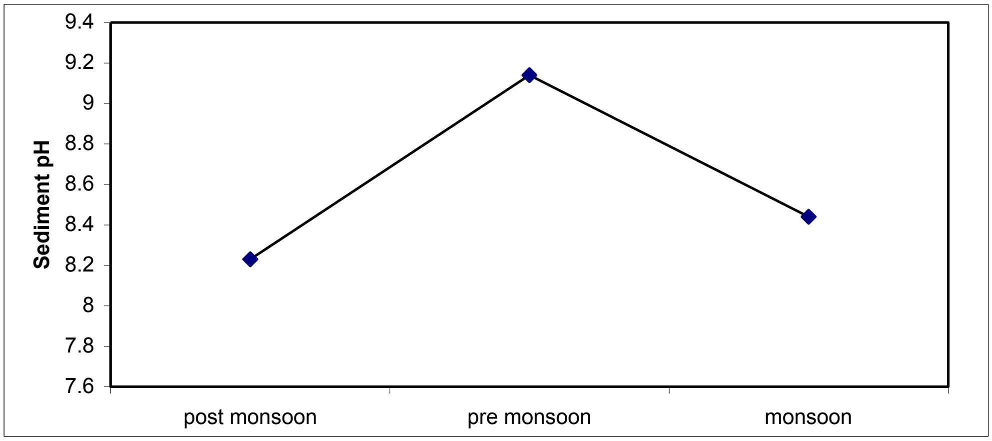


Fig. 57 Seasonal variation in sediment pH

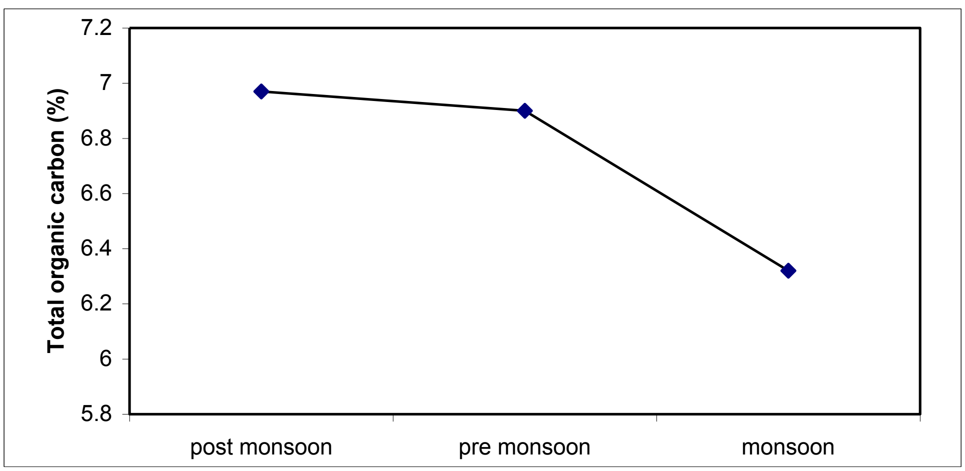


Fig. 58 Seasonal variation in total organic carbon

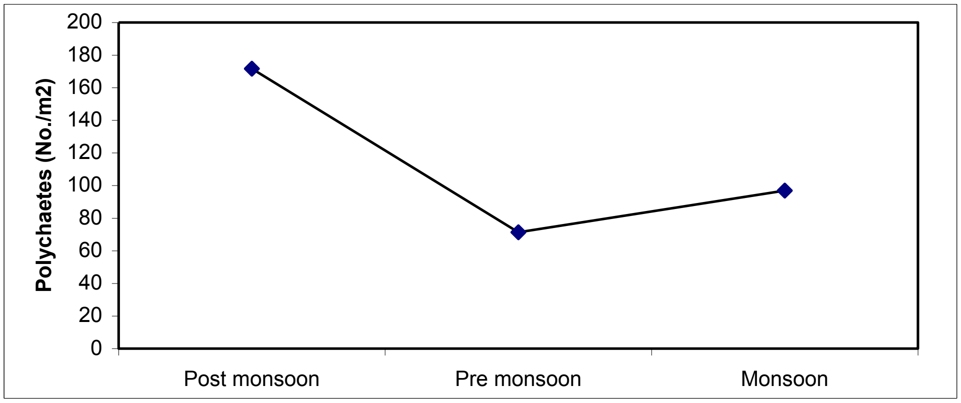


Fig. 59 Seasonal variation in polychaetes

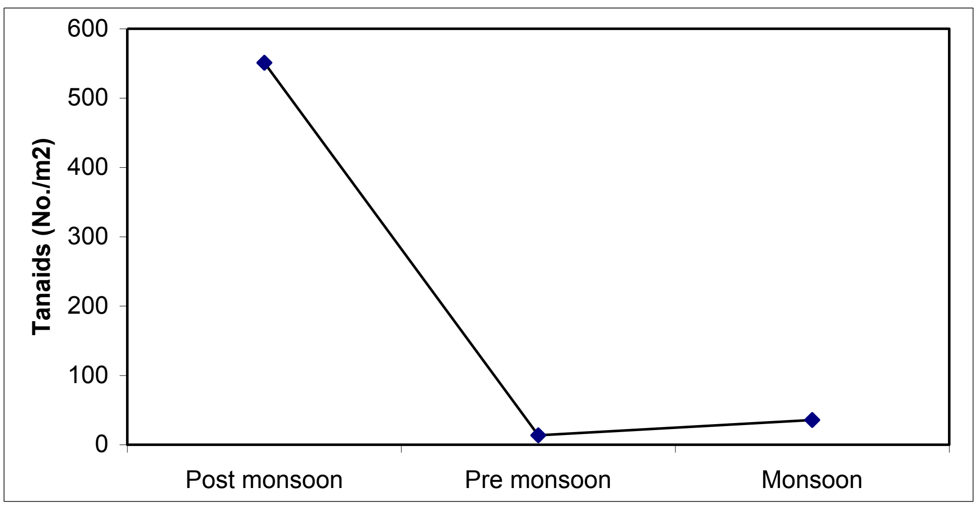


Fig. 60 Seasonal variation in tanaids

