DISTRIBUTION OF BENTHIC INFAUNA IN THE COCHIN BACKWATERS IN RELATION TO ENVIRONMENTAL PARAMETERS

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By

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DECEMBER, 2000

DECLARATION

I hereby declare that this thesis entitled "**Distribution of benthic infauna in the Cochin backwaters in relation to environmental parameters**" is an authentic record of the research work carried out by me, in the Regional Centre of National Institute of Oceanography, Kochi-14, under the supervision of Dr.(Mrs.) K. Saraladevi, Scientist, National Institute of Oceanography, Regional Centre, Kochi-14 in partial fulfillment of the requirement for the Ph.D degree of the Cochin University of Science and Technology and that no part thereof has been previously formed the basis for the award of any degree, diploma or associateship in any University.

Sheeba

Kochi – 682 014 (SHEEBA. P)
December 2000.

CERTIFICATE

This is to certify that this thesis entitled "**Distribution of benthic infauna in the Cochin backwaters in relation to environmental parameters**" is an authentic record of the research work carried out by Smt. Sheeba. P, under my supervision and guidance in the Regional Centre of National Institute of Oceanography (Council of Scientific and Industrial Research), Kochi-14 and that no part thereof has been previously formed the basis for the award of any other degree, diploma or associateship in any University.

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CONTENTS

CHAPTER 1

INTRODUCTION

1.1 ESTUARINE ENVIRONMENT

An estuary has been defined as "a body of water in which the river water mixes with and measurably dilutes the sea waters" (Ketchum, 1951). Emery and Stevenson (1957) described it as the mouth of a river or an arm of the sea where the tides meet the river currents. Pritchard (1967) defined estuary as "a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage". They, by these definitions form natural mixing areas between marine and fresh water zones. Estuaries are generally regarded as one of the most productive aquatic systems and the nutrient supply through fresh water input is important in sustaining their high rate of primary production. Estuaries also function as important sinks and transformers of nutrients, thus altering the quantity and quality of nutrients transported from land to the sea. On an aerial basis of any class of ecosystems, estuaries receive some of the highest inputs of nutrients because of the local influences and from land drainage. Estuaries are important areas of human use for fisheries, transportation, aquaculture and recreational pursuits. Thus by virtue of their natural location and easy accessibility estuaries are more amenable to anthropogenic influences. Moreover many animals spend their life in estuaries either partially or wholly.

In Kerala there are 41 rivers flowing towards west and draining into the Arabian Sea through the backwaters. Major rivers of Kerala namely Chaliyar, Bharathapuzha, Chalakkudypuzha, Periyar, Pampa, Muvattupuzha, Kallada and Achankovil together carry an estimated discharge of 45060 X 10^6 m^3 of water annually into Arabian Sea. (Anonymous, 1974).

It has been estimated that 5 X 10^5 m^3 of trade effluents are being dumped into the rivers of the State every day (Joysing, 1976). Indiscriminate discharge of industrial effluents with high BOD, toxic chemicals and suspended solids has progressively been rendering many rivers unsuitable for fishing and recreation uses. In Kerala, 85% of the people depend directly on water from rivers, ponds and wells for their daily requirements.

Industrial development along with support facilities and associated township developments also place demands on natural sources of supply of water. Hence the location of any chemical industry need to be selected ensuring on the availability of reasonably good water for the process and the facilities for discharging waste into surface waters without impairing other utilities.

The Cochin backwaters including Vembanad Lake, occupy an area of about 256 square kilometers. The area is about 96 km long and 3-4 km wide on an average. It extends from about 9°30' to 10°20' lat N and 76°13' to 76°50' long E. The backwaters occupy an alluvial plain lying parallel to the coast between the Arabian Sea to the west and the Western Ghats to the east in Peninsular India. The complex system has two perennial openings to the sea, at Crangannore in the north and at Cochin in the south. The one at Thottappally, south of Alleppey is open only during the southwest monsoon and is also regulated by a spill way across the mouth of the estuary. Many rivers and rivulets discharge into the system. The average tidal range at Cochin is about one meter.

The Cochin backwaters constitute a vast estuary, under the monsoonal regime, flushed by rains and runoff from land during monsoon. After the rainy season, the intrusion of seawater into the estuary can be traced upto 15-20 km upstream during the inter-monsoon period. Progressing upstream, the seawater gradually loses its identity by admixture with freshwater from land run off.

Seasons tend to telescope into each other in intensity and duration since monsoons are variable. Thus the south west coast estuaries present themselves as highly variable environments. Despite these characteristics, however, estuaries are hospitable to those benthic species, which are able to cope with the environment. The water characteristics within estuaries change continuously under the influence of tidal forcing, land runoff and winds in some cases. Owing to the heterogeneous nature of estuarine waters the benthic animals have to endure a wide range of environmental changes when the circulation carries different kinds of water over their site or burrow (Stone and Reish, 1965). A common feature of many estuaries is a turbidity cloud or mud section. The benthic animals are often confronted with changes of the sediment in or upon which they live.

With an increase in depth in the estuarine sediments, the oxygen usually decreases, and the deeper sediment layers are characterized by low redox potentials and high amounts of hydrogen sulphide. In this sulphide system no macrobenthic animals occur without contact with the overlying water but meio and microfaunal species live there in fairly large numbers (Fenchel and Riedl, 1970). In many estuaries the preponderence of fine particles in the sediments and the high contents of organic matter make this sulphide system an important part of the estuarine habitat.

Estuaries also offer some positive advantages for benthic animals. Compared to the open coast, estuaries are relatively sheltered against wind, waves and ocean swell. Most estuaries are also rich in allochthonous material provided by river input, those from salt marshes, mangroves or from the coastal sea, augmented by high primary production within the system. Often combinations of these factors prevail. Because of the shallow depth of most estuaries, suspended food particles are readily available for benthic animals through sinking as well as through downward transport by turbulent water movements (Wolff *et al*, 1976 a). Estuarine and coastal waters are rich in nutrients, and hence phytoplankton productivity is high in estuaries when turbidity is low. On the other hand, in turbid estuaries, eventhough there are sufficient nutrients, lack of sufficient amount of light restricts primary production. In the Cochin backwaters, the estimated annual consumption of primary production by the zooplankton herbivores is approximately 25 per cent of the total production. The unconsumed basic food supports a detritus food chain. The estuarine phytoplankton production is also supplemented by the productivity of other systems such as marsh grasses, weeds and others such as mangroves (Nair and Thampy, 1980). Qasim *et al.* (1969), estimated that the gross production ranges from 273-293 gC/m^2 /year with an average of 280 gC/m^2 /year, while the net production is 184-202 gC/m^2 /year with an annual consumption by zooplankton herbivores of 30 gC/m^2 leaving a large surplus of basic food in the estuary. Inspite of seasonal and spatial variations the estimated annual gross production for the entire Vembanad lake comprising about 300 km^2 is about 1,00,000 tones of carbon (Nair *et al.*, 1975), indicating that availability of food is unlikely to be limiting to benthic communities.

The level of primary production is increasing from the open sea towards the coast and is maximum in the coastal waters. The estimated gross production within the 50 m depth contour is 434 gC/m^2 /year (James *et al.* 1983). Nair & Pillai (1983) found that three main ecological factors namely salinity, light and nutrients govern the rate of productivity in this ecosystem.

Madhupratap *et al.* (1977), estimated the secondary production of the Cochin backwaters and compared it with the reported values of primary and tertiary production from the area. Zooplankton biomass (dry weight) in the Cochin estuary ranged from 0.7 to 384.0 mg/m^3. The average zooplankton production was estimated to be 31.8 mg dry wt./m^3/day (11.6g/m^3/year). The deeper regions of the backwaters showed higher secondary production (52.5 mg/m^3/day) than the shallow reaches at the head (14.0 mg/m^3/day) and between Cochin and Azhikode (9.1 mg/m^3/day). The ratio of secondary production to primary production at the lower reaches (Cochin to Aroor) was found to be 12.5% which closely matches Cushing's (1971) average transfer coefficient (12.4%) from primary to secondary level from the major upwelling areas of the world. A conversion factor of 0.075 g dry weight/ml displacement volume (Madhupratap & Haridas, 1990) was used to estimate the dry weight of mesozooplankton and 34.2% of it was considered for carbon estimation (Madhupratap *et al.*, 1981).

Productivity of benthos is related to the primary production of the overlying water column (Lie, 1968). In Mandovi and Zuari estuarine system of Goa the annual primary production is 205g/C/m^2/year (Bhattathiri, personal communication), while the zooplankton production is reported to be 7.81 g/C/m^2/year (Goswami, 1979). Observed macrobenthic-standing stock is 4.08 g/C/m^2/year, which is mainly derived from organisms like polychaetes and bivalves. Sanders (1956) suggest annual production to be about twice the standing stock and therefore, the estimated biomass production will be about 8.16 g/C/m^2/year (Parulekar *et al*, 1980).

Mean figure for tertiary production, taking 1% of primary production and 10% of secondary production (Cushing, 1971 & 1973) and raising their-carbon values by the factor 7.41 to obtain wet weight for fish (Vinagradov, 1953) is approximately 2400 tonnes. Accordingly the catches of plankton-eating fishes from the Cochin backwaters were about 1470 to 2640 tonnes (Madhupratap *et al.*, 1977). Most of the estuarine fishes are omnivorous and the common estuarine fishes like *Mugil* can feed at different trophic levels (Odum, 1971).

Apart from primary food, part of the secondary production also contributes to the detritus ecology of the system. Any estimate of fish production from plankton alone, without considering detritus will be an underestimate (Qasim & Sankaranarayanan, 1972). In fact organic detritus plays an important role in the food chain of the backwaters. This is evident from the higher percentage of prawns in the composition of annual fish landings and fairly high harvest of clams (88,000 tonnes of live and 1,70,000 tonnes of dead shells annually (George & Sebastian, 1970). Detritus in the estuary is derived from other sources such as land drainage; waste dumped into it, faecal pellets of the inhabitants and the decay of large quantities of the weed *Salvinia* brought into it during the monsoons. The availability of large quantities of detritus and phytoplankton thus provide ample scope for the expansion of culture fishery of prawns, mussels and oysters in the estuary.

1.2 BENTHOS

1.2.1 Definition and types of benthos

The term benthos refers to those organisms, which live on or in the bottom of any body of water (Bostwick, 1983). Phytobenthos is the collective name for all plants among the benthos, such as the diatoms, macroalgae and higher plants. Zoobenthos comprises of all animals occupying the bottom habitat. Those found on hard substrates, such as rocks, wood and shells are very different from those of the soft sediments such as sand and mud. Both types of substrata are occupied by species, which live upon the surface of the bottom sediments – the epifauna, in soft sediment; there is the infauna, the species living within the bottom. Benthic animals are divided into three categories according to size (1) macrobenthos (2) meiobenthos and (3) microbentos (Mare, 1942). This distinction of benthos into three size groups is arbitrary and varies according to the workers and according to the type of substratum occupied by the community. The lower size limit of macrobenthos depends upon the mesh size of the finest sieve used and usually varies between 0.5 and 3.0mm according to different workers. The upper limit of meiobenthos depends upon the mesh size of the sieve used for separating macrobenthos from meiobenthos. This generally falls between 0.5 and 1.0 mm. In most of the meiobenthos investigations it necessary to have a lower size limit to eliminate the fine sediment in the process of extraction of organisms. This lower limit is between 0.04 and 0.1 mm (McIntyre, 1969).

1.2.2 Adaptations to estuarine environment

The adaptations of estuarine benthos should be viewed as morphological responses to physiological stresses. This postulate is supported by the high percentage of anomalies in low salinities (Muus, 1967). Physiological adaptations to the estuarine environment are widespread among benthic animals. The major adaptations are in the regulation of the osmotic and ionic composition of the body fluids, and survival under conditions of reduced oxygen.

Estuarine benthic animals make many behavioural adaptations to their environment. Burrying behaviour is wide spread, although it is not limited to estuaries. Sanders *et al.*, (1965) demonstrated that infaunal species survived in interstitial water but died in the ebb water flowing over the sediments in the locality where they were collected. It is probably for this reason that marine infaunal species occur further up the estuary than marine epifaunal species do. On the other hand burrying is also a common method to escape predator pressure and desiccation.

The small-scale distribution of benthic organisms in estuaries is related to such factors as depth, current speed and sediment characteristics. Benthic animals respond to gradients such as exposure to wave action, rate of dilution of sea water by river water, turbidity, oxygen saturation and in some cases and effect of pollutants. Of these variables salinity is the most important natural component in the estuarine environment. Turbidity caused by suspended particles may affect suspension feeders negatively and at very high turbidities such species do not occur. Oxygen shortages also have mainly negative effects. Anoxic areas are not inhabited by macrobenthic species, although meio and microbenthos may be found. Areas influenced by organic pollution are often dominated by short-lived opportunistic species, with a resilient core population.

1.2.3 Food and feeding in benthos

All kinds of organic matter in the estuarine environment – planktonic and benthic organisms, detritus bacteria and dissolved organic matter – are potential sources of food. According to the feeding habit, benthic animals are categorized as suspension feeders (species feeding on organic particles suspended in the water), selective deposit feeders (those which separate their food particles from the sediment by action of ciliated tentacles, by appendages equipped with setae, by current through inhalent siphon etc.), nonselective deposit feeders (those which ingest the sediment as a whole, use the digestible particles and pass the remainder through their gut), predators, scavengers and grazers.

1.2.4 Benthic productivity

Benthic production is of importance in assessing the biological productivity of an area. It is well recognized that the distribution and abundance of benthic animals of a region is directly related to the fisheries of that region. Benthos that, form an important source of food for demersal fishes can be good indicators of fish stocks. Benthic production in estuaries is quite high when compared to other aquatic habitats because of the relative abundance of food in estuaries, combined with the shallow depth of most of the estuaries. In such situations food becomes readily available to the bottom living animals through sinking and vertical transport by turbulent water movements caused by waves and tidal currents. Another possible cause is the presence of opportunistic species, which produce more generations per year compared to the other slower reproducing fauna.