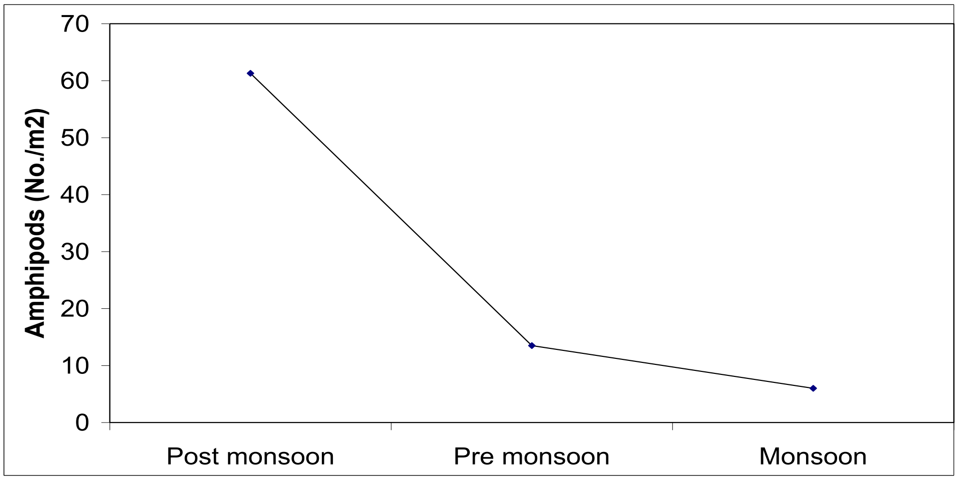


Fig. 61 Seasonal variation in amphipods

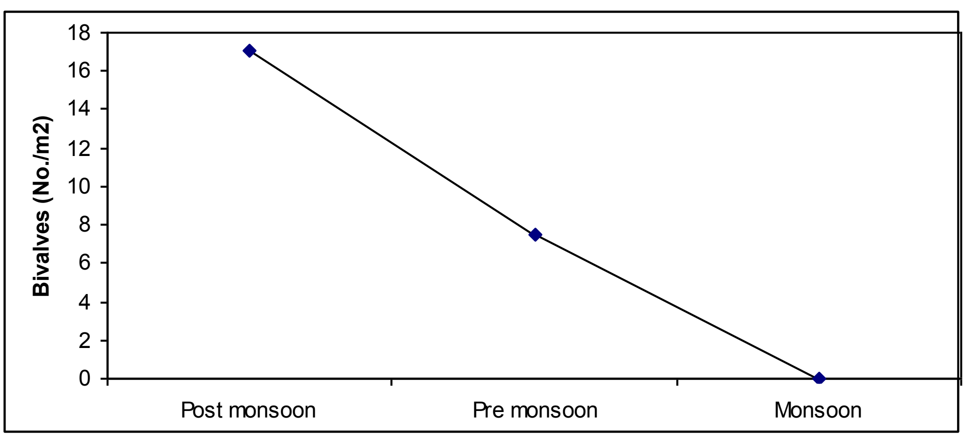


Fig. 62 Seasonal variation in bivalves

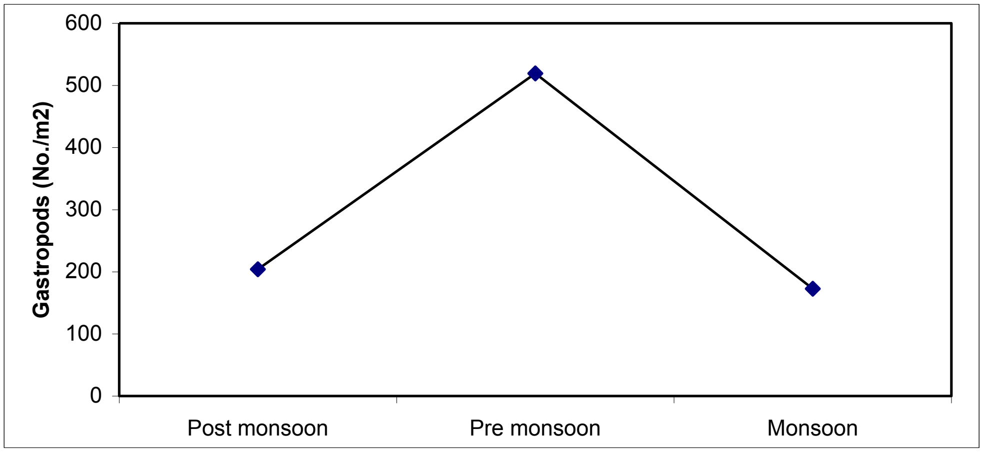


Fig. 63 Seasonal variation in gastropods

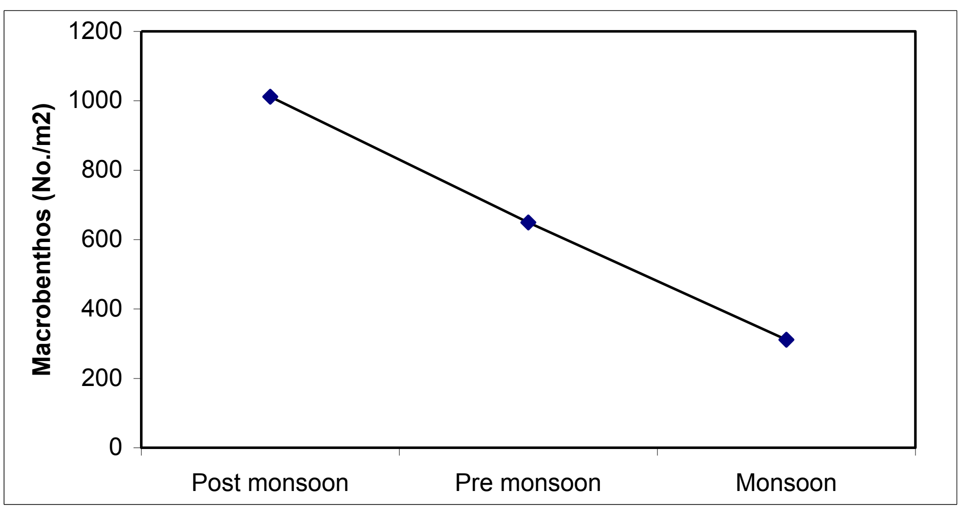
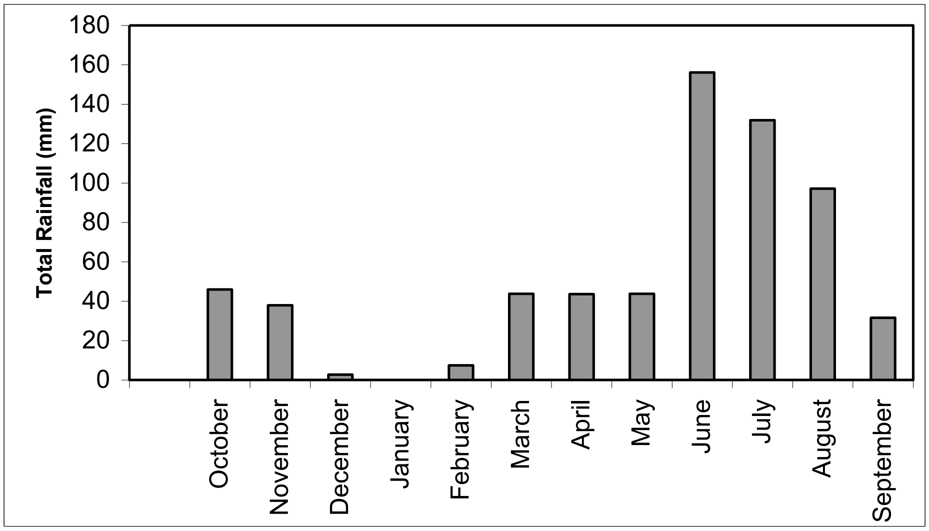
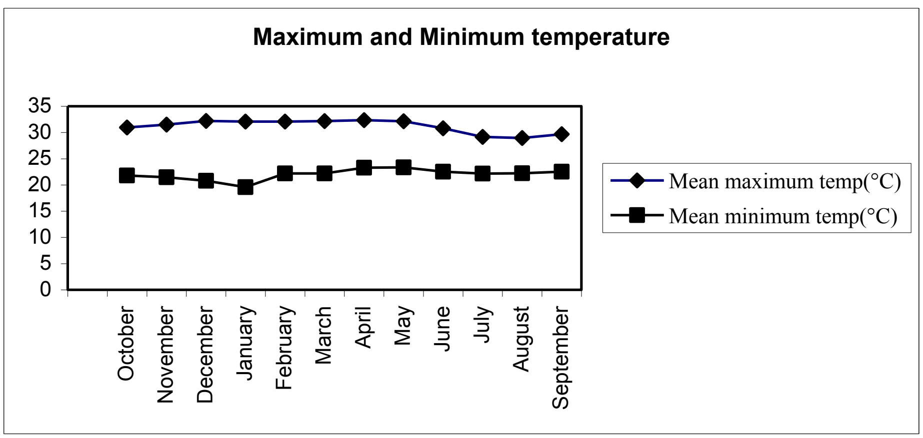
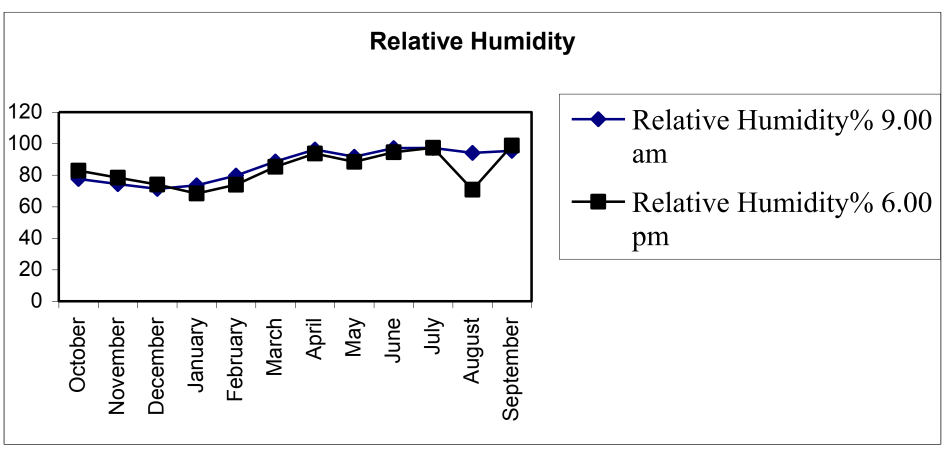


Fig. 64 Seasonal variation in total abundance of macrobenthos

Fig. 65 Monthly variation of meteorological parameters







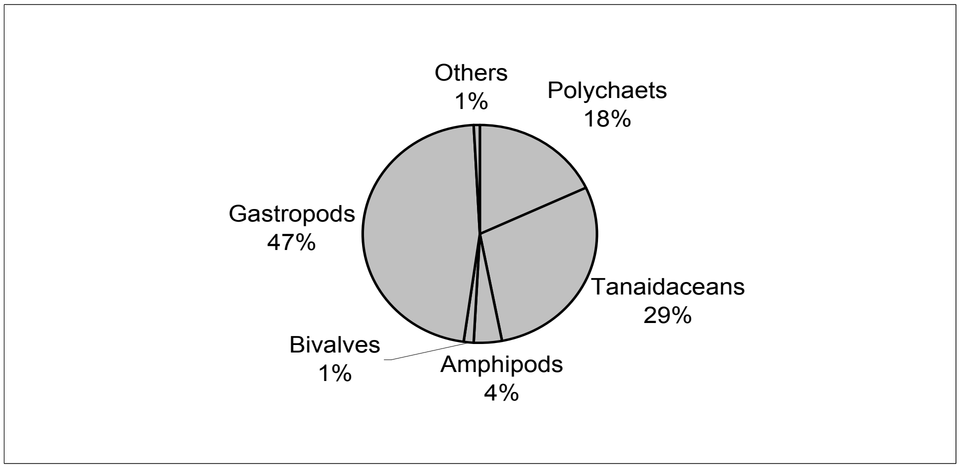


Fig 66 Percentage composition of various macrobenthic groups during the study period