1.2.5 Importance of benthos as indicators

Information on the composition of standing bottom communities can in a way be related to stresses undergone by the preceding community at that and adjacent areas. The concept of indicator species is of great importance in biological monitoring and benthic invertebrates are recognized as useful tools. Ideally indicator organisms are those species that have narrow and specific environmental tolerances. The principal underlying assumption in using indicator organisms, specific assemblages or communities for water quality assessment is that the presence of an indicator is a reflection of its environment. An organism cannot survive indefinitely in an environment that does not provide its physical, chemical and nutritional requirements. Indicator organisms are used primarily to identify rather than to measure environmental changes. The use of marine invertebrate animals or populations, as indicators was first suggested by Wilhelmi (1916). Studies on benthic indicator species of marine and freshwater pollution were carried out by several workers (Belegvad, 1932; Gaufin and Tarzwell, 1952; Reish, 1957a; Hynes, 1966; Ganapati and Raman, 1970; Butler *et al.*, 1972; Anger, 1975; Philips, 1977 and Remani *et al.*, 1983). A variety of benthic organisms like *Capitella capitata*, *Nereis caudata* and *Balanus amphitrite* have been identified as possible indicators of the presence of certain chemical species in the marine environment (Reish, 1957b, Perkins, 1979 and Rege *et.al.* 1980). The ability of many marine molluscs to concentrate metals in their tissue from the surrounding waters has become a useful tool in marine environmental research. The suitability of mussels as test animals and sentinel organisms in nature for the uptake of pollutants results from their widespread distribution and easy accessibility for collection and owing to their sedentary and filter feeding habit. The use of mussels for the purpose of monitoring coastal water quality has received much attention in recent years. Work in this field was stimulated by the suggestion made by Goldberg (1975) for Global Mussel Watch. Subsequently considerable amount of research on various aspects like physiological, cytological, cytochemical, chromosomal, bioassay, ecological consequences of stress, biochemical etc. under Mussel Watch programme was carried out by Bayne *et al.* (1985).

Benthic organisms can be used as bio-markers in the assessment of contamination in marine ecosystem. Biological markers have received considerable attention among environmental toxicologists as tools for detecting exposure to and effects of environmental contamination. A biological marker can be defined as a xenobiotically induced variation in cellular or biochemical components or processes, structure or function that is measurable in a biological system or sample. (McCarthy *et al.*, 1990). The rate of bioconcentration potential of an organism is dependent on many factors such as temperature, physiological status varying with sex and season and biomagnification potential that increases within the perfect level (Narbonne and Michel, 1993).

1.2.6 Economic importance

The penaeid shrimps such as *Penaeus monodon, P. indicus, Metapenaeus dobsoni, M. monoceros, M. affinis* and *Parapenaeopsis stylifiera* are the most valuable commercial sea foods of Kerala. The life history of these species except the last one involves an estuarine phase as their post-larvae and juveniles migrate to estuaries, which are their nursery grounds. As the shrimps grow, they move into deeper waters of the estuary and from there to the sea where they contribute to the marine fishery (Gopalan *et al.*, 1983). The giant freshwater prawn *Macrobrachium rosenbergii* used to contribute to a lucrative fishery in the middle and lower half of the Vembanad Lake. *Scylla serrata, Portunus pelagicus, P. sanguinolentus* and *Charybdis cruciata* are the four species of crabs, which are commercially important. Crab fishery in India is yet to be recognized as a major fishery, despite the abundant occurrence of food crabs all along the Indian coastal and inland waters. The export figure of crabs reached 654 tones in 1990-1991 indicating the potential for future (Marichamy, 1993). Molluscs as such have great importance in that they form valuable fisheries and a very cheap source of protein. Besides, they are used as source of lime and as constituents of medical preparations. When they are exploited for these purposes indiscriminately, a large number of young ones are also caught, causing depletion in the population. Extensive beds of oysters and clams of commercial importance were available in the backwaters. Of particular importance is the edible estuarine oyster *Crassostrea madrasensis*. Remnants of their beds known as "Muringa Madu" still exist in the Cochin backwaters. Reduction in the area of backwaters by dredging and reclamation as well as for mining the subsoil shells and salt water extrusion projects have affected this fishery adversely. Major species contributing to the fishery like *Villorita* are adapted to saline conditions and thrive at salinities as high as 15 ppt. The existing subsoil shell deposits might be available for a few more years more for commercial exploitation. But in the long run the regeneration of the shell resources will be hampered by the changing ecology of this region (Gopalan, *et al.*, 1983).

1.2.7 Estuarine pollution and benthos

Owing to their easy accessibility and consequent high human influences, rivers, estuaries and coastal areas are more susceptible to effects of pollution. Estuaries are the transition regions of freshwater streams to the tidal saline ocean. The flow in an estuary is affected by the conditions at both ends of this transitional zone and are modified by the configuration of the estuary, by winds and by point discharges. Man modifies the configuration of estuaries, the freshwater flows and waste discharges. These modifications affect the currents, suspended solid concentration and dissolved materials in the estuary. All biota are subjected to these effects. It is evident that perturbation of any type whether natural or man-made, may cause shifts in the kinds and number of species and relative sizes of population. This also affects the reproductive success, prey-predator relationship and various interactions between species.

Rivers being often used as disposal areas for domestic and industrial wastes, estuaries act as transit area for pollutants on their way to marine environment. Hence it is important to consider effects of pollutants on the estuarine sediment, water and biota. Knowledge of the ecological requirements of an aquatic organism can be of considerable value in determining the changes that occur in aquatic habitat due to pollution. Pollutants may alter stream environment thereby affecting the aquatic life in a numbers of ways. These changes may include an increase in contents of dissolved nutrients, decrease or increase in amount of dissolved oxygen, increase in turbidity value or a change in the character of the stream bottom. The degree or extent of the effect of these changes on the aquatic life varies with the type and amount of the pollutant and character of the biota.

Benthic populations are structural communities with numerous connecting links. Disruption of these communities by external stress like pollution can affect the entire aquatic food web. Continuous discharge of industrial wastes into the aquatic environment endangers the safety of aquatic life and can reach the human body through the food chain. Although pollution may be caused by chemical or physical agencies it is essentially a biological phenomenon. Klein (1962) stated that after years of chemical and physical testing of river water the boards are today experiencing difficulties in the setting up of standards for effluents and it will only be in the light of biological surveys and tests that these standards can eventually be successfully determined. A knowledge of the biological aspects of pollution is not only of interest but also essential to study the problems of pollution in a given area. Biologists recognized the limitations of chemical and physical measurements of water quality and have searched for organisms, which could serve as indicators of different degrees of pollution. Because of their sedentary habit benthos form a reliable parameter for biological monitoring. Until 1963, the study of marine bottom living animals and plants were primarily, the province of basic research, but for some studies devoted to the productivity of bottom fishing grounds. Emphasis was placed on satisfying our own scientific curiosity as to life history studies of non-commercial bottom animals, physiology, composition and abundance of benthic communities. In the intervening years between 1963 and 1972 there has been a steady shift in the study of benthic communities from the basic to the applied aspects such as the effect of oil pollution on the benthic standing crop and productivity. The sand deposits, where oil accumulates, will have characteristic benthic assemblages, which reveal their linkage to the ancient shoreline. These clues supplied by benthic studies, have been of help to locate new deposits of oil and gas (Parker, 1974).

Most of the bottom dwelling animals are a detritus feeder. The role of predators decline as depth increases and detritus feeders and other bottom feeders become the predominant forms. Benthic fauna has a direct relationship with the type of the bottom and the physical nature of the substratum act as a limiting factor to a considerable extent (Sanders, 1958). Benthos therefore may be treated as sensitive indicators of the conditions of accumulation of organic matter in sediments and its nature (Bordovskiy, 1964). The changes brought about by the deposition of pollutants on the bottom greatly affect the bottom fauna and flora. Generally pollution affects stream community structure, predominantly by reducing species diversity. The elimination of non-tolerant species is often accompanied by a) increase in stream productivity of benthic invertebrates due to lack of predation and competition b) changes and simplification in food chain and c) in the case of organic pollution a seemingly inexhaustible allocthonous source of food for the remaining tolerant species. A reduced production and biomass of macrofaunal species contributing to the higher trophic level due to pollution will have a direct impact on demersal fishes.

Recently the Cochin backwaters has undergone vast anthropogenic environmental alterations, leading to an estimated reduction of its extent by about 35% as a result of construction of bunds and reclamation for agriculture, harbour and urban development. Since 1970, an area covering 176 hectares has been reclaimed for harbour and urban development. The growing inflow of effluent from industrial, agricultural, domestic and retting sources compound its deterioration. The decreased volume of backwaters with limited exchange with the sea reduces the diluting capacity of the backwaters. The physical alteration also play their role in changing the abundance of flora and fauna (Gopalan *et.al.*, 1983).

1.3 EARLIER WORK ON ESTUARINE AND COASTAL BENTHOS

Studies on bottom fauna was first made by Annandale (1907), Peterson (1913) and Annandale and Kemp (1915) in the 20th century in India. The bottom fauna of the brackish water of Madras was studied by Panikkar and Aiyar (1937). The benthos of Malabar and Trivandrum coasts were studied by Seshappa (1953) and Kurian (1953) respectively. The studies on benthos in the Vellar estuary and Chilka Lake were done by Balasubramanian (1961) and Rajan (1964) respectively. Kurian (1967) has given an account of benthos of south west coast of India. A comparative study of the marine and estuarine fauna of nearshore region of the Arabian sea was made by Desai and Krishnan Kutty (1967 b). *Capitella capitata* – an indicator species of Vishakapatnam harbour was studied by Ganapati and Raman (1970). Work on benthos of the mud banks of Kerala coast was done by Damodaran (1973). Ansari (1974) has investigated the macrobenthic production in the Vembanad Lake. The benthic population of estuarine region of Goa was studied by Parulekar and Dwivedi (1974). Kurian *et al.* (1975) have investigated the distribution of bottom fauna of Vembanad Lake. A seasonal change in the benthic production of the Kali estuary was investigated by Harkantra (1975). Parulekar *et al.* (1976) have worked on the distribution and abundance of benthic fauna off Bombay. Ansari *et al.* (1977) have made observations on the distribution of macrobenthos in five shallow bays of central west coast of India. The quantitative distribution of benthos in the depth range 20 – 1700m from the Bay of Bengal was studied by Ansari *et al.* (1977). Parulekar *et al.* (1980) have made an observation on the benthic macrofauna annual cycle of distribution, production and trophic relations in Goa estuaries. Harkantra *et al.* (1980) have worked on the benthos of shelf region along the west coast of India. Murugan *et al.* (1980) studied the bottom fauna of Veli Lake. Hårkantra and Parulekar (1981) attempted a study of the qualitative and quantitative differences in the spatial and temporal distribution and production of benthic macrofauna in the coastal zone of Goa. Divakaran *et al.* (1981) studied the benthic community of Ashtamudi estuary. Parulekar *et al.* (1982) have given an account of the benthic production and assessment of demersal fishery resources of Indian seas. The ecology and distribution of benthic fauna of Ashtamudi estuary was carried out by Nair *et al.* (1984c). The benthic production of northern Vembanad Lake was studied by Anvar Bachan (1984). Distribution and abundance of benthos of the Ashtamudi estuary was studied by Nair and Abdul aziz (1987). Benthic fauna in relation to physico-chemical parameters and sediment composition of Vellar estuary was investigated by Chandran (1987). Murugan and Ayyakannu (1991) have given an account of benthic macrofauna in Cuddalore – Uppanar backwaters. Vijayakumar *et al.* (1991) have made observations on the macro and meiofauna from Kakinada bay and backwaters. Ansari *et al.* (1994) has worked on macrobenthos of Marmagao harbour. Harkantra and Parulekar (1994) have studied the macro invertebrates of Rajpur bay. The mangrove environment of Maharashtra coast was studied by Jagatap *et al.* (1994). Manikandavelu and Ramadhas (1994) have worked on the bioproduction dynamics of mangrove bordered brackish water along Tuticorin coast. Bijoy Nandan and Abdul Azis (1995a) have made observations on the benthic polychaetes of the retting zone in the Kadinamkulam kayal. Fish mortality from anoxic and sulphide pollution in the estuaries of Kerala was studied by Bijoy Nandan and Abdul Azis (1995b). Studies on the benthos of the Veli estuary, Thiruvananthapuram was made by Asha Nair and Abdul Aziz (1995). Prabha Devi *et al.* (1996) have given an account of the water quality and benthic fauna of the Kayamkulam backwaters and Arattupuzha coast. Chandra Mohan *et al.* (1997) have given an account of the role of Godavari mangroves in the production and survival of prawn larvae. The mangrove ecosystem fringing on the Mandovi – Zuari estuaries on the central west coast of India was investigated by Wafar *et al.* (1997). The ancient mangrove of Goa was studied by Antonio Mascarenhas and Onkar Chauhan

(1998). Phytoplankton and macrobenthos in the nearshore waters off an oil terminal at Uran (Maharashtra) was studied by Jiyalal Ram *et al.* (1998). The estuarine and nearshore benthos of Vashishti estuary, Maharashtra was studied by Vijalakshmi *et al.* (1998).

1.3.1 Studies on benthos from the Cochin backwaters

The bottom fauna of Cochin backwaters was studied by Desai and Krishnan Kutty (1967a). Kurian (1972) has worked on the ecology of benthos of Cochin backwaters. The biochemical constituents of some faunal components of the Cochin backwaters were studied by Gopalakrishnan *et al.* (1977). Incidence of fish mortality due to industrial pollution from the upper reaches of Cochin backwater was reported by Unnithan *et* al. (1977). Ansari (1977) and Pillai (1978) have studied the distribution of macrobenthos of the Cochin backwaters. The effect of pollution on benthos was made by Remani (1979). Fish mortality due to ammonia poisoning in Chitrapuzha was reported by Venugopal *et.al.* (1980). Nair *et al.* (1983) have studied the population dynamics of estuarine amphipods in Cochin backwaters. Remani *et al.* (1983) have reported on the indicator species of organic pollution in the Cochin backwaters. Effect of pollution on the benthic communities in Cochin backwaters was studied by Saraladevi (1986). The spatial and temporal distribution of benthos in northern limbs of Cochin backwaters was made by Saraladevi and Venugopal (1989). Saraladevi *et al.* (1991) have given an account of the benthic communities and co-existence in the northern limb of Cochin backwaters. Benthic ecology of the prawn culture fields in the Cochin backwaters was studied by Aravindakshan *et al.* (1992). Studies on the benthic fauna of the mangrove swamps of Cochin area was conducted by Sunilkumar (1993). Impact of environmental parameters on polychaetous annelids in the mangrove area was investigated by Sunilkumar and Antony (1994). The comparative study on the community structure and distributional ecology of benthos in the mangrove swamps of Cochin estuary was made by Sunil Kumar (1995). The effect of dredging on benthic fauna in and around Cochin harbour was studied by Rasheed (1997). A new record of five species of polychaetes from the mangrove ecosystem of Cochin backwaters was reported by Sunilkumar (1999).