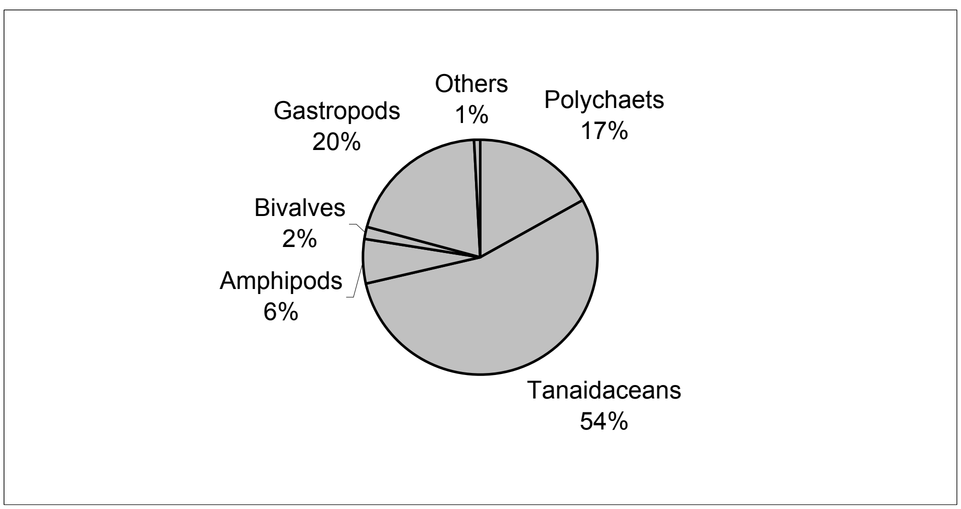


Fig 67 Percentage composition of various macrobenthic groups during Postmonsoon

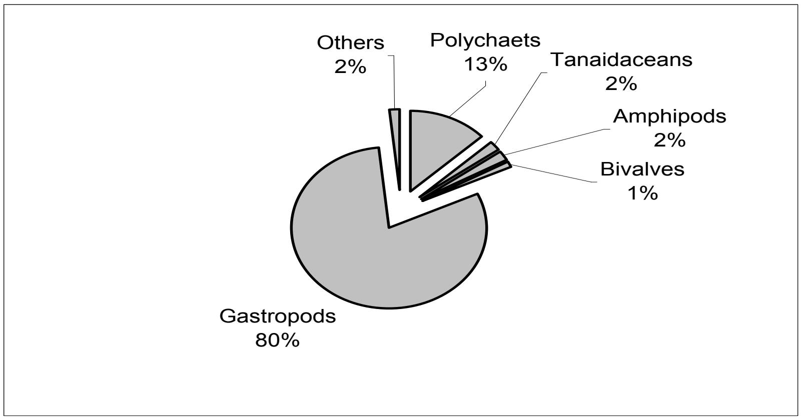


Fig 68 Percentage composition of various macrobenthic groups during premonsoon season

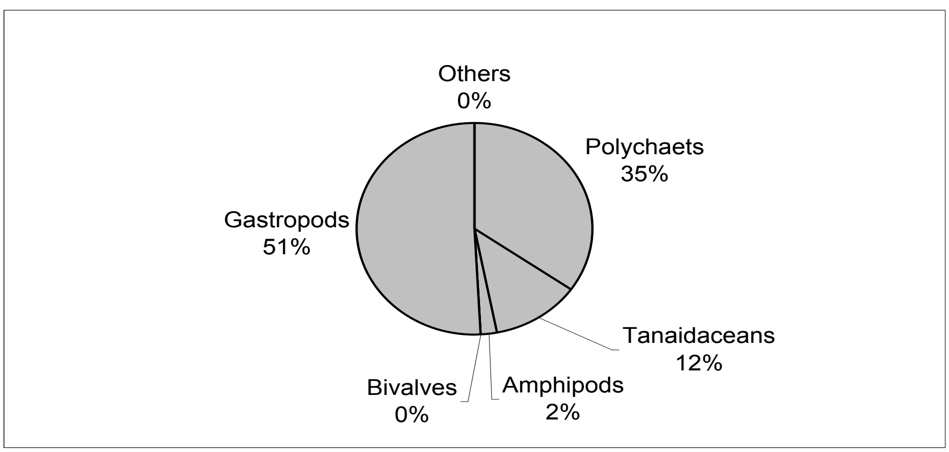


Fig 69 Percentage composition of various macrobenthic groups during monsoon season

Discussion

5. DISCUSSION

5.1 MACROBENTHOS

Benthic organisms constitute an important component in the food of the culturable varieties of prawn and finfish. So estimation of the average number and weight of benthic organisms is considered as one of the prerequisites for stocking a brackishwater pond (Mitra *et al*., 1992).

In the present investigation the macrobenthic groups obtained were gastropods, tanaids, polychaetes, amphipods and bivalves. There were a few other groups which were present in small numbers in some months or other, and these include penaeid prawns and cumaceans. These are grouped as 'others'.

Gastropods were the dominant group observed during the study period. It showed a maximum abundance of 1119 no. /m^2 during the second half of May, (Table1). Gastropods constituted 20%, 80%, and 51% of the total macrobenthos in the culture field during the postmonsoon, premonsoon and monsoon seasons respectively. (Fig. 67, 68 and 69). Average abundance of gastropods during the study period was 292 no. /m^2 (Table 1) which constituted 47% of the total macrobenthos (Fig. 66). In Cochin backwaters Desai (1971) found domination of molluscs in sand dominated sediments.

Tanaids were the second major group and constituted 54%, 2% and 12% of the macrobenthos during the postmonsoon, premonsoon and monsoon seasons respectively (Fig. 67, 68 and 69). It showed a maximum abundance of 1429 no. /m^2 during the first half of November (Table 1). Average abundance of tanaids during the study period was 184 no. /m^2 (Table 1) which constituted 29% (Fig.66).

The polychaetes constituted 17%, 13% and 35% during the postmonsoon, premonsoon and monsoon seasons respectively (Fig. 67, 68 and 69). It showed a maximum abundance of 227 no. /m^2 during the first half of September (Table 1).

Average abundance of polychaetes during the study period was 115 no. /m^2 (Table 1) which constituted 18% (Fig.66) of the total macrobenthos. Raman *et al.* (1975) and Datta and Sarangi (1980) observed the monsoon abundance of polychaetes in Pulicat Lake, Tamil Nadu and in a brackishwater bheri at Taldi, West Bengal, which are corroborated by the present observation.

In order to examine the influence of the hydrographic parameters on the total benthic fauna and the different groups, correlation values were calculated (Table 7). Tanaids showed a negative correlation with salinity and nitrite while polychaetes showed a positive correlation with phosphate and a negative correlation with nitrate. The present finding that postmonsoon season is the most productive period for macrobenthos abundance agrees with the findings of Joseph (1988), Sudheer (2003) and Anon (2004). The findings of Anon (2004) that the benthic groups obtained were polychaetes, molluscs and crustaceans from the Panangad region of Vembanad Lake agree with the present results. According to Ansari (1974) there was a decline in the density of benthos with the commencement of monsoon, which probably might be due to the fall in salinity. Desai and Krishnankutty (1967) also reported a marked decline of macrofauna during the southwest monsoon. It was indicated that because of constant water flow and relative shallowness, dissolved oxygen might not be a limiting factor for the bottom fauna (Kurian, 1975).