1.4 SCOPE AND PURPOSE OF THE STUDY

For sustainable fishing and aquaculture activities in the coastal areas, maintenance of water quality is very important. Proper understanding of the environmental parameters and their effects on biota is a pre-requisite in the management of any ecosystem. Sediments are indicators of the quality of water overlying them and hence their study is useful in the assessment of environmental pollution. The grain size distributions described for a given habitat may be very different from those within the ambit of the organism. In addition to grain size, other proposed causative factors include organic content, microbial content, food supply and trophic interactions, but no single mechanism has been able to explain patterns observed across many different environments. Benthic production is of importance in assessing the biological productivity of an area. It is well recognized that the distribution and abundance of benthic animals of a region are directly related to the demersal fishery of that region. Since the pollution effects are more conspicuous in the bottom a qualitative and quantitative study of the bottom dwelling animals, sediment characteristics and the hydrographical features of the overlying water will be useful to evaluate the extent of pollution affecting the system.

A remarkable extent of information is available dealing with various aspects such as hydrography, nutrients, primary productivity, plankton, benthic fauna and crustacean and molluscan fishery resources of Cochin estuary. Considering the importance of benthos, an attempt has been made to study their composition, distribution, abundance and diversity in relation to the environmental parameters in three different environments. Only one attempt to study the overall effects of industrial pollution on benthos and water quality has been made so far. This study was based on material collected from northern limb of Cochin backwaters in 1981 and published by Saraladevi (1986). The above stations were covered in this study also. The present data is examined against the backdrop of this available information and an attempt is made to evaluate the changes if any, over time (about 15 years) on benthic communities in a system subjected to ongoing stress from industrial effluents. The environments selected were (1) the lower reaches of Cochin backwaters on the northern and southern limb of the mouth of the estuary (2) the mangrove ecosystem of Puduvypin, an island formation bordering the estuary and (3) the dredging and disposal sites of Cochin Port Trust area. The data generated will be helpful in assessing the present status of benthic productivity of these vital ecosystems and for ecological monitoring and future evaluations.

CHAPTER 2

MATERIALS AND METHODS

Materials for the present study were collected from three different environments of Cochin backwaters. Descriptions of the area of sampling and station locations are given in the chapters covering each area. Water samples, sediments and benthos were collected from the following three areas.

2.1 SAMPLING LOCATIONS

2.1.1 Lower reaches of Cochin backwaters

Regular monthly collections were made at 14 stations from the northern and southern limbs of Cochin backwaters, sewage discharge site and barmouth for a period of one year from 1996 June to 1997 May. The year is divided into pre-monsoon (February-May), monsoon (June-September) and post-monsoon (October-January).

2.1.2 Mangrove ecosystem of Puduvypin

From Puduvypin mangrove area monthly samples were collected for 10 months from 6 stations from June 1993 to April 1994. Collections in March and May were not made due to some technical reasons. The year is divided into pre-monsoon (February and April), monsoon (June-September) and post-monsoon (October-January).

2.1.3 Dredging and disposal sites of Cochin Port Trust area

Extensive sampling was done from nearshore and offshore areas including dredging and disposal sites during September 1992 (high fresh water input) and January 1993 (low river discharge).

2.2 SAMPLING METHODOLOGY

Water quality:

Water samples were collected from the surface and bottom. Surface samples were collected using a clean plastic bucket while Niskin sampler was used for collection of bottom samples. Secchi disc of the standard size of 30 cm diameter was used to measure light penetration in water. Samples for dissolved oxygen were collected in 125 ml stoppered glass bottles taking care that no air bubbles are getting trapped in the sample. The samples were fixed immediately with manganous chloride solution (Winkler A) followed by alkaline potassium iodide (Winkler B) solution. Samples for BOD were collected in 300 ml stoppered glass bottles without any air bubble getting trapped in the bottle and incubated.

Water samples for the analyses of salinity and nutrients were collected in pre-cleaned polyethylene bottles. Temperature and pH of the water samples were measured in the field and nutrient samples were transported to the laboratory in ice boxes and estimations of ammonia-N, nitrite-N, nitrate-N and inorganic phosphate were made immediately. Salinity was also measured using the same samples in the laboratory.

Benthos and Sediment

Duplicate grab samples were collected from all stations using a Van Veen grab (mouth area $0.048m^2$) and sieved through a strainer of 0.5mm pore size. Samples for grain size and organic carbon content were treated separately.

2.3 ANALYTICAL METHODS

Water quality

pH measurements were made using a portable pH meter (PHILIPS, model pp 9046, accuracy ±0.01) and salinity was measured with an electrodeless induction type salinometer (DIGI-AUTO, model 3G, Tsurumi Seiki, Japan, accuracy $\pm0.01 \times 10^{-3}$) after proper calibration.

Dissolved oxygen was determined by the Winkler method, as recommended in Strickland and Parsons (1972). The principles of the determination and the possible sources of systematic errors discussed by Grasshoff (1983a) were also noted.

Biochemical Oxygen Demand (BOD_5) was measured by the method recommended by American Public Health Association (1960). The sample was incubated for 5 days at 20°C in the dark. The reduction in dissolved oxygen concentration from initial to final during the incubation period yields a measure of the biochemical oxygen demand.

Nutrients

a. Ammonia-N

Ammonia-N was determined according to the indophenol blue method of Koroleff[1] (1983). In a moderately alkaline medium, ammonia reacts with hypochlorite to form monochloramine which in the presence of phenol, catalytic amount of nitroprusside ions and excess hypochlorite forms indophenol blue. The formation of monochloramine requires a pH between 8 and 11.5. At higher pH, ammonia is incompletely oxidised to nitrite. Both calcium and magnesium ions in seawater precipitate as hydroxide and carbonate at pH higher than 9.6, however their precipitation can be prevented by complexing them with citrate buffer.

Great care was taken to ensure that samples, blanks and standards were not contaminated during the course of analysis. The samples were fixed by addition of reagents and the absorbance measured at 630 nm after colour development (about 6 hours). The measured ammonia include both free dissolved ammonia gas and the ammonium ions.

b. Nitrite-N

Nitrite-N was measured by the method of Bendschneider and Robinson (1952). In this method, nitrite in the water sample when treated with sulphanilamide in acid solution results in diazo compound which reacts with N-1-naphthyl ethylene diamine dihydrochloride to form an azo dye. The absorbance of it is measured at 543 nm.

c. Nitrate-N

Nitrate-N in the water sample was quantitatively reduced to nitrite by passing the sample through a reduction column filled with copper coated cadmium granules and measured as nitrite. During the reduction stage, ammonium chloride buffer is added to the sample to maintain a stable pH (Grasshoff, 1983b). The estuarine samples containing high concentration of nitrate-N were diluted before passing them through the column.

d. Inorganic Phosphate

Determination of inorganic phosphate involves the measurement of the concentration of orthophosphate ions by the formation of a reduced phosphomolebdenum blue complex in an acid solution containing molybdic acid, ascorbic acid and trivalent antimony. The most accepted method based on this reaction, which was developed by Murphy and Riley (1962) is that given by Strickland and Parsons (1972). A variation of this method described by Grashoff *et al.* (1983) is adopted in the present work. Instead of single solution reagent as in the Murphy and Riley procedure, two stable reagent solutions are used here. 0.5 ml of the mixed reagent containing molybdic acid and antimony tartrate were added to 25 ml aliquots of the samples followed by 0.5 ml of ascorbic acid reagent. The absorbance was measured at 882 nm within 30 minutes to reduce any possible interference from arsenate. Turbidity corrections were made wherever found necessary.

Chlorophyll 'a'

Chlorophyll 'a' was estimated following the methods UNESCO (1966). A known volume of water sample was filtered through a millipore (0.45μm pore size) with a MgCO3 suspension. This millipore was dissolved in 10 ml of 90% acetone and the pigment was extracted by placing the tube in a refrigerator in complete darkness for about 10-20 hrs and was centrifuged for 10 minutes at 3000-4000 rpm. The extinction of the supernatant solution was measured spectrophotometrically against a cell containing 90% acetone at 750, 665, 645, 630, 510 and 480 nm and the concentration of pigment was calculated using standard equations.

Particulate Organic Carbon

A known volume of water sample was filtered through GF/C (1.2 μm pore size) and on drying to a constant weight at 60°C, particulate organic carbon was estimated by the method of El.Wakeel and Riley (1957).

Suspended solids

Suspended solids were determined by filtering water sample through a previously weighed millipore filter paper (0.45 µm pore size), drying the residue to a constant weight at 80°C to 90°C and re-weighing. The differences in weight indicate the amount of suspended solids.

Attenuation coefficient ('K' value)

Attenuation coefficient ('K' value) was calculated using the formula $K = 1.5/D$ (Qasim *et al.*, 1968), where D is the depth of visibility in meters as determined by secchi disc.

Sediment samples - grain size analysis and estimation of organic matter

The samples were dried in a hot air oven at 95°C. The percentage of sand, silt and clay portions of this dried material was determined by pipette analysis (Krumbein and Petti John, 1938). Another portion dried to a constant weight around 60°C was used for estimation of organic carbon, using the method of El Wakeel and Riley (1957). Organic matter was calculated by multiplying organic carbon values by a factor of 1.724 (Trask, 1939). Energy content was obtained from organic matter using an equivalent of 21.6 J/g dry weight (Marchant and Williams, 1977).

Benthos

Grab samples collected were sieved through a 500 µm mesh (Birkett and McIntyre, 1971) and preserved in 5% neutral formalin mixed with rose bengal stain for subsequent identification. The actual number of organisms counted were converted to number/m^2. The biomass values were expressed as wet weight in g/m^2 (shell on weight).

Fishery potential based on benthic productivity

Organic carbon equivalent for the benthic biomass was determined by the procedure of Lie (1968) and productivity estimates were made as per the methodology of Sanders (1956) and Crisp (1979).

The annual benthic productivity was calculated from the biomass as given below :

Dry weight = 22% of wet weight

Carbon content = 34.5% of dry weight, (Parulekar *et al.*, 1980)
Annual benthic production = Carbon content X 2g C/Yr. (Sanders, 1956).
Annual biomass production is calculated as twice the standing stock (Harkantra and Parulekar, 1994)
The potential yield is taken as the 10% of the benthic standing stock (Parulekar *et al.*, 1982).

2.4 STATISTICAL METHODS

Data on benthos was subjected to statistical analysis for making inferences depending on the availability of sample size. Tuckey's test of additivity (Tuckey, 1949) was applied to verify the additivity nature of the input parameters and for selecting the optimal transformation if not additive (Federer, 1967).

Three way analysis of variance was applied on the transformed data to make comparison, station wise, species wise and month wise and also the interaction of first order among these three variables. Having observed significant differences Duncan's Multiple range test/ least significant difference (lsd) test was applied for pair wise comparison (Snedecor and Cochran, 1967).

Step up regression model was fitted to predict the total benthic abundance to select the relatively most important parameters/first order interaction effects and simultaneously to delete the most insignificant parameters through significance test for the regression coefficient after standardisation of data (Sokal and Rohlf, 1981 & Jayalakshmy, 1998).

Species co-existence was studied by using Karl Pearson's linear correlation coefficient (Snedecor and Cochran, 1967). Station/season wise associations were studied through community coefficient for station/seasons based on benthic abundance (Clifford and Stephenson, 1975).

Benthic community structure was studied by using diversity/evenness indices such as Margalef's species richness index (Margalef, 1968), Shannon Weaver's species diversity index (Shannon and Weaver, 1963), Simpson's species concentration factor (Simpson, 1949), Pielou's species dominance index (Pielou, 1966a & b), Heip's evenness index (Heip, 1974 & Jayalakshmy, 1998) and niche breadth (Lydia Ignatidaes, 1994).

Multivariate Q-mode and R-mode factor analysis was applied for determining the differential groups of species/months which provide the maximum information about the study area and thereby for grading the studied stations based on pollution aspects (Morrison, 1978).

CHAPTER 3

POLLUTED ENVIRONMENT OF COCHIN BACKWATERS

3.1 INTRODUCTION

The Cochin estuary is the largest of the estuaries along the Kerala coast. Two major rivers Periyar and Muvattupuzha drain into the northern and southern parts of the estuary respectively. The southern part also receives discharges from 4 other rivers namely Manimala, Pampa, Achancovil and Meenachil.

The industrial belt of the Greater Cochin is situated on the either banks of Periyar River. The major industries towards northern part of the Cochin city are Caprolactum plant, Hindustan Insecticide, Cominco Binani Zinc Ltd., Travancore Chemicals and Manufacturing Co. Ltd., FACT Udyogamandal, Indian Rare Earth Ltd., Catalysts and Chemicals Ltd., Indian Aluminium Co. Ltd., Travancore Rayons Ltd., Tata Oil Mills Ltd. and Hindustan Petroleum Ltd. Large quantities of industrial effluents from these factories along with the effluent from the sewage treatment plant of Cochin City make the northern part of the estuary heavily polluted. About 25km east of Cochin and bordering the Chitrapuzha river (branch of Muvattupuzha) is the village of Ambalamedu. Here a complex of four factories has been established. These factories are Fertilizers and Chemicals Travancore Limited (FACT) Cochin division, Hindustan Organic Chemicals Limited (HOC), Cochin Refineries Ltd. (CR) and Carbon and Chemicals Ltd. (CC). Effluents from these factories along with the water that drains through vast areas of agricultural land make the southern part of Cochin backwaters heavily polluted.

Like any other estuary located in the vicinity of metropolitan cities and industrial conglomerates, Cochin backwater system is also subjected to increasing human interference. The booming city of Cochin has a population of nearly a million and 70 of the industries of Kerala State are situated in this area. The effluents from the industries and urban wastes nearly 1.4 X $10^6 m^3$ of wastewater form a major source of pollution in this estuary. In addition, the estuary receives organic wastes from domestic sewage, coconut husk retting yards, fish processing plants etc.

Waste disposal operations intentionally releasing materials to marine water either via. direct pumping or pipeline discharges constitute point sources of pollution. The dumping of municipal sewage sludge, dredged spoils and industrial wastes and the discharge of municipal and industrial effluents from the outfall are the primary point source categories responsible for introducing pollutants to marine waters. Principal non-point sources of pollutants from land-based systems include urban and rural runoff, septic tank leakage, ground water transport, erosion or deposition of concentrated soils and atmospheric deposition.

The impact of organic enrichment due to sewage disposal and waste input from wildlife and agricultural operations are occasionally very pronounced in marine benthic communities. Results of numerous investigations have provided consistent correlation between organic enrichment and gross measures of community structure (i.e. species richness, dominance, diversity and total animal abundance). The toxic chemicals associated with sewage wastes also play significant role in generating the benthic impacts.

Retting is a native method prevalent along the coast of Kerala since ages as an indigenous practice for the processing of coconut husk. The extensive backwaters provide facilities for retting in 357 villages along the coastal belt of the state and the average production of coir fibre is reported to be 30,000 metric tones per year. The continued and intensive exploitation of the backwaters for retting of coconut husk has caused deleterious effect on the fishery resources of the state and several backwaters have transported into hot spots of pollution. This has led to a clash between the coir industry on one hand and the fishing industry on the other, along the coastal belt of the state. Retting of coconut husk is brought by the pectinolytic activity of microorganisms like bacteria, fungi and yeast releasing large quantities of organic substances such as pectin, pentosan, polyphenols, tannins etc. into the medium. As a result kayals of Kerala became increasingly polluted causing extensive damage to the biotic communities in the zones.

3.2 LOCATION OF THE SAMPLING STATIONS (Fig. 3.1)

The stations are located 25km upstream towards the southern (stns. 1 to 5) and northern (stns. 8 to 13) limbs of Cochin backwaters. Stations were selected at the effluent discharge site at Ambalamedu and Eloor. In each limb collections were also made immediately downstream of the industrial complex. Two stations (stns. 6 & 7) were located at the sewage discharge area and the barmouth (stn. 14) is taken as a reference station. The details of the 14 stations are as follows.

Stations	Locations	Depth (m)
1	Industrial belt at Ambalamedu	1.5 – 4.0
2	Downstream the effluent discharge point.	1.5 – 3.5
3	Kaniampuzha	3.0 – 5.5
4	Thykoodam	3.5 – 7.0
5	Thevara canal	1.5 – 8.0
6	Mullassery canal	1.5 – 4.0
7	Market canal	1.5 – 3.0
8	Ponnarimangalam	2.0 – 4.0
9	Vaduthala	2.0 – 8.0
10	Varapuzha	3.5 – 6.5
11	Old Panchayath Jetty at Eloor	3.5 – 5.0
12	Effluent discharge point at Eloor	2.0 – 4.0
13	Pathalam	2.5 – 4.0
14	Cochin barmouth	3.0 – 12.0

3.3 RESULTS

3.3.1 Water quality (Figs. 3.2 – 3.13 & Table 3.1)

Temperature (°C)

In the southern limb, at stns. 1 to 5 the minimum temperature of 27.00 was noticed during July and maximum of 33.00 was recorded during March irrespective of depths. The vertical gradient in temperature observed in this area was minimum (0.50) during March and May and maximum (1.0) during August. In the sewage discharge stations (stns. 6 & 7) minimum temperature recorded was 25.80 during June and maximum (32.50) during March in surface waters. The temperature gradient in this area was 1.0 during March, July and August. Northern limb (stns. 8 to 13) also showed the lowest (25.0) and peak (33.0) temperature in surface waters during July and March & May respectively. The vertical gradient in temperature observed in this area was 1.30 during April. The lowest temperature (25.50) recorded in barmouth (stn. 14) was in August and highest value (31.0) was in November. The maximum temperature gradient at this station was 0.5 during February, November and April.

Seasonal variations showed that pre-monsoon average were higher at all stations compared to monsoon and post-monsoon. The seasonal averages for the surface and bottom at different stations in the southern limb ranged from 31.50 to 32.0 (av.31.71) and 31.18 to 31.75 (av. 31.42) during pre-monsoon; 28.88 to 29.35 (av.29.16) and 28.58 to 29.05 (av. 28.81) during monsoon and 29.0 to 29.98 (av. 29.36) and 28.92 to 29.73 (av. 29.21) during post-monsoon. The corresponding surface and bottom values for the sewage discharge points were 31.13 to 31.38 (av. 31.25) and 30.65 to 31.10 (av. 30.87) during pre-monsoon and 28.48 to 28.70 (av.28.59) and 28.08 to 28.28 (av.28.18) during monsoon and 29.58 to 29.75 (av. 29.66) and 29.45 to 29.53 (av. 29.4) during post-monsoon. The seasonal average for the northern limb (stns. 8 to 13) varied from 31.48 to 32.25 (av. 31.84) for the surface and 31.33 to 32.08 (av.31.65) for bottom during pre-monsoon. The monsoon values fluctuated between 27.23 and 28.63 (av. 27.73) in the surface and 27.13 and 28.40 (av. 27.56) for the bottom. Temperature during post-monsoon varied from 28.50 to 28.83 (av. 28.63) in the surface and 28.30 to 28.75 (av. 28.47) in the bottom waters. In the barmouth area the averages for pre-monsoon, monsoon and post-monsoon were 29.25, 26.40 and 28.88 for surface and 29.00, 26.0 and 28.67 for the bottom respectively.

The seasonal averages for surface and bottom waters for the entire area were 31.52 and 31.27 during pre-monsoon, 28.27and 27.99 during monsoon and 29.05 and 28.90 during post-monsoon respectively.

The annual range in temperature varied from 27.00 to 33.00 in the southern limb, 25.80 to 32.50 in the sewage area, 24.90 to 33.0 in the northern limb and 25.00 to 31.50 at the barmouth. The annual range in temperature for the study area varied from 25.00 to 33.00 with an annual average of 29.61 for the surface and 29.38 for the bottom.

Salinity (psu)

In the southern limb where the freshwater regime prevailed in most of the months, the spatial variation in salinity was pronounced, but the values were found to be fluctuating between the months at all stations. In the area between the stns. 1 to 4, salinity was very low (<1) in the water column from June to October. November onwards salinity increased from <I to nearly 3 at stn. 4 surface and 0.05 to 4.24 in the bottom. But at stn. 3, the salinity increased from January onwards ranging between 0.21 and 2.25 in the surface and 0.18 and 4.47 in the bottom. Towards the upstream stations (stns.1 & 2) an increase (>1) was noticed during March and April but again a drop in salinity (<1) was noticed in May. In these stations a marginal difference of < 0.05 was recorded between surface and bottom values. At stn. 3, the maximum salinity gradient of 6.18 was obtained during March whereas no gradient was observed from June to October. At stn. 5, except for a stray value of 11.98 for surface and 31.71 for bottom during August, the values were < 3 during monsoon months. From November onwards, the values increased up to 21.51 at the surface during April and 25.43 at the bottom during March.

In the sewage discharge area, which is inside the estuary, at stn. 6 the minimum salinity was 0.06 for surface and 0.07 for bottom during September and the maximum salinity values for surface and bottom were 21.56 (January) and 23.56 (March) respectively. At stn. 7, the minimum and maximum values for surface and bottom were 0.05 (September) & 21.18 (March), 0.03(September) & 21.17 (March) respectively. At stn. 6, the minimum salinity gradient was in September (0.01) and the maximum in July (4.92) whereas the corresponding values for stn. 7 were 0.02 (September) and 3.11 (May).

In the downstream of northern limb, at stn. 8, the maximum vertical salinity gradient of 20.56 was observed during March (8.55 at the surface and 29.11 at the bottom) and no salinity gradient in June and July. At stn. 9, the maximum salinity was noticed in March (15.62) in the bottom and maximum vertical salinity gradient was 10.39. In the upstream stations (stns. 10 to 13) the freshwater conditions prevailed throughout the year. At stn. 10, almost all the values were <1 except two stray values of 13.24 (March) and 7.86 (May) in the bottom. At stns. 11, 12 and 13 all the values were <1 except a value of 3.40 (January) in the bottom at stn. 12.

At stn. 14 (Barmouth), fluctuating values were observed due to the tidal influence. High salinity of 32.60 at surface and 34.10 at bottom and 31.15 at surface and 31.98 at bottom during November and December were observed, but these values dropped to 23.35 at the surface and 25.97 at the bottom during May. With the onset of monsoon the values still reduced to 2.47 at surface and 12.78 at the bottom and again maintained high salinity during post-monsoon months.

In the southern limb, seasonal variations were not pronounced at stns.1 to 4 though the values were slightly high during pre-monsoon compared to the other seasons. At stn. 5, the average values for pre-monsoon monsoon and post-monsoon were 17.11, 3.61 and 11.57 for surface and 19.34, 8.42 and 12.90 for bottom respectively.

In the sewage area, stns. 6 & 7 showed well marked seasonal variation. At stn. 6, the average values for pre-monsoon, monsoon and post-monsoon were 17.57, 0.96 and 11.31 for surface and 20.66, 2.00 and 12.60 for bottom respectively. The corresponding values for stn. 7 were 16.85, 0.86 and 9.91 for surface and 17.80, 0.94 and 10.40 for bottom.

Towards the downstream of northern limb, stns. 8 and 9 showed well-marked seasonal difference. At stn. 8, the average values for pre-monsoon, monsoon and post-monsoon were 8.18, 0.50 and 8.98 for surface and 17.83, 0.47 and 12.52 for bottom respectively. The corresponding values for stn. 9 were 3.17, 0.05 and 3.33 for surface and 5.85, 0.04 and 4.49 for bottom. At stn. 10, the maximum average salinity during pre-monsoon was 5.41 for bottom and the averages for monsoon and post-monsoon were <1. Almost freshwater conditions prevailed at stns. 11, 12 and 13 throughout the year.

At stn. 14, the average pre-monsoon values were high compared to monsoon and post-monsoon and the values were 26.86, 1.73 and 24.32 for surface and 30.18, 6.25 and 30.44 for bottom respectively.

The annual range in salinity varied from <1 to 11.50 (av. 1.43) at stns. 1 to 4, 0.09 to 31.71 (av. 12.13) at stn. 5, 0.03 to 23.56 (av. 8.69) in the sewage area, <1 to 29.11 (av. 2.06) in the northern limb and 0.26 to 34.10 (av. 19.95) at the barmouth. For the entire study area the salinity varied from <1 to 34.10 during the investigation period.

pH

At stns.1 to 4 in the southern limb the pH ranged between 6.43 and 8.96 in the water column. The surface and bottom values showed not much difference. Both the minimum and maximum values were observed during November. After stn. 4 the values showed an increasing trend. At stn. 5, the pH ranged between 6.88 and 8.25 in the surface and bottom. In the sewage discharge site (stns. 6 & 7) low value (6.65) was recorded during September and high (8.31) during November. The same trend was noticed in the downstream stations (stns.8 to 10) of northern limb. Near the effluent discharge site, (stns. 11 & 12) a sudden decrease in pH (4.49 - 5.94) was noticed in the water column from November to January and it slowly increased reaching a maximum of 8.43 at stn. 13. Stn. 14 maintained normal pH ranging between 7.12 and 8.20 around the year.

Seasonal variation showed that pre-monsoon values were always high compared to other seasons. Though there was monthly variation in pH values the seasonal variation was not well defined. In general the annual range in pH was 6.5 and 8.96 except for some stray values at stations near the industrial complex at Eloor.

Dissolved oxygen (ml/l)

During the investigation the dissolved oxygen levels in the surface water was generally high compared to bottom at all stations. Spatial distribution of oxygen in the water column showed a wide range between 0.98 and 5.99 in the southern limb (stns 1 to 5). Being in the estuarine region the sewage discharge site did not show any oxygen depletion and the dissolved oxygen values here varied from 3.25 to 5.30. The northern limb also showed well-oxygenated condition at all stations the values being within the range of 3.32 and 5.97.

Temporal distribution showed an increasing trend in dissolved oxygen levels from stn. 4 onwards during June and August. After a high value in July at stn. 5, it showed irregular pattern in other stations. During September the values maintained a steady pattern. During October the dissolved oxygen levels were low in the southern limb and it increased towards other stations. November and December showed fluctuating values with comparatively low dissolved oxygen in the northern limb. On the contrary the dissolved oxygen values during January at stations in the southern limb was high compared to the other areas. Except for one or two low values at stn. 4 during February, April and May the dissolved oxygen showed fluctuating values at all other stations during this period. In general the distribution of dissolved oxygen showed no definite pattern during the study period.

The seasonal averages of dissolved oxygen for the water column ranged from 2.24 to 4.11 at stns. 1 to 4 and 3.34 to 3.56 at stn. 5 in the southern limb, 3.89 to 4.73 in the sewage discharge site, 3.15 to 4.73 in the northern limb and 3.82 to 3.93 in barmouth during pre-monsoon. During monsoon the corresponding values were 3.11 to 3.83, 4.62 to 4.89, 4.02 to 4.18, 4.37 to 5.45 and 3.99 to 4.64. During post-monsoon the values fluctuated between 3.24 and 4.34 at the stns. 1 to 4 and 3.26 and 3.71 at stn 5 in the southern limb, 3.92 and 4.10 in the sewage discharge area, 3.38 and 5.11 in the northern limb and 3.79 and 4.03 at the barmouth.

The annual variations in dissolved oxygen levels for the water column varied from 0.98 to 5.99 (av. 3.42) at stns. 1 to 4. Except for a few low values in November, the annual values at stn. 5 ranged between 2.54 and 5.69 (av. 3.89). In the sewage discharge site, the annual range in dissolved oxygen level was between 3.25 and 5.30 (av. 4.14). In the northern limb, except one or two low values it varied from 2.21 to 5.97 (av. 4.55). In the barmouth region the values were between 3.05 and 5.11 (av. 4.01). Annual range in dissolved oxygen for the entire study area was between 1.67 and 5.99 for surface (av. 4.13) and 0.98 and 5.93 for bottom (av. 3.80).

Biochemical Oxygen Demand (BOD_5) (mg/l)

In general the BOD_5 values were very low throughout the investigation period. It did not show any definite pattern and the values were < 5 at all stations except a value of 5.17 (May) at stn. 12. Low BOD_5 was noticed during monsoon months and high values during dry months. The values were comparatively high in the upstream stations of southern limb and sewage discharge site and at stn. 12, downstream of the effluent discharge point in the northern limb.

Seasonal averages of the different stations in the southern limb including stn. 5 ranged from 2.08 to 3.55 (av. 2.92), 3.20 to 4.20 (av. 3.59) and 1.05 to 3.32 (av. 2.37) during pre-monsoon, monsoon and post-monsoon. In the sewage discharge site the values varied from 3.36 to 4.37 (av. 3.87), 0.98 to 2.02 (av. 1.50), 1.51 to 1.33 (av. 1.42) during the three respective seasons. The BOD_5 values in the northern limb were comparatively low varying from 1.22 to 2.65 (av. 1.94), 0.37 to 2.0 (av. 1.14) and 0.55 to 2.29 (av. 1.04) during pre-monsoon, monsoon and post-monsoon respectively. In barmouth region the corresponding values were 2.43, 1.92 and 1.38. The annual range in BOD_5 for the entire study area ranged between 0.00 and 5.17 with an average of 1.80.