The nature of substratum could be another important factor influencing the abundance of bottom fauna. The bottom of the pond, where the study was carried out was muddysand in nature. The correlation coefficients between textural compositions of the sediments *viz.* sand, silt and clay and the total benthic abundance were worked out. The correlations between textural composition of the sediments and different benthic groups were also studied. Total abundance of benthos showed significant negative correlation with sand while positive correlation with clay. Individual groups like polychaetes, amphipods and bivalves showed significant positive correlation with sand while gastropods showed significant negative correlation. Polychaetes and bivalves showed significant negative correlation with silt while gastropods showed significant positive correlation. Total abundance of macrobenthos showed significant positive correlation with clay. Individual groups like polychaetes, tanaids and amphipods showed a significant negative correlation with clay. 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; Anon, 2004). Seasonal fluctuations in the characteristics of substratum have been found to influence the qualitative and quantitative composition of the benthic fauna in the backwater as well as in the culture field 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.

The effect of salinity on benthic macrofauna in the Cochin backwaters has been studied by Desai and Krishnankutty (1967), Kurian (1967), Ansari (1977) Pillai (1977) and. A decrease in bottom fauna probably due to the fall in salinity has been reported by Pillai (1977). He observed that recolonization of bottom fauna started during the beginning of the postmonsoon season reaching the maximum in the premonsoon season. Aravindakshan *et al.,* (1992) found that the benthic abundance is not supported by high salinity conditions in the prawn culture field 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. Sunilkumar (1998, 2002) has stated that the drastic change in salinity in the southwest monsoon does not affect the benthic productivity in the culture field. According to Datta and Sarangi (1986), polychaetes dominate in areas of relatively high salinity and low organic matter where as amphipods and tanaids are found more frequently in low saline zones having higher organic matter content. In the present study, tanaids which were the second major group showed their maximum abundance during the postmonsoon season when salinity was < 5ppt. During early premonsoon, when salinity was >30 ppt, they were totally absent. Polychaetes were present throughout the study period except during the first and second half of February which coincided with the maximum salinity. Hence, it can be seen that the results of the present investigation generally agree with the above observations.

pH showed seasonal variation in the culture field during the present study. The values were low during postmonsoon and high during the premonsoon. Statistical analysis of seasonal variation by t-test showed significant difference between postmonsoon and premonsoon seasons. There was a sudden drop in pH with the onset of monsoon. Though the correlation between the pH and benthic population was not statistically significant, an inverse relationship between them was observed. During the study period the highest pH was estimated in the second half of June which coincided with the lowest benthic abundance (Table 1, 2 and Fig. 23). 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 the culture field showed comparatively low oxygen values during the premonsoon and high values during the monsoon months (Fig. 6 & 30). Temperature and dissolved oxygen may not be limiting factors for benthos (Anon 2004). 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. Sudheer (2003) and Anon (2004) have reported that the correlation between the benthic population and the dissolved oxygen content was not statistically significant. The dissolved oxygen values did not indicate any correlation with the distribution of benthic fauna as reported in Arabian shelf waters by Parulekar and Wagh (1975), Sreeramamoorty and Sharma (1986). No correlation between abundance of benthic macrofauna with water temperature was observed. Similar condition was observed in

Cochin backwaters (Kurian, 1972), in Zuari and Mandovi estuaries (Parulekar and Dwivedi, 1975) and in Vembanad Lake (Kurian *et al*.,1975). Results of the present investigation are also agreeing with the above findings.

Anon (2004) reported that turbidity can affect the benthic organisms some times directly in case of heavy suspended load and indirectly by affecting primary production. The correlation between the benthic population and turbidity was not significant statistically but an inverse relationship was observed in the culture field (Fig.31). Similarly, a direct relationship has been noticed in the transparency and total benthic abundance (Fig. 32).

In the present study hardness was low during northeast monsoon and southwest monsoon and found not correlated with total benthic abundance (Fig. 25). Similarly alkalinity values were also not correlated with total benthic abundance (Fig. 24). Anon (2004) reported significant negative correlation between nutrients and benthic density at some stations of Panangad region of Vembanad lake. Polychaetes have shown a positive correlation with phosphate-P (r = 0.465**). Primary production as well as chlorophyll values were not correlated with total benthic abundance (Fig. 33 & 34). Sediment pH was not correlated with macrobenthic abundance (Fig. 35). Although benthic abundance was not correlated with total organic carbon statistically, higher benthic density coinciding with higher values of total organic carbon was observed during the postmonsoon season (Fig. 36). A positive correlation of organic carbon with faunal abundance was observed by Sanders (1956), Damodaran (1973) and Harkantra *et al*., (1980).

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 back waters. The present study reveals that macrobenthic population density in the prawn filtration field is controlled by several factors instead of a single factor and the nature of the substratum is the most important in this respect.

5.2 HYDROGRAPHICAL PARAMETERS

5.2.1 Salinity

Among the hydrographical parameters of the prawn filtration field salinity was highly variable during different months. (Table 1, Fig. 2, 40). Salinity ranged between 0.05‰ and 30.63‰. Salinity values were low (<2‰) during the southwest monsoon period and also during the second half of October, when the monsoons were active and fresh water flow predominated over the tidal flow. The salinity values started increasing in the premonsoon season and reached high values (>25‰) during the second half of January and in the first half of February. A considerable reduction in salinity was noticed during the late premonsoon due to premonsoon showers (Table 8, Fig. 65). The rainfall was 7.3 mm in February, 43.74 mm in March, 43.56 mm in April and 43.74 mm in May and these rains might be the reason for the decrease in salinity during the period.

Varma *et al.* (2002) on analysing long term daily variations at a station near Panangad Jetty noticed salinity range between 0‰ to 32‰. Similar values had been reported by Sankaranarayanan et *al.*, (1982), Joseph (1988) and Sudheer (2003) from the culture fields in Cochin. Present results are also in agreement with the above findings.

Salinity showed statistically significant negative correlation with dissolved oxygen (r= -0.556**). Statistically significant positive correlation of salinity with nitrite-N (r= 0.608**), hardness(r= 0.682**) alkalinity(r=0.723**), pH (r=0.652**) which indicates that the increase in salinity resulted in a corresponding increase in pH, alkalinity and hardness. This might be due to the increase in the amount of dissolved salts due to increase in salinity.