Nitrite-N (µmol/l)

The concentration of nitrite was found to be high in the southern limb compared to the northern limb. In the southern limb, the concentration was high in the upstream stations, which decreased towards downstream. The nitrites showed the low concentrations at stns. 1 to 5 from June to October, and then with a steady increase up to May except at stn. 5 where the maximum values for surface and bottom were noticed in June. The minimum values at stn. 1 was 3.48 at surface and 2.92 at bottom in October. The maximum concentration of nitrite at stn. 1 was in

February and the values were 42.22 (surface) and 41.87 (bottom) whereas at stn. 5 the values dropped to 11.06 at surface and 11.29 at bottom in June. The values fall within the annual range of 2.58 to 42.06 at surface and 2.84 to 41.60 at bottom at stn. 2. At stn. 3 the minimum values were 2.39 at surface and 2.51 in the bottom in July and maximum concentration were 41.49 at surface and 39.36 in the bottom in April. The values ranged between 2.70 to 39.74 at surface and 2.72 to 38.53 at bottom t stn. 4. The minimum values at stn. 5 were 1.04 at surface and 0.98 in the bottom. The values in the sewage area were very low compared to the southern limb. At stn. 6 all the values were < 2, except a value of 2.88 at bottom in June. The values decreased upto 0.25 at surface and 0.42 at bottom in March. Stn. 7 showed the minimum concentrations of 0.50 and 0.31 at surface and bottom in March whereas the maximum values were 2.96 at surface and 3.11 at bottom in June. In the northern limb, the downstream stations showed some higher values and towards the upstream the concentration decreased. At stn. 8, till November all the values were <1 except a value of 1.18 at surface in August and the maximum values observed were 6.41 (surface) and 7.54 (bottom) in April. At stn. 9 the values were <1 except in June, January, March and April and maximum values observed were 3.98 at the surface and 3.89 at bottom in April. At stn. 10, the values ranged between 0.0 and 2.07 at surface and 0.20 and 4.04 at bottom. Station 11 showed the minimum values of 0.02 at surface and 0.00 at bottom in July and the corresponding maximum values were 3.96 (February) and 1.71 (April). At stn. 12, the values fall in the range of 0.07 to 1.77 at surface and 0.02 to 1.79 at bottom. At stn. 13 the levels of nitrite were <1 except the values of 1.29 at surface and 1.43 at bottom in October. In the barmouth (stn. 14) the minimum values were 0.0 and the maximum values were 1.55 and 1.63 at surface and bottom respectively in June.

The seasonal averages for nitrite were always high in the pre-monsoon compared to monsoon and post-monsoon at stns. 1 to 4. The averages for pre-monsoon were 39.71, 40.31, 36.69 and 34.11 at surface and 40.33, 39.91, 33.44 and 30.84 at bottom at stns. 1 to 4. The corresponding monsoon averages were 8.01, 8.62, 8.18 and 4.35 at surface and 8.02, 8.61, 4.51 and 3.90 at bottom. The post-monsoon values were 24.71, 24.15, 16.36 and 14.71 for surface and 25.00, 25.67, 15.55 and 13.06 for bottom respectively. At stn. 5, the averages for pre-monsoon,

monsoon and post-monsoon values were 4.02, 3.77 and 2.16 for surface and 2.86, 5.51 and 1.98 for bottom respectively. In the sewage discharge site seasonal variation was not well marked. At stn. 6, the pre-monsoon, monsoon and post-monsoon averages were 1.25, 1.25 and 1.05 at surface and 1.28, 1.43 and 1.01 at bottom. The corresponding values at stn. 7 were 1.54, 1.60 and 1.06 at surface and 1.44, 1.61 and 1.03 at bottom. Towards the northern limb the average pre-monsoon values were higher than the monsoon and post-monsoon seasons except at stn. 13, where the post-monsoon values were higher than the Pre-monsoon and monsoon average values. The average values for pre-monsoon, monsoon and post-monsoon periods were 0.36, 0.19 and 0.48 at surface and 0.37, 0.27and 0.53 at bottom respectively at stn. 13. At stns. 8 to 12, the average pre-monsoon values were 2.58, 1.84, 1.25, 2.32 and 1.25 at surface and 2.92, 1.69, 1.61, 0.85 and 0.83 for bottom respectively. In the barmouth the nitrite content in the water column was very low (<I) and seasonal variation was less.

Seasonal averages for the stns. 1 to 4 varied from 30.84 to 40.33 (av.36.92) during pre-monsoon, 3.90 to 8.62 (av. 6.80) during monsoon and 13.06 to 25.67 (av. 19.90) during post-monsoon irrespective of depth. At stn. 5, the corresponding values were 2.86 to 4.02 (av.3.44), 3.77 to 5.51 (av. 4.65) and 1.98 to 2.16 (av. 2.07). In the sewage discharge site the seasonal average showed a narrow range between 1.25 to 1.54 (av. 1.38) during pre-monsoon, 1.25 to 1.61 (av. 1.47) during monsoon and 1.01 to 1.06 (av. 1.04) during post-monsoon. In the northern limb seasonal variation for different stations ranged from 0.36 to 2.92 (av. 1.48) during pre-monsoon, 0.26 to 0.80 (av. 0.51) during monsoon and 0.48 to 1.15 (av. 0.80) during post-monsoon. In the barmouth region the averages for the water column were 0.76, 1.01 and 0.56 during the three seasons.

The annual range in nitrite concentration in the water column was between 2.39 and 42.22 (av. 21.10) at stns. 1 to 4, 0.98 and 11.29 (av. 3.38) at stn. 5, 0.25 and 3.11 (av. 1.29) in the sewage discharge site, 0.0 and 7.54 (0.93) in the northern limb and 0.0 and 1.63 (av. 0.77) in the barmouth. The annual range in nitrite for the entire area varied from 0.0 to 42.22 with an average of 5.49.

Nitrate-N (µmol/l)

The nitrate showed very high concentration in the southern limb compared to northern limb. The upstream station (stns. 1 & 2) showed the maximum concentration of nitrate in April, the values being 2027.10 at stn. 1 and 2192.80 at stn. 2 at surface whereas the corresponding bottom values were 1976.90 and 2216.10. These values decreased to 7.00 and 88.69 at stn. 1 & 2 at surface and the bottom values were 9.34 and 15.17 respectively during March. At stn. 3, the concentration fall within the range of 11.67 to 1329.20 at surface and 12.84 to 1091.10 at the bottom; the low and high values were during March and April respectively. At stn. 4, the minimum concentrations were in March at surface (7.00) and bottom (11.67) and the maximum in February and the corresponding values were 972.11 (surface) and 1091.44 (bottom). At stn. 5, the minimum values were in December at surface (15.08) and in March at bottom (24.51) and the maximum concentrations were observed in July at surface (1019.34) and bottom (1011.72). Stn. 6 and 7 showed very low values compared to southern limb. The nitrate concentration was not detected in the water column during November and March and the levels peaked during April (114.37) at surface and during June (93.42) at bottom. At stn. 7, the values ranged from 0.0 (November and March) to 1010.65 (July) at the surface and 0.0 (March) to 843.44 (July) at the bottom. Towards the northern limb, nitrate varied spatially as well as temporally. The spatial variation delineated decreasing trend towards upstream stations. At stn. 8, nitrate was minimum (24.51) in December and maximum (404.51) in July at surface and it ranged between 0.0 (January) and 618.44 (July) in the bottom. At stn. 9, the values ranged from 18.56 (November) to 1160.65 (July) at surface and 0.0 (November) to 1669.98 (March) at bottom. At stns. 10 and 11 the maximum values were in March and minimum in May in the water column except at the bottom at stn. 11, where the minimum is in January. The values ranged between 10.50 to 1693.32 at surface and 4.85 to 1798.35 at bottom at stn. 10 and the corresponding value at stn. 11 were 5.29 to 1483.26 and 2.33 to 1162.33. The range fall between 5.84 and 409.26 at surface and 0.0 and 524.92 at bottom at stn. 12 whereas at stn. 13 the corresponding ranges were 4.67 to 244.03 and 0.0 to 259.28. At barmouth (stn.14) also high values were noticed in July with a maximum value of 451.23 at surface and 340.57 at bottom. The minimum concentration was in August at surface (5.47) and nitrate was not detected in November and February at bottom.

Seasonal variation in the nitrate content showed that monsoon values were comparatively lower than pre-monsoon and post-monsoon in all regions and the surface and bottom values did not show much difference. The pre-monsoon averages for the water column of the different stations in the southern limb ranged between 392.98 and 900.93 (av. 667.11). The corresponding values for monsoon varied from 258.35 to 342.59 (av. 309.87) and post-monsoon values were within the range of 223.07 and 743.90 (av. 458.13). At stn. 5, the monsoonal average was high (350.40) compared to pre-monsoon (268.12) and post-monsoon (89.46). The sewage discharge site showed the same trend with a high average during monsoon (173.31) followed by pre-monsoon (25.12) and post-monsoon (20.45). The seasonal averages for the two stns. 6 and 7 varied from 16.58 to 32.26 during pre-monsoon, 58.72 to 302.20 during monsoon and 13.04 to 27.75 during post-monsoon. The pre-monsoon and monsoon average values in the northern limb were almost 13 times higher than post-monsoon values. The nitrate values in the water column showed a wide range between 7.03 and 468.01 (av. 228.49) during pre-monsoon and between 105.28 and 346.80 (av. 212.71) during monsoon and between 17.47 and 53.61 (av. 36.13) during post-monsoon. In the barmouth region the monsoonal average (149.81) showed a three fold increase than the post-monsoon (39.72) and nine times increase than the pre-monsoon average (16.15). Surface average values were higher than the bottom during the three seasons.

The annual range in nitrate concentration in the water column was between 7.00 & 2216.10 (av. 478.36) at stns. 1 to 4, 15.08 & 1019.34 (av. 235.99) at stn. 5, 0.0 & 1010.65 (av. 72.95) in the sewage discharge site, 0.0 & 1798.35 (av. 159.11) in the northern limb and 0.0 & 451.23 (av. 68.56) in the barmouth. The annual range in nitrate for the entire area varied from 0.0 to 2216.10 with an average of 203.00.

Ammonia-N (µmol/l)

The concentration of ammonia in the southern limb was very high except during August compared to northern limb. Stns. 1 to 4 in the southern limb showed maximum concentration of ammonia, which decreased towards downstream. The minimum values were 0.44, 0.33, and 0.33 for surface and 0.17, 0.33 and 0.22 for bottom for stns. 1, 2 and 3 respectively. The corresponding maximum surface values were 151.85, 158.99 and 158.93 and bottom values were 167.56, 159.16 and 159.21. At stn. 4 the minimum values were 0.71 and 0.50 in August and maximum in May for surface (160.15) and in January for bottom (160.09). In all these stations an increase from <1 (August) to >100 (October) was observed and these higher concentrations were maintained till May. At stn. 5, The values were very low (0.22 for surface and 0.28 for bottom) compared to other stations except a high value of 139.57 (May) for surface and 74.96 (May) for bottom. The sewage discharge area showed >3 fold decrease in ammonia concentration compared to southern limb, the values being 21.60 and 16.59 for surface and 24.30 and 18.14 for bottom at stns. 6 and 7 respectively. At the downstream station of northern limb (stn. 8) the surface values were in the range of 0.0 (November) to 24.40μmol/l (May) and bottom values ranged between 0.0 (July, November and March) and 27.11 (May). An increase in concentration towards the upstream stations was noticed up to stn. 12. The maximum concentration of ammonia at the stns. 9 to 11 were in the month of February except at stn. 11 bottom where it was in January. The corresponding surface values were 41.66, 40.72 and 55.49 and bottom values were 41.99, 57.20 and 40.16. At stn. 12, the maximum surface value (116.06) was in March and bottom value (108.70) in February. The ammonia concentration in the upstream of the effluent discharge point (stn. 13) was very low and ranged between 0.0 and 5.09 in the water column. At barmouth (stn. 14), the values ranged from 0.0 to 5.53 for surface and 0.0 to 22.62 for bottom where the maximum values were in January.

The average values for monsoon was low compared to pre-monsoon and post-monsoon at all stations except at stns. 6 and 7 (sewage area) and stn. 14 (barmouth). Stns. 1 to 4 showed maximum variation between seasons. Here for monsoon the average values were < 50 whereas for pre-monsoon the average values were in the range of 132.08 to 154.41. At stn. 5, The pre-monsoon, monsoon and post-monsoon averages were 73.52, 5.63 and 27.16 for surface and 45.40, 7.12 and 23.97 for bottom respectively. At stns. 6 and 7, the post-monsoon values were high compared to pre-monsoon and monsoon. The average values during pre-monsoon, monsoon and post-monsoon were 4.36, 0.73 and 9.82 for surface and 6.40, 0.76 and 9.42 for bottom respectively at stn. 6. The corresponding values at stn. 7 were 5.68, 1.20 and 9.10 for surface and 2.64, 1.74 and 8.13 for bottom. Towards the northern limb, the maximum average value for all the seasons were at stn. 12, where the values for pre-monsoon, monsoon and post-monsoon were 75.72, 21.86 and 39.82 for surface and 56.38, 1.97 and 31.70 for bottom respectively. The corresponding values at stn. 11 were 31.01, 11.47 and 29.69 for surface and 24.42, 8.70 and 30.34 for bottom. For all the other stations in the northern limb the average for all the 3 seasons fall within the range of 10 and 30. The lowest seasonal averages were observed at stn. 13, where the pre-monsoon, monsoon and post-monsoon averages were 1.96, 0.07 and 0.98 for surface and 1.52, 0.65 and 1.27 for bottom respectively. At stn. 14, the average values were 1.26, 0.48 and 3.11 for surface and 1.19, 0.54 and 5.93 for bottom during pre-monsoon, monsoon and post-monsoon respectively.

The annual range in ammonia in the water column were 0.17 to 167.56 (av. 92.15) at stn. 1 to 4, 0.22 to 139.57 (av. 30.47) at stn. 5, 0 to 24.3 (av. 5.00) in the sewage discharge site, 0 to 116.06 (av. 15.74) in the northern limb and 0 to 22.62 (av. 2.09) in the barmouth. The annual range in ammonia for the entire study area was between 0 to 167.56 with an annual average of 29.09.

Phosphate-P (µmol/l)

At stns. 1 to 4 in the southern limb the concentrations of phosphate were high compared to other stations. Levels of phosphate were low from June to December, increased steadily from January with a maximum concentration during this period in the water column. The values from stn. 1 to 4 were 148.47, 149.83, 150.51 and 150.70 respectively at surface and the corresponding values at bottom were 147.41, 148.72, 150.65 and 148.33. The minimum values at stn. 1 was 1.36 at surface (October) and 8.00 at bottom (June) and at stn. 2 the values were 12.73 (October) and 17.97 (December) respectively. The lowest value was in December and highest in January in the water column at stn. 3 and 4. The values ranged between 12.07 (December) and 150.51 (January) at surface and 11.82 (December) and 150.65 (January) at bottom at stn. 3. At stn. 4, the ranges were 10.93 to 150.70 at surface and 11.84 to 148.33 at bottom, the lowest values being in December and the highest in January. At stn. 5, higher values were noticed in June, January & May with a maximum value of 25.60 and 32.72 in the water column in May. The minimum values were 1.59 (December) and 1.69 (March) at surface and bottom respectively. In the sewage area, at stns. 6 and 7 minimum values observed were in December which was <1 and high values were observed only in May with a maximum of 33.29 and 43.99 at stn. 6 and 34.89 and 39.01 at stn. 7 in the water column. In the northern limb from stns. 8, 9 and 10 the maximum levels of phosphate observed was in May and these values were 20.33, 21.39 and 20.68 respectively at surface and the corresponding values in the bottom were 20.50, 20.93 and 20.80. All the other values were <5 except a value of 7.54 at stn. 10 bottom in December and the minimum values were <1. At stn. 11 and 12 the maximum concentrations were in February with high values of 30.98 and 30.77 at stn. 11 and 25.76 and 29.91 at stn. 12 in surface and bottom respectively. At stn. 13 the values fall in range of 0.25 to 20.07 at surface and 0.15 to 20.03 at bottom. At stn. 14 the minimum values were 0.44 at surface in April and 0.45 at bottom in July and the maximum values observed were 32.86 at surface and 32.77 in the bottom during May.

The observations showed that the average seasonal values were low during monsoon compared to pre-monsoon and post-monsoon at stn. 1, 2 and 3. At stn. 1 the average pre-monsoon, monsoon and post-monsoon values were 111.76, 18.81 and 64.18 at surface and 121.85, 18.52 and 66.39 at bottom respectively. The corresponding values at stn. 2 were 101.94, 25.36 and 68.45 at surface and 98.26, 26.68 and 71.24 at bottom. The average pre-monsoon, monsoon and post-monsoon values were 103.90, 25.13 and 61.25 for surface and 89.03, 25.54 and 61.53 for bottom respectively at stn. 3. At stn. 4 the average monsoon values in the surface and bottom (26.81 & 26.23) were lower than pre-monsoon (72.35 & 65.28) and post-monsoon (56.86 & 54.67) seasons. At stn. 5 also the post-monsoon values (8.99 and 7.61) were lower than pre-monsoon (11.33 and 13.07) and monsoon (9.17 and 14.06). In the sewage area at stn. 6 and 7 pre-monsoon values were higher than monsoon and post-monsoon. At stn. 6, the average pre-monsoon values for the surface and bottom were 9.96 and 13.38 whereas the monsoon and post-monsoon values were 6.46 and 5.16 and 2.08 and 2.32 respectively. At stn. 7, the corresponding values were 10.49 and 11.64 for pre-monsoon, 5.93 and 6.20 during monsoon and 2.04 and 2.37 during post-monsoon. The seasonal variations in the phosphate concentration were comparatively low in the northern limb and surface and bottom values did not show much difference. The seasonal average for the water column of different stations in this limb varied from 5.62 to 16.84 (av. 9.86), 2.24 to 11.18 (av. 4.54) and 0.67 to 8.54 (av. 4.17) during pre-monsoon, monsoon and post-monsoon respectively. The values were slightly high in the effluent discharge site (stns. 11 and 12). At stn. 14 the phosphate levels for the surface and bottom were 8.93 and 8.90 during pre-monsoon, 6.61 and 1.91 during monsoon and 1.63 and 2.31 during post-monsoon.

The annual range in phosphate levels in the water column were 1.36 to 150.70 (av. 61.34) at stns 1 to 4, 1.59 to 32.72 (av. 10.71) at stn. 5, 0.51 to 43.99 (av. 6.50) for the sewage discharge area, 0.15 to 30.98 (av. 6.33) in the northern limb and 0.23 to 32.86 (av. 5.05) in the barmouth. The phosphate concentration for the entire study area ranged annually from 0.15 to 150.70 with an average of 17.99.

Chlorophyll `a' (mg/m^3)

In general stations in the southern limb registered high pigment content compared to other stations and the values were very low in the northern limb through out the observations. In the upstream stations of southern limb the minimum values observed were 3.87 and 3.70 in the water column at stn. 1 in August, 9.98 at surface (September) and 8.14 at bottom (June) at stn. 2 and 9.37 and 8.38 at stn. 3 in the water column in June. The maximum values of 151.83 at surface and 85.74 at bottom were observed at stn. 2 in January and these values decreased towards upstream and downstream of this station. Towards upstream at stn. 1, the values were 84.13 and 89.82 in the water column in January with a decrease in February and again increased in March. At stn. 3, the maximum values observed was in February, 77.68 at surface and 96.61 at bottom. At stn. 4, the chlorophyll values fall within the range of 6.18 to 79.89 at surface and 3.63 to 69.43 at the bottom. Stn. 5 showed low values of 3.57 at surface in August and 6.21 at bottom in March and high values of 72.06 and 30.10 in the water column in January.

In the sewage area, the minimum concentrations were observed in September at stn. 6 (2.51 and 2.31) as well as at stn. 7 (2.03 and 2.24) for surface and bottom. The maximum chlorophyll was noticed in April in the surface and bottom (73.49 and 42.54) at stn. 6 whereas at stn. 7 the maximum surface value was in March (49.79) and bottom value in July (41.29).

In the northern limb, towards upstream the values were found to be decreasing. The low values observed in the water column were 3.77 and 2.92 at stn. 8 and 1.53 and 1.94 at stn. 9 whereas the high values noticed were 47.46 and 35.41 at stn. 8 and 31.08 and 30.49 at stn. 9. The annual ranges of chlorophyll at stn. 10 were 0.88 to 17.40 at surface and 0.37 to 17.65 at bottom. The corresponding values at stn. 11 were 0.41 to 21.24 and 0.88 to 18.30. At stns. 12 and 13 the minimum concentrations in surface and bottom were in August, 0.44 and 0.44, at stn. 12, and 1.29 and 0.85 at stn. 13. The maximum concentrations were in July at stn. 12 (17.60 and 17.62) and stn. 13 (17.21 and 18.47) in the surface and bottom respectively.

In barmouth a minimum concentration of 2.11 and 1.08 and a maximum of 39.59 and 40.90 were observed in the surface and bottom in June and July respectively.

The seasonal averages showed that at stn. 1, pre-monsoon, monsoon and post-monsoon averages were 38.01, 10.99, and 31.20 for surface and 26.57, 10.16 and 33.26 for bottom respectively. The corresponding values at stn. 2 were 42.90, 14.18 and 57.35 for surface and 42.40, 13.22 and 34.73 for bottom. Stn. 3 and 4 showed maximum average values during pre-monsoon compared to monsoon and post-monsoon. The values at stn. 3 were 53.72, 13.76 and 18.53 for surface and 37.22, 13.14 and 15.26 for bottom, during pre-monsoon, monsoon and post-monsoon seasons respectively. The corresponding values at stn. 4 were 49.93, 13.48 and 7.76 at surface and 34.26, 11.56 and 10.83 at bottom. At stn. 5, the premonsoon, monsoon and post-monsoon averages were 16.74, 18.20 and 25.67 at surface and 17.50, 22.57 and 16.18 at bottom.

In the sewage area, the minimum average values noticed were during post-monsoon; 8.73 and 8.78 at surface and 9.80 and 8.85 at bottom at stn. 6 and 7 respectively. The pre-monsoon averages were the maximum at stn. 6 and 7 and the corresponding values were 39.15 and 28.31 at surface and 27.19 and 23.24 at bottom.

In the northern limb, at stn. 8, the pre-monsoon, monsoon and post-monsoon averages were 27.63, 11.26 and 12.09 at surface and 17.40, 11.78 and 8.18 at bottom respectively. The corresponding values at stn. 9 were 13.18, 10.91 and 15.57 at surface and 16.51, 8.22 and 12.38 at bottom. At stns. 10 to 13 the minimum average values were during pre-monsoon except at stn. 10 and 11 bottom, where the minimum averages were during post-monsoon season (2.18 at stn. 10 and 2.62 at stn.11). The maximum average values were during monsoon except at stn. 11 surface (6.57) where it was during post-monsoon. The maximum average at stn. 10 to 13 were 6.78, 5.38, 5.91 and 8.86 at surface and 5.43, 5.35, 5.49, 9.06 at bottom respectively during monsoon.

In barmouth (stn. 14) the minimum average values were during post-monsoon at surface (6.30) and during pre-monsoon at bottom (8.05). The maximum values were during pre-monsoon (13.38) and monsoon (15.44) at surface and bottom respectively.

The seasonal averages for the different stations in the southern limb showed comparatively high values during pre-monsoon and post-monsoon. The averages varied from 26.57 to 53.72 (av. 40.63), 10.16 to 14.18 (av. 12.56) and 7.76 to 57.35 (av. 26.11) during pre-monsoon, monsoon and post-monsoon.

At stn. 5, the corresponding values were between 16.74 and 17.50 (av. 17.2), 18.20 and 22.57 (av. 20.38), 16.18 and 25.67 (av. 20.93). In the sewage discharge site the corresponding pigment values varied from 23.24 to 39.15 (av. 29.23) during pre-monsoon, 14.62 to 19.05 (av. 16.76) during monsoon and 8.73 to 9.80 (av. 9.04) during post-monsoon. Northern limb stations registered average values ranging from 1.32 to 27.63 (8.27) 5.22 to 11.78 (av. 7.86) and 2.18 to 15.57 (av. 6.89) during pre-monsoon monsoon and post-monsoon. In barmouth area the average chlorophyll fall within the range of 8.05 to 13.38 (av. 10.71), 12.62 to 15.44 (av. 14.03) and 6.3 to 12.48 (av. 9.39) during the three seasons respectively. The annual range in chlorophyll was 3.63 to 151.83 (av. 26.43) in the southern limb, 3.57 to 72.06 (av. 19.47) at stn. 5, 2.03 to 73.49 (18.33) in the sewage discharge point, 0.35 to 47.46 (av. 7.79) in the northern limb and 1.08 to 40. 90 (av. 11.38) at the barmouth.

The chlorophyll content for the entire study area ranged annually between 0.35 and 151.83 with an annual average of 16.68.

Particulate Organic Carbon (mg/l)

During the investigation period no definite pattern was noticed in the temporal and spatial distribution of POC and the values were comparatively low at the stations in the northern limb. In the southern limb at stn. 1, the POC ranged between 0.38 (December) and 8.57 (November) at the surface and 1.26 (June) to 14.11 (November) at the bottom. At stn. 2, the minimum values observed were 0.63 (April) and 0.76 (June) and the maximum of 8.82 (November) and 8.59 (November) in the surface and bottom respectively. Stn. 3, registered low value of 1.64 for surface and 0.25 for bottom during September and October and increased to 7.40 in the surface and 12.35 in bottom during March and November respectively. At stns. 4 and 5 the surface values ranged from 0.25 (October) to 8.57 (May) and 1.26 (August) to 19.91 (May) respectively. The corresponding bottom values were 1.26 to 8.57 and 1.26 to 11.59, the minimum values recorded during October and July, while both the maximum values were in November. In the sewage area at stn. 6 the minimum values observed were 0.21 at surface (December) and 0.13 at bottom (March), whereas the maximum values observed were 5.67 and 6.30 in the surface and bottom in July. The POC ranged from 0.0 (June) to 10.08 (July) at surface and 0.13 (December) to 8.57 (July) at bottom at stn. 7. In the northern limb the surface POC values ranged annually from 0.63 (December) to 9.45 (July) at stn. 8 and 0.0 (June) to 3.15 (April) at stn. 9 and 0.13 (April) to 7.56 (July) at stn. 10, whereas the bottom values fall in the range of 0.76 (June) to 3.28 (July & May), 0.0 (June) to 4.91 (July) and 0.13 (September) to 3.53 (July) respectively. At stns. 11 to 13, the effluent discharge site the values were very low and ranged between 0.0 to 0.13 in the surface and 0.0 to 0.05 in the bottom. The maximum values observed at the surface were 6.30, 3.15 and 8.19 and at the bottom the values were 4.16, 3.15 and 5.67 respectively and these values were observed in July. In the barmouth region the minimum value of 0.13 in the surface and bottom was recorded in March and the peak value for surface and bottom (5.29 and 11.34) were in July.

Seasonal variation in the POC content showed that the values were moderate and more or less comparable during pre-monsoon and post-monsoon. Monsoonal averages for different stations were low and ranged between 1.16 and 3.06 (av. 2.30), whereas pre-monsoon averages were between 3.03 and 5.26 (av. 4.22) and post-monsoon values were in the range of 2.19 and 6.65 (av. 3.66) in the southern limb. At stn. 5 the corresponding values ranged from 3.62 to 6.33 (av. 4.98), 2.11 to 3.17 (av. 2.64) and 4.14 to 4.85 (av. 4.49) during the three seasons. In the sewage discharge site the averages fluctuated between 0.82 and 3.31 (av. 1.80), 2.33 and 3.88 (av. 3.11) and 1.52 and 2.98 (av. 2.03) during pre-monsoon, monsoon and post-monsoon. In the northern limb stations monsoonal averages were more compared to other seasons, and the values fluctuated between 0.50 and 2.24 (av. 1.30), 0.95 and 4.06 (av. 1.97) and 0.63 and 2.14 (av. 1.36) for the respective seasons. Barmouth registered high values during monsoon and averages were 0.76 to 1.11 (av. 0.93) for pre-monsoon, 2.96 to 4.95 (av. 3.96) and 2.14 to 2.45 (av. 2.49) for the respective seasons.

The annual range in POC for the water column was 0.25 to 14.11 (av. 3.39) at stns 1 to 4, 1.13 to 19.91 (av. 4.04) at stn. 5, 0.0 to 10.08 (av. 2.31) for the sewage discharge site, 0.0 to 9.45 (av. 1.54) for the northern limb and 0.13 to 11.34 (av. 2.39) for the barmouth. The entire study area hold a POC content ranging between 0.00 and 19.91 with an annual average of 2.73.