5.2.2 Water temperature

The higher values of water temperature were noted during the premonsoon which showed a declining trend with the onset of the monsoon (Table 2, Fig. 3, 41). The lowest temperature was measured during postmonsoon. Similar trend in temperature had 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 second half of January in the culture field. The low values observed during this period could be attributed to the winter effect. Similar values were reported by Sankaranarayanan *et al.* (1982) from the tidal ponds of Ramanthuruthu Island (Cochin). There was a gradual increase in temperature from first half of February and high values (>31°C) were measured from second half of April to first half of May. Silas and Pillai (1975) also observed same pattern, which they attributed to higher receipt of solar radiation and warm weather condition. 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 drop in temperature was noticed in the surface layers, concurrent with the freshwater influx.

Temperature showed statistically significant negative correlation with salinity (r= -0.537**) and positive correlation with turbidity (r= 0.381*), dissolved oxygen (r= 0.605**), primary productivity (r= 0.592**), chlorophyll (r= 0.477**) and sediment pH (r= 0.476**).

5.2.3 pH

In the prawn filtration field, high pH (>8) values were recorded during the late postmonsoon (second half of December to second half of January) and premonsoon period (February and May) with a slight drop in March and April. 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 premonsoon period and with the onset of the monsoon a sudden drop was noticed. The drop in pH in March and

April may be due to premonsoon showers (Fig. 65). Sankaranarayanan *et al.* (1982) and Nair *et al.* (1988) observed high pH values during premonsoon season in the tidal ponds of Ramanthuruthu Island, when salinity values were high. Low pH values were confined to the southwest monsoon season when the system was dominated by freshwater. Similar trend was observed during the present investigation also (Table 2; Fig. 4& 42).

Statistical analysis of seasonal variation by t-test showed no significant difference in postmonsoon and premonsoon. pH showed positive correlation with salinity (r= 0.652**), alkalinity (r= 0.800*), hardness (r= 0.464**), chlorophyll (r= 0.361**) and nitrite-N (r= 0.477**). It showed a negative correlation with nitrate-N (r= -0.573**) and total organic carbon (r= -0.415*). Sankaranarayanan *et al*., (1982) reported a positive correlation between pH and salinity.

5.2.4 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 higher values of alkalinity (>200 mg $CaCo_3$/l) were recorded during late postmonsoon and premonsoon from second half of December to first half of February and also during first and second half of May (Table 2, Fig. 5). Lower values of alkalinity (<100 mg $CaCO_3$/l) were recorded during the postmonsoon period from second half of October to second half of November. Alkalinity values in the monsoon months did not show much variation. Similar trend has been reported by Silas and Pillai (1975) from Cochin backwater.

Alkalinity showed a positive correlation with salinity (r= 0.723**), pH (r= 0.800**), hardness (r= 0.639**), nitrite-N (r= 0.399*) and chlorophyll (r= 0.449*). It showed a negative correlation with nitrate (r= -0.416*).

5.2.5 Hardness

Total hardness ranged between 19 and 796 mg $CaCO_3$/l and higher values were obtained during premonsoon. With the onset of monsoon a drastic reduction in hardness was noticed. Hardness showed positive correlation with salinity (r=0.682**), pH (0.464**) and alkalinity (r=0.639**). Hardness was not significantly correlated with benthos during the study period. The hardness was negatively correlated with nitrate-N(r=-0.575**) and dissolved oxygen (r=-0.466**). Seasonal study of hardness revealed that hardness was highest during postmonsoon and lowest during monsoon. (Table 4, Fig. 6 and 44).

5.2.6 Turbidity

Turbidity was highest during south west monsoon and lowest during postmonsoon (Table 4, Fig.12 and 50). Anon (2004) reported that turbidity showed clear seasonal variation and highest values were recorded during south west monsoon season. However In the present study t-test on seasonal variation between premonsoon and postmonsoon showed no significant difference. Higher values in turbidity during premonsoon season may be due to the higher amount of premonsoon showers obtained during the study period. The maximum turbidity during monsoon period might be due to runoff (Anon, 2004) and churning up of the bottom of the pond due to low depth.

5.2.7 Dissolved Oxygen

In the present investigation high dissolved oxygen values were estimated during monsoon period and low values were estimated during postmonsoon period from the culture field. (Table 2, Fig. 11 and 49). Haridas *et al.* (*1973*) and Pillai *et al.* (1975) reported high dissolved oxygen values during the monsoon period and low values during the postmonsoon and early premonsoon periods from the Cochin backwaters. Qasim *et al*. (1969) stated that the higher oxygen concentration during the period could be due to the higher primary production occurring in the surface layers. Dissolved oxygen was found positively correlated with primary production and negatively correlated with salinity in the present study. Results of the present investigation are also agreeable with the above findings.

5.2.8 Primary Production

Information on primary production is essential for assessing the fertility of aquatic system (Anon, 2004). Fortnightly variation of primary production (Table 2, Fig.32) in general showed four peak values. Maximum values were recorded during second half of October, first half of March, first half of May and second half of June. Maximum gross production was recorded during first half of May (3904 mg $C/m^3/hr$) while minimum (22.5 mg $C/m^3/hr$) was seen during first half of September. Qasim *et al. (1969),* Gopinathan *et al.* (1984) and Anon (2004) observed trimodal pattern in primary production from Cochin backwaters. It was also pointed out that primary production occurs in small pulses and without seasonal rhythm.

For the entire Vembanad Lake considerable seasonal variation in primary production with postmonsoon season as the peak period (maximum of 125mg $C/m^3/hr$) and comparatively lesser rates during the monsoon period was reported by Kunjukrishna Pillai *et al.* (1975). On the other hand, Qasim *et al.*(1974), Nair *et al.*(1975) and Gopinathan *et al.*(1984) reported high production during monsoon and early postmonsoon periods when salinity was low or moderate in Cochin backwaters. Hence it can be seen that generally the present findings are in agreement with the above findings.

Anon (2004) reported that primary production in the Panangad area of Vembanad Lake is found to be higher than that reported for coastal areas and other estuaries in India and is therefore highly fertile compared to many other aquatic systems.

Nutrients, light, temperature and species composition are the main factors influencing the phytoplankton productivity (Smith,1980) in the present study primary production was found correlated with dissolved oxygen, temperature, chlorophyll and sediment pH.