Suspended Load (mg/l)

Temporal and spatial distribution of suspended load showed high values at all stations during monsoon months and comparatively low values during pre-monsoon months. At stn. 1, the suspended load ranged between 14.00 (February) and 880.80 (June) at the surface and 12.00 (January) and 515.40 (September) at the bottom, where as at stn. 2 the values fall in the range of 22.40 (March) to 826.00 (June) at surface and 15.40 (February) to 942.80 (June) at the bottom. The minimum values for surface and bottom were noticed during pre-monsoon months and maximum during the monsoon months. The minimum surface values were in February at stn. 3 (7.40) and at stn. 4 (6.00) where as at stn. 5 it was in March (10.40). The maximum values were 491.60, 523.20 and 1365.20 respectively at all the stations in June. At the bottom the values ranged from 6.00 (February) to 540.00 (June) at stn. 3, 38.80 (March) to 471.50 (August) at stn. 4 and a low value of 31.20 (March) increased to a very high value of 2440.00 at stn. 5.

In the sewage area the minimum surface values were 15.80 (February) and 11.00 (November) at stns. 6 and 7 respectively, whereas the corresponding maximum values were 513.60 and 905.60 respectively both in June. At stn. 6, the bottom values fall in the range of 16.80 (December) to 590.30 (September) while the corresponding range at stn. 7 were 25.60 (November) to 430.40 (June).

Towards the northern limb, at stns. 8 to 12, the suspended load was very low from January to May and thereafter the values increased in the water column. At stn. 8 the values ranged between 5.60 (March) to 728.80 (June) and 15.00 (November) to 1189.20 (June) at the surface and bottom respectively. The corresponding values at stn. 9 were 2.60 (February) to 730.40 (June) and 4.00 (February) to 1286.40 (June). Stn. 10 showed the minimum values of 7.20 (March) and 7.60 (May) and the maximum suspended load of 1102.60 and 1328.40 in the water column. At stn. 11, the minimum values were observed in February (2.40 and 3.80) and maximum in June (552.80 and 679.20) in the water column. At stn. 12, an annual range of 2.40 (April) to 650.00 (June) at surface and 4.60 (March) to 614.40 (June) at bottom were observed where the corresponding values at stn. 13 were 5.80 (February) to 580.80 (June) and 1.80 (November) to 696.00 (June).

At the barmouth the minimum values observed were 15.20 (March) at surface and 32.20 (January) at bottom. The maximum values were 317.52 and 553.12 in the water column in September.

The seasonal averages showed that the monsoonal averages were always higher compared to pre-monsoon and post-monsoon at all the station. In the southern limb at stn. 1 to 5 the minimum seasonal averages were during pre-monsoon period and these values were 56.15, 50.86, 35.85, 46.10 and 58.35 respectively at the surfaces, where the corresponding maximum averages during monsoon were 391.82, 480.50, 202.01, 276.71 and 523.61. At the bottom the minimum average values were 62.70, 111.90, 60.55, 62.95 and 96.35 during pre-monsoon and the maximum averages of 248.13, 398.77, 267.36, 281.32 and 803.81 during monsoon at the stn. 1 to 5 respectively.

In the sewage area at stns. 6 & 7, the minimum averages were during pre-monsoon and the corresponding values were 33.30 & 58.40 at the surface and 63.30 & 107.60 at the bottom; where as the maximum average values were during monsoon; 362.40 & 542.11 at the surface and 430.10 & 395.02 at the bottom.

In northern limb also, the minimum average values observed were during pre-monsoon and the maximum during monsoon. At stns. 8 to 13 minimum seasonal averages was minimum at stn. 11 (6.00 at surface and 7.00 at the bottom) during pre-monsoon whereas the maximum average was observed at stn. 10 surface (448.17) and stn. 9 bottom (541.73) during monsoon.

In barmouth (stn. 14), the averages for pre-monsoon, monsoon, and post-monsoon were 42.65, 233.23 and 100.95 respectively at the surface and the corresponding bottom values were 52.10, 333.03 and 112.85.

The seasonal averages for suspended load in the water column at different stations in the southern limb varied from 35.85 to 111.90 (av. 60.74), 202.01 to 480.50 (av. 317.94) and 60.60 to 174.0 (av. 138.52) during pre-monsoon, monsoon and post-monsoon respectively. At stn. 5 the corresponding averages were 58.35 to 96.35 (av. 77.35) during pre-monsoon, 523.61 to 803.81 (av. 663.71) during monsoon and 128.30 to 265.90 (av. 197.10) during post-monsoon. Sewage discharge site showed a range of 33.30 to 107.60 (av. 65.63), 362.40 to 542.11 (av. 432.41) and 104.15 to 174.45 (152.54) during the respective seasons.

In the northern limb stations the seasonal averages varied from 6.0 to 67.40 (av. 23.82), 333.42 to 541.73 (av. 411.30) and 35.65 to 191.40 (av.106.05) during pre-monsoon, monsoon and post-monsoon. Barmouth registered a range between 46.65 and 52.10 (av. 69.55), 233.23 to 333.03 (av. 283.13) and 100.95 and 112.85 (av. 106.50) during the three seasons respectively.

The annual values in suspended load varied from 6 to 942.80 (av. 171.57) at stns. 1 to 4 in the southern limb, 10.4 to 2440.00 (av. 312.72) at stn. 5, 11.0 to 905.6 (av. 200.24) in the sewage discharge site, 1.80 to 1328.40 (av. 180.43) in the northern limb and 15.20 to 553.12 (av. 145.80) in the barmouth area. The annual range for the entire area was between 1.80 and 2440.00 with an annual average of 202.15.

Attenuation coefficient (`K' value)

At stn. 1 & 2 the attenuation coefficient ranged between 1.5and 5.0, whereas at stn. 3 & 4 the values reduced to 1.2 to 3.0. At stn. 5 the values were in the range of 1.5 (June & March) and 7.5 (December). In the sewage area the `K' value was high and reached up to 6.0 in June, whereas a highest value of 15.0 was noticed at stn. 7. Stations in the northern limb (stns. 8 to 13) showed the maximum value of 5.0 whereas the minimum value in the downstream stations (stns. 8 to 10) was 1.0 and still reduced to 0.75 in the upstream stations (stns. 11 to 13). At stn. 14, the values were in the range of 0.86 and 3.0

The results showed that higher attenuation coefficient was observed during the monsoon season compared to pre-monsoon and post-monsoon in the sewage area, northern limb and barmouth. In the southern limb all the seasons showed almost the same trend and the values ranged between 1.0 & 3.0 during pre-monsoon, 1.2 & 3.0 during monsoon and 1.2 & 7.5 during post-monsoon. The corresponding ranges were 1.5 & 3.0, 1.5 & 15.0 and 1.2 & 2.0 in the sewage area, 0.6 & 2.0, 2.0 & 5.0 and 1.0 & 5.0 in the northern limb and 1.0 & 1.5, 0.86 & 2.0 and 1.5 & 3.0 in the barmouth.

3.3.2 Sediment characteristics (Figs. 3.14 – 3.17 & Table 3.2)

Grain size distribution (%)

At stn. 1, except June & October, substratum was predominated by clay forming 53.95 to 83.80 followed by 6.49 to 34.26 silt. The percentage of sand, silt and clay was 64.69, 13.21 and 22.10, in June and 52.03, 0.22 and 47.95 in October respectively. The substratum was in a different proportion at stn. 2, i.e. silty clay from June to September, sandy clay in October, December and May, clayey sand in April and clayey silt in November and February & March. At stn. 3, except September and November, the substratum was predominated by sand (50.98 to 77.24) followed by clay (22.75 to 49.00). In September and November, the proportion of sand, silt and clay was 42.08, 0.22 & 57.70 and 26.90, 7.80 & 65.30 respectively. The sand predominated in most of the months at stn. 4 also except in July, August, October and March. The substratum was clayey sand forming 50.00 to 71. 93% sand and 28.05 to 49.70% clay. In July, August and March the substratum was silty clay with the sand, silt and clay percentage of 7.22, 13.03 & 79.75, 26.16, 27.74 & 46.10 and 24.03, 24.27 & 51.70 respectively. In October, the sand, silt & clay percentage were 37.80, 0.10 & 62.10. Though the clay dominated forming 43.00 to 86.40 in all months except February, monthly variations were noticed in the percentage composition of sand and silt at stn. 5. In February clayey silt substratum was observed and the sand, silt & clay percentage were 4.84, 60.36 & 34.80. At stn. 6, except in April, May & June rest of the months had sediment predominated by sand portion forming 40.91 to 75.60, whereas the silt and clay varied from 0.01 to 33.45 and 5.80 to 68.10 respectively. In April, May and June, the sand percentage were 15.35, 28.13 and 39.04 respectively. At stn. 7 also the sand predominated throughout the investigation period except in July, August, September, October, December and May where the sand, silt & clay percentage were 44.75, 5.15, & 50.10, 24.38, 37.87 & 37.75, 45.40, 0.05 & 54.55, 9.67, 16.08 & 74.25, 17.76, 21.49 & 60.75 and 48.37, 0.18 & 51.45 respectively. The rest of the months showed the substratum predominated by sand with a percentage varying from 48.57 to 71.52 followed by 15.20 to 42.00 clay and 0.07 to 34.94 silt. At stn. 8, from May to November except in July the substratum was sandy clay whereas in July and December to April, the clayey sand substratum was noticed. For the entire investigation period, sand, silt & clay varied from 11.29 to 72.12, 0.03 to 19.61 and

27.60 to 88.65 respectively. At stn. 9, the substratum was clayey sand except in June, August and October where the sand, silt & clay percentage were 32.05, 16.65 & 51.30, 35.81, 3.39 & 60.80 and 28.40, 1.05 & 70.55 respectively. In the rest of the months, the respective ranges for sand, silt and clay percentage were 53.47 to 80.51, 0.01 to 11.05 and 18.80 to 46.50. In June and November the sand, silt & clay percentage were 21.81, 27.49 & 50.70 and 19.32, 23.39 & 57.29 at stn. 10. The substratum was sandy in August, September and January and the corresponding sand percentages were 88.61, 80.04 & 81.58. In April and May sand and clay showed almost same composition and the sand, silt and clay percentage were 44.10, 11.25 & 44.65 in April and 51.51, 1.24 & 48.45 in May. The rest of the months showed the clayey sand substratum, sand percentage varied from 51.51 to 73.59, silt from 0.13 to 15.75 and clay from 26.38 to 36.25. At stn. 11, the substratum was predominated by sand and the values ranged from 50.31 to 99.90, whereas the silt and clay percentage were 0.01 to 8.68 and 0.80 to 49.45. The substratum was clayey sand in all the months at stn. 12; except in July, October & May where it was sandy clay. The sand, silt and clay percentage varied from 30.60 to 94.48, 0. 00 to 23.43 and 5.00 to 69.40. At stn. 13, the substratum was clayey sand throughout the investigation period. The ranges in sand, silt and clay were between 51.01 & 90.89, 0.01 & 8.36 and 9.10 & 48.55. At stn. 14, monthly variation was well pronounced in the composition of sediment. The clay predominated in all the months, except June & August, whereas in December & February the substratum was silty clay and the respective percentage of sand, silt & clay were 16.70, 23.60 & 59.70 and 32.37, 33.63 & 34.00. The sand, silt & clay percentage during the investigation period ranged respectively from 16.24 to 52.28, 0.07 to 33.63 and 21.20 to 83.35.

Seasonal variation in the composition of sediment differs from station to station. At stn. 1 & 2, during pre-monsoon, monsoon & post-monsoon, the clay percentage predominated. Stn. 3, hold clayey sand throughout the observation whereas at stn. 4 the substratum was sandy clay during monsoon and in the other seasons it was clayey sand. At stn. 5 sandy clay substratum was registered throughout the year. At stn. 6 & 7 the sand and clay showed almost equal share during all the three seasons. At stn. 8, the substratum was sandy clay during pre-monsoon and monsoon whereas in post-monsoon the substratum was clayey sand.

At stn. 9 to 13 clayey sand substratum was noticed during the investigation period. At stn. 14 sand and clay showed equal portion during pre-monsoon and monsoon and during post-monsoon the substratum was dominated by clay. In general, clay percentage was > 50 at stn. 1, 2, 5, 8 and 14 whereas sand percentage dominated at stns. 3, 4, 6, 7 and 9 to 13.

Organic matter (%)

In the southern limb at stns. 1, 2 and 3 the minimum values for organic matter were 0.95 (October), 1.13 (April) and 0.12 (July) respectively where as the corresponding maximum values were 10.41 (February), 10.58 (July) and 10.46 (February). At stn. 4 the values ranged from 0.95 (February) to 6.72 (January). Stn. 5 registered higher values ranging between 1.90 (September) and 10.23 (August). In the sewage discharge site the values varied from 0.06 (March) to 10.23 (August), at stn. 6 and the corresponding value at stn. 7 were 1.22 (November) and 5.82 (January). In the northern limb, the downstream station showed the minimum value of 0.32 (March) and maximum of 5.82 (February). At stns. 9 to 11, the minimum values were 0.18 (December), 0.06 (July to October) and 0.06 (August, September and March) respectively whereas the corresponding maximum values were 7.14 (February), 6.72 (June) and 6.55 (June). At stn. 12, compared to the downstream stations the values were high and ranged between 0.06 (June, August and February) and 9.75 (January). At stn. 13, the values again decreased and varied from 0.06 (July, September and May) to 5.11 (January). In the barmouth (stn. 14), the values were in the range of 1.78 to 4.22 minimum being in April and maximum in December.

Seasonal variation in the organic matter showed that the values were more or less comparable during the different seasons. In the southern limb the average values for different stations ranged from 1.60 to 5.09 (av. 3.33), 2.58 to 5.45 (av.3.85), and 3.83 to 6.64 (av. 4.94) during pre-monsoon, monsoon and post-monsoon respectively. The corresponding values at stn. 5 were 4.76, 5.16 and 3.88. In the sewage discharge site the averages fluctuated between 2.01 and 4.03 (av. 3.74), 3.80 and 5.90 (av. 4.89) and 2.52 and 4.14 (av. 3.33) during pre-monsoon, monsoon and post-monsoon. In the northern limb the averages varied from 0.23 to 5.28 (av. 2.49), 1.32 to 3.63 (av. 2.57) and 1.76 to 7.43 (av. 3.61) for the respective seasons.

Barmouth registered slightly high average values during post-monsoon and averages were 2.86 for pre-monsoon, 3.49 for monsoon and 3.69 for post-monsoon.