5.2.9 Chlorophyll-a

Chlorophyll is probably the most often used estimator of algal biomass and hence its measurement is an alternative approach for the estimation of primary production (Anon, 2004). In the present study chlorophyll-a ranged between 3.30mg/m^3 and 62.70 mg/m^3. Higher values were observed during late premonsoon and monsoon periods where as lower values were observed during late monsoon and early postmonsoon periods. Chlorophyll-a was found positively correlated with temperature (r= 0.477**), pH(r=0.361*), alkalinity (r=0.449*), primary production(r=0.692**) and sediment pH(r= 0.574**) Anon (2004) correlated primary production with chlorophyll-a at 1% level (r=.6). In the present study also chlorophyll-a was found correlated with primary production at 1% level(r=.692). The lower value of correlation indicates the factors like grazing etc. leading to loss of standing crop.

5.2.10 Nutrients

5.2.10.1 Phosphate-P

In the present study phosphate-P ranged between 16.3 µg at/l and 3.05µg at/l. High values were recorded during monsoon months while very low values were recorded during early post monsoon and pre monsoon periods. Phosphate-p was positively correlated with silicate-Si(r=.394*). No significant difference in phosphate-P was found between premonsoon and postmonsoon periods on t-test. High values (>10µg at/l) were recorded during first half January, first half of August and second half of September suggesting a trimodal pattern.

Manikoth and Salih (1974) observed that phosphate-P exhibited marked seasonal fluctuation. According to them, phosphate-P ranged between 0.85 and 5.4 µg at/l, in the Vembanad Lake with highest values in monsoon season. In the present study also high values are recorded during monsoon periods, which may be due to the maximum influx of fresh water. High value of phosphate –P estimated during first half January might be due to decomposition of organic matter as reported by Reddy (1982) in Nethravathi-Gurpur estuary.

5.2.10.2 Nitrate-N

Like phosphate-P, nitrate-N also did not show any significant difference between postmonsoon and premonsoon on t-test. High values were observed during early postmonsoon and late monsoon periods when fresh water condition prevailed and low values during premonsoon months. Values of nitrate-N ranged between 12.12 µ at/l and 3µg at/l. Haridevi *et al.* (2003) reported high monthly fluctuations in nitrate concentration in Panangad region of Vembanad Lake. The range was between 0.1 and 21.3 µmol/l. High values were reported during monsoon and low values during premonsoon. 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. The above findings are in agreement with the present study.

5.2.10.3 Nitrite-N

In the present investigation high values were observed during premonsoon and late monsoon period. The values ranged between 0.4µ at/l and 3.01µ at/l. Anon 2004 reported a similar increase in the Panangad area of Vembanad Lake. Regarding the seasonal fluctuations of nitrite-N, various workers have reported different types of oscillations in the monthly values at various localities. Sankaranarayanan and Qasim (1969) have reported a trimodal oscillation in the Cochin backwaters, while Sahu (1981) reported a bimodal oscillation in the Nethravathi-Gurpur estuary. Manikoth and Salih (1974) reported four dominant peaks in Cochin backwaters. Gupta *et al.* (1980) recorded a dominant premonsoon peak in the Nethravathi-Gurpur estuary.

In the present study one peak was observed during premonsoon (second half of February) and another peak during late monsoon (second half of September). In general, the nitrite-N, concentrations were much lesser in comparison to the values of nitrate-N, because nitrate-N is a transitory stage in the nitrogen cycle of the system. Nitrate-N was positively correlated with salinity , pH, alkalinity and hardness during the study period.

5.2.10.4 Silicate-Si

In the present investigation the seasonal fluctuation of silicate-S exhibited a bi-model oscillation with primary maximum during second half of September and secondary one during first half of January. The primary and secondary minima occurred during second half of October and first half of March respectively. The values of silicate-Si ranged between 134.2µ at/l and 4.81µ at/l. Analysis of seasonal variation by t-test showed. No significant difference between postmonsoon and premonsoon.

Earlier workers have reported an inverse relation between silicate concentration and salinity in the estuarine and coastal waters along the east and west coast of India (Pai, 1980; Sahu, 1981; Anon, 2004). In the contrast to these observations, high values of silicate were found to be corresponding to high salinities by Manoj Kumar in Malpe estuary (1988). In the present study also the inverse relation between salinity and silicate was not found.

5.2.11 Transparency

Factors affecting transparency of the water in the pond are silt, planktonic organism and suspended organic matter (Mc Combie, 1953). In pond, turbidity from planktonic organism in often desirable to a certain extent where as that caused by suspended clay particle is generally undesirable Boyd *et al* (1978) had observed that almost all problems related to dissolved oxygen in culture ponds were 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 visibilities decreases below 20 cm. In the present investigation, Secchi disc readings were within the range of 30 and 46 cm. Higher readings were recorded during monsoon, which could be attributed to low plankton production. Low values were observed during post monsoon and premonsoon months, which may be due to the increase in plankton bloom. Parameswaran *et al* (1971) and Das (2004) have recorded similar type of results from fresh water pond in Assam and brackish water pond in Cochin respectively.

5.3 SEDIMENTARY CHARACTERISTICS

5.3.1 Total Organic Carbon

Estimation of organic carbon in the soil would serve as an important indicator in determining the availability of detritus as food for the benthic fauna as well as for bottom feeding fishes and prawns. Bader (1954), while studying the abundance of bivalves in relation to percentage organic carbon, has observed a decrease in population at a level of above 3% organic carbon. He pointed out that beyond this level, products of bacterial decomposition resulting in a decline of the available oxygen become limiting factor. Kurian (1967) suggested that high productivity of benthos in the estuary may be due to high percentage of organic carbon content.

The present study total organic carbon values ranged between 4.75% and 9.15%. There was no significance difference between postmonsoon and premonsoon in total organic carbon content on t- test. It showed a positive correlation with benthos though not statically significant. It showed statically significant positive correlation with nitrate while negative correlations with pH and nitrate.

Renjith (2006) reported a range between 0.06% and 3.5% in the Panangad region of Vembanad Lake and found that percentage of organic carbon to total carbon did not show any seasonal trend. In the present study also no seasonal trend was noticed.

5.3.2 Soil texture

The nature of the bottom soil studied during the course of the present investigation showed that the substratum generally represented a combination of sand, silk and clay. The composition of the sediment showed no seasonal variation (fig.). By applying folk's (1974) classification, sub stratum of the present study area was identified as muddy sand. The nature of the substratum of the bottom soil studied during the course of present study showed that it contains on an average sand (70.97%), silt (15.61%) and clay (13.79%) in which sand is the dominant component.

The present observation that sand is the dominant component of the sub stratum of the prawn filtration pond and seasonal variations were minimal agree with the findings of Joseph(1998) and Sudheer(2003) based on their study in some prawn culture fields of Panangad region.

5.3.3 Sediment pH

pH of the interstitial water of the sediments or the pore water has been considered as an important factor in the study of sediments since it is known to control the chemical characteristics of the pore water. Further, pH is known to control and is controlled by both biogenic and abiogenic reactions. In the present study, sediment pH varied between 7.58 and 9.78. Generally minimum values of pH were observed during postmonsoon season. This is as expected since the pH is known to increase with salinity. Similar findings were reported by Manojkumar (1988) in the Malpe estuary. Statistical analysis of seasonal variation by t-test showed significant difference between postmonsoon and premonsoon.

Summary

6. SUMMARY

1. The present study was carried out to find out the seasonal variations in macrobenthos of a brackishwater prawn culture field adjacent to the Vembanad Lake and to correlate them with the variations in hydrographical conditions and sedimentary characteristics of the pond.
2. Fortnightly samples for hydrographical and biological studies were collected during the period from October 2007 to September 2008. Hydrographical factors like temperature, salinity, turbidity, pH, transparency, total alkalinity, hardness, dissolved oxygen, primary production, chlorophyll-a and transparency. Bottom samples for macrobenthos and sedimentary characteristics were taken using a Van Veen grab.
3. To study the relationship between macrobenthos, different hydrographic parameters and sedimentary characteristics, linear correlation coefficients (r) were worked out.
4. In the prawn filtration field, water temperature showed peak values during premonsoon period and with the onset of monsoon the values decreased. Lowest value was recorded in postmonsoon season.
5. Salinity showed wide variations and ranged between 0.05‰ and 30.63‰ in the prawn filtration field. A sudden drop in salinity was observed during March and May due to premonsoon showers.
6. High pH (>8) values were observed during late postmonsoon (second half of December to second half of January) and premonsoon period (February and May). With the onset of monsoon, the pH values decreased.
7. High values of alkalinity (>200 mg Ca CO_3 /l) were recorded during late postmonsoon and premonsoon. Low values (<100 mg Ca CO_3 /l) were recorded during early postmonsoon period.

8. Hardness showed high values during premonsoon period. With the onset of monsoon, the drastic reduction in hardness was noticed. Low values were recorded during early postmonsoon and late monsoon periods.
9. Turbidity was highest during southwest monsoon and lowest during postmonsoon. High values were also noted during premonsoon period when there were considerable premonsoon showers.
10. Dissolved oxygen showed high values during monsoon and low values during postmonsoon. Conspicuous quantities of fresh water with relatively low temperature might be the reason for higher values during monsoon and consequent increase in temperature can be the reason for the low values during postmonsoon. Dissolved oxygen was found negatively correlated with salinity and positively correlated with primary production.
11. Primary production showed four peak values. Maximum values were recorded during second half of October, first half of March, first half of May and second half of June. Primary production was found positively correlated with dissolved oxygen, water temperature, chlorophyll and sediment pH.
12. Chlorophyll-a ranged between 3.30 mg/m^3 and 62.70 mg/m^3. High values were observed during monsoon and late premonsoon whereas low values were observed during late monsoon and early postmonsoon period.
13. Phosphate-P ranged between 16.3 µg at/l and 3.05 µg at/l .High values (>10µg at/l) where recorded during first half of January, first half of August and second half of September suggesting a trimodal pattern. Phosphate-P was positively correlated with Silicate-Si.
14. High values of Nitrate-N were observed during early postmonsoon and late monsoon periods when fresh water condition prevailed and low values during premonsoon months.
15. High values of Nitrite-N were observed during premonsoon and late monsoon period. Lowest value was recorded during second half of October.

16. Seasonal fluctuation of Silicate-Si exhibited a bimodal oscillation with primary maximum during second half of September and primary minimum during second half of October.
17. Total organic carbon of the sediment in the prawn filtration pond ranged between 4.75% and 9.15%. Total organic carbon did not show any seasonal variation during the study period.
18. Substratum of the pond bottom was identified as muddy sand. Substratum contained mainly sand and did not show seasonal variation during the study period.
19. Very high (>9) values of sediment pH were observed during late premonsoon period and low values (<8) were estimated during early postmonsoon period.
20. Gastropods, tanaids, polychaetes, amphipods and bivalves were the benthic groups obtained during the present investigation.
21. Gastropods were the dominant group observed during the study period and constituted 80% and 51% of total macrobenthos during premonsoon and monsoon respectively. Gastropods showed positive correlation with clay.
22. Tanaids were the second major group. They were the dominant group during postmonsoon period, forming 54% of the total macrobenthos.
23. Polychaetes were the third major group. They constituted 35% of the total macrobenthos during monsoon season and they were the second maximum during that period.

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STRUCTURE AND THE SEASONAL CHANGES OF THE MACROBENTHIC COMMUNITY IN RELATION TO THE HYDROGRAPHY OF A PRAWN FILTRATION POND

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ABSTRACT OF THE THESIS

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ABSTRACT

Present study was carried out in the prawn filtration pond of the College of Fisheries adjacent to Cochin backwater to find out the seasonal variation of macrobenthos and to correlate them with the seasonal variation in hydrographical parameters and sedimentary characteristics of the pond. Fortnightly samples for hydrographical parameters, sedimentary characteristics and biological studies were collected during the period from October 2007 to September 2008. Hydrographical parameters like salinity, water temperature, turbidity, pH, total alkalinity, hardness, nutrients, dissolved oxygen, primary production, chlorophyll – a and transparency were observed.

Polychaetes, tanaids, amphipods, bivalves and gastropods were the benthic groups obtained. Prawn juveniles and cumaceans encountered very rarely, during the study period were grouped as 'others'. Among these gastropods, tanaids and polychaetes were the dominant forms. In the culture field, benthic populations were maximum during post monsoon months and showed a decreasing trend during pre monsoon and with the onset of monsoon it further decreased. Gastropods were the most dominant group observed during pre monsoon, forming 80% of total macrobenthos. Tanaids were the second major group and they were the dominant group during the post monsoon period forming 54% of total macrobenthos. Polychaetes were the third major group and constituted 35% of total macrobenthos during monsoon season and they were the second maximum during that period. In the culture field benthic abundance was found to be mainly influenced by substratum characteristics. Among the different hydrographical parameters studied for seasonal variation, water temperature, pH, primary production and chlorophyll were found to be significantly different. Among the sedimentary characteristics studied for seasonal variation, sediment pH was found to be significantly different.