The annual range for organic matter in the southern limb varied from 0.12 to 10.58 (av. 4.28). The values at stn. 5 were between 1.90 and 10.23 (av. 4.60). The corresponding values in the sewage discharge site showed a range of 0.06 to 10.23 (av. 3.75). Northern limb recorded wide range of organic matter between 0.06 and 9.75 (av. 2.87). Barmouth region registered a value between 1.78 and 4.22 (av. 3.33).

The annual range in organic matter of the entire study area was between 0.06 (stn. 6, 10, 11, 12 & 13) and 10.58 (stn. 2) with an average of 3.77.

Energy content (J/g dry weight)

The energy content calculated from the organic matter varied from station to station and between months. In the southern limb at stns. 1, 2 and 3 the minimum values were 205.63 (October), 244.30 (April) and 25.70 (July) respectively where as the corresponding maximum values were 2248.56 (February), 2286.79 (July) and 2261.09 (February). At stn. 4 the values ranged from 2055.63 (February) to 1451.95 (January). Stn. 5 registered higher values ranging between 411.05 (September) and 2209.68 (August). In the sewage discharge site the values varied from 12.96 (March) to 2209.68 (August), at stn. 6 and the corresponding values at stn. 7 were 263.30 (November) and 1259.06 (January). In the northern limb, the downstream station (stn. 8) showed the minimum value of 69.98 (March) and maximum of 1259.06 (February). At stns. 9 to 11, the minimum values were 38.66 (December), 12.96 (July to October) and 12.96 (August, September and March) respectively whereas the corresponding maximum values were 1541.59 (February), 1451.95 (June) and 1416.31 (June). At stn. 12, compared to the downstream stations the values were high and ranged between 12.96 (June, August and February) and 2106.86 (January). At stn. 13, the values again decreased and varied from 12.96 (July, September and May) to 1104.84 (January). In the barmouth (stn. 14), the values were in the range of 385.34 to 912.38 minimum being in April and maximum in December.

Seasonal variation in the energy content showed that the values were more or less comparable during the different seasons. In the southern limb the average values for different stations ranged from 531.79 to 1098.97 (av. 766.13), 558.84 to 1178.77 (av.841.56), and 830.36 to 1745.66 (av. 1147.03) during pre-monsoon, monsoon and post-monsoon respectively. The corresponding values at stn. 5 were 1027.89, 1332.99 and 839.87. In the sewage discharge site the averages fluctuated between 433.62 and 873.77 (av. 653.70), 822.31 and 1275.10 (av.1048.71) and 544.43 and 894.56 (av.719.50) during pre-monsoon, monsoon and post-monsoon. In the northern limb the averages varied from 50.54 to 1141.08 (av. 538.60), 285.93 to 784.62 (av. 556.55) and 380.65 to 1604.34 (av. 746.78) for the respective seasons. Barmouth registered slightly high average values during post-monsoon and averages were 616.68 for pre-monsoon, 754.87 for monsoon and 798.34 for post-monsoon.

The annual range for energy content at stns. 1 to 4 in the southern limb varied from 25.70 to 2286.79 (av. 918.24). The values at stn. 5 were between 411.05 and 2209.68 (av. 1066.92). The corresponding values in the sewage discharge site showed or range of 12.96 to 2209.68 (av.807.30). Northern limb recorded wide range of organic matter between 12.96 and 2106.86 (av. 613.98). Barmouth region registered a value between 385.34 and 912.38 (av. 723.30).

The annual range in energy content of the entire study area was between 12.96 (stn. 6, 10,11, 12 & 13) and 2286.79 (stn. 2) with an average of 825.95.

3.3.3. Bottom fauna (Figs. 3.18 – 3.49 & Tables 3.3 – 3.5)

Standing stock (Density – No./m^2 & Biomass – g/m^2) - Fig. 3.18 & Tables 3.3 - 3.4

The benthic density was very low at stn. 1 and the total number of organisms obtained during the investigation period were 63 with a biomass of 0.29g. The average annual benthic density and biomass were 0.5/m^2 and 0.024 g/m^2 respectively. The seasonal averages for benthic density was 5/m^2during pre-monsoon and 11/m^2 post-monsoon and biomass was 0.025g/m^2 during pre-monsoon and 0.05g/m^2 during post-monsoon.

Benthic fauna was present only during June at stn. 2 and the density and biomass were $84/m^2$ and $0.34g/m^2$ and the averages were $7/m^2$ and $0.028g/m^2$.

Station 3 recorded the total number of 1020064 specimens in the entire study period with an annual average density of $85005/m^2$. The total biomass (shell on weight) recorded was $471304.58g/m^2$ (av. $39275.38g/m^2$) and by removing the shells of bivalves the biomass was 462771.17 (av. $38564.26g/m^2$). The pre-monsoon, monsoon and post-monsoon averages for density were $158764/m^2$, $31638/m^2$ and $64615/m^2$ respectively. The average biomass including shells for pre-monsoon, monsoon and post-monsoon were $85171.47g/m^2$, $4770.00g/m^2$ and $27884.68g/m^2$ respectively. Excluding shells the average biomass during monsoon was 2636.65g/m2 whereas no biomass excluding shell was taken during pre-monsoon and monsoon due to the presence of only small gastropods.

At stn. 4, the total number recorded during the study period was 23035 with an annual average of $1919/m^2$. The total biomass (shell on weight) recorded was 45273.71g (av. $3772.81g/m^2$) and excluding shells the biomass was 6643.13 (av. $553.59g/m^2$). The seasonal averages showed that the density was high during pre-monsoon ($2577/m^2$) compared to monsoon ($1461/m^2$) and post-monsoon ($1721/m^2$). The seasonal averages of biomass (including shells) during pre-monsoon, monsoon and post-monsoon were $5140.53g/m^2$, $1089.77g/m^2$and $5088.14g/m^2$respectively. The corresponding values for excluding shells were $770.16g/m^2$, $187.67g/m^2$and $702.95g/m^2$.

A total benthic number of 8210 was recorded during the study period with an annual average of $684/m^2$ at stn. 5. The density varied from 21 to $2503/m^2$. The monsoon average was 5.8 times higher ($1107/m^2$) compared to pre-monsoon ($189/m^2$) and 1.5 times higher than post-monsoon ($757/m^2$). The total biomass recorded was 84.28g with an annual range 0.35 to 35.10 g/m^2 (av. $7.02g/m^2$). The seasonal averages during pre-monsoon, monsoon and post-monsoon were $10.11g/m^2$, $7.49g/m^2$ and $3.47g/m^2$ respectively.

The total number recorded at stn. 6 were 13245 with an annual average of 1104/m^2. The average for monsoon (1537/m^2) was higher compared to pre-monsoon (1057/m^2) and post-monsoon (718/m^2). The total biomass recorded was 60.03g with an annual average of 5.00g/m^2. The seasonal averages were high during post-monsoon (8.12g/m^2) compared to pre-monsoon (2.40g/m^2) and monsoon (4.50g/m^2).

At stn. 7 the total density recorded during the study period was 20159 (av. 1680/m^2). Monsoon average (2575/m^2) showed almost two fold increase than pre-monsoon (1062/m^2) and post-monsoon (1403/m^2). The total benthic biomass was 71.27g (av. 5.94g/m^2). The pre-monsoon, monsoon and post-monsoon averages were 5.49, 5.16 and 7.17g/m^2 respectively.

A total density of 8780 was obtained during the investigation period with an annual average of 732/m^2 at stn. 8. The monsoon values showed two fold increase (1092/m^2) than pre-monsoon (524/m^2) and post-monsoon (580/m^2). The total biomass was 203.63g (av.16.97g/m^2). The seasonal averages observed were 14.55, 18.94 and 17.42g/m^2 during pre-monsoon, monsoon and post-monsoon respectively.

At stn. 9, the total density observed was 11637 with an annual average of 970/m^2. The monsoon average (1097/m^2) was high compared to pre-monsoon (999/m^2) and post-monsoon (814/m^2). The total biomass obtained was 61.08g (av. 5.09g/m^2). The maximum seasonal average was during monsoon (6.53g/m^2) followed by pre-monsoon (4.74g/m^2) and post-monsoon (4.00g/m^2).

The total density was low at stn. 10 (1297) compared to other stations. The annual average was 108/m^2. The seasonal averages showed that the value during pre-monsoon was 319/m^2, which reduced to 5/m2 during monsoon, and no animals were observed during post-monsoon. The total benthic biomass was 5.95g with an annual average of 0.50g/m^2. The seasonal averages during pre-monsoon, monsoon were 1.31g/m^2 and 0.18g/m^2 respectively.

At stn. 11, organisms were noticed only during post-monsoon (av. $94/m^2$). The total density was 376 with an annual average of $31/m^2$. The total biomass was 3.28g with an annual average of $0.27g/m^2$. The post-monsoon average was $0.82g/m^2$.

The total density observed at stn. 12 were 17257 and the annual average was $1438/m^2$. The pre-monsoon, monsoon and post-monsoon averages were 672, 53 and $3590/m^2$ respectively. The total biomass observed was 70.42g with an annual average of $5.87g/m^2$. The monsoon average ($13.68g/m^2$) was high compared to pre-monsoon ($0.57g/m^2$) and post-monsoon ($3.36g/m^2$).

The total density observed at stn. 13 was very low (480) with an annual average of $40/m^2$. The monsoon average ($104/m^2$) was high compared to post-monsoon ($16/m^2$) and no organisms were observed during pre-monsoon. The total benthic biomass was 10.61g with an annual average of $0.88g/m^2$. The monsoon and post-monsoon averages were $1.99g/m^2$ and $0.67g/m^2$ respectively.

Station 14 ranked second in benthic density (831558) with an annual average of $69297/m^2$. The pre-monsoon, monsoon and post-monsoon averages were 205, 25669 and $182016/m^2$ respectively. The total biomass (2728.80g) was also high compared to other stations with an annual average of $227.40g/m^2$. The monsoon average was very high compared to pre-monsoon ($11.70g/m^2$) and post-monsoon ($179.88g/m^2$).

In general the benthic density was very low at stns. 1 (63)and 2 (84) in the southern limb and at stns. 11 (376) and 13 (480) in the northern limb. Peak density was noticed at stn. 3 (1020064) and a second peak at barmouth (831558). The total density at other stations varied from 1297 (stn. 10) to 23035 (stn. 4).

Community structure (Figs. 3.19 – 3.49 & Table 3.5)

Station 1

Polychaetes numbering 63 were the only group constituting 100% of the benthic community. Numerical abundance showed considerably low values due to their occurrence only in October ($42/m^2$) and April ($21/m^2$). Seasonal variation revealed a mean density of $5/m^2$ during pre-monsoon, which increased to $11/m^2$during post-monsoon.

Only one species *Capitella capitata* belonging to the family Capitellidae was noticed and the frequency of occurrence of this species was 2/12in this station.

Station 2

Polychaetes numbering 63 were the dominant group contributing 75% of the benthic community; with a mean value of $5/m^2$. Numerical abundance showed low values due to their low density in July.

Gastropods numbering 21were the other group constituting 25% of the benthic community with a mean value of $2/m^2$.

The seasonal variation showed a mean density of $21/m^2$ during monsoon and no animals were recorded during pre-monsoon and post-monsoon.

Two species of polychaetes namely *Capitella capitata* and *Branchiocapitella singularis* belonging to the family Capitellidae were identified. The frequency of occurrence of both species were 1/12 contributing 100% of the polychaete fauna and showed their presence only in the monsoon months. The density of species recorded was $42/m^2$ and $21/m^2$ for *Capitella capitata* and *Branchiocapitella singularis* respectively.

Gastropods were represented by a single species namely *Littorina littorea* numbering $21/m^2$.

Station 3

Gastropods numbering 1013093 were found to be the dominant group contributing 99.30% of the benthic community with a mean annual value of $84424/m^2$. The frequency of occurrence was 12/12. This high abundance was due to the high density throughout the year, with a maximum of $618800/m^2$ in February followed by $126250/m^2$ in December and $104500/m^2$ in October. The minimum density was observed in June ($1130/m^2$) and the second maximum in April ($2667/m^2$). The seasonal averages showed a maximum density of $158560/m^2$ during pre-monsoon followed by post-monsoon ($64150/m^2$) and reduced to $30564/m^2$ in monsoon. Only one gastropod sp. was recorded with high numerical abundance throughout the study period.

Polychaetes numbering 4719 were the next dominant group contributing 0.45% of the benthic community with an annual average of $393/m^2$. The numerical abundance was low compared to gastropods though the frequency of occurrence was 11/12 and this group was not recorded in June. The maximum density was $2731/m^2$ in August followed by $480/m^2$ in February and $334/m^2$ in December and the minimum was in April ($21/m^2$). The seasonal averages indicated high values during monsoon ($798/m^2$) followed by pre-monsoon ($199/m^2$) and post-monsoon ($183/m^2$).

Lycastis indica, Dendronereis aestuarina and *Perinereis cavifrons* (family – Nereidae), *Prionospio polybranchiata* (family – Spionidae), *Disoma orissae* (family – Disomidae) and *Capitella capitata, Heteromastides bifidus, Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis* (family – Capitellidae) were the 9 species of polychaetes encountered during the study. Out of these *Lycastis indica* occurred frequently (11/12) followed by *Prionospio polybranchiata*, of which the frequency of occurrence was 7/12 and *Dendronereis aestuarina* by 3/12. The species with maximum density (1941) was *Lycastis indica* followed by *Dendronereis aestuarina* (1792) and *Prionospio polybranchiata* (608). The species with minimum density was *Disoma orissae* (21), which occurred only in August, followed by *Heteromastides bifidus* and *Capitella capitata* each contributing $42/m^2$ during August and November respectively. The seasonal abundance showed that the maximum abundance of polychaetes was during monsoon compared to pre-monsoon and post-monsoon.

Next in abundance were bivalves with a total number of 2168 constituting 0.21% of the benthos with an average value of $181/m^2$. The frequency of occurrence was 5/12. They were not present in July and from December to May. November and August contributed higher abundance of $1063/m^2$ and $958/m^2$ respectively compared to the very low value of $21/m^2$ in June and October. The mean value of $271/m^2$ was observed during monsoon and post-monsoon seasons and was absent during pre-monsoon. *Villorita cyprinoides* was the only species of bivalve encountered during the study period.

Chironomids numbering 42 forming 0.02% of the benthos was fourth in abundance with a monthly mean value of $4/m^2$. This group was present with a low density of $21/m^2$ in September and November only and the frequency of occurrence was 2/12.

Amphipods and Planaria worm were the rare groups in this station each numbering 21 and forming 0.01% of the benthic community with a mean value of $2/m^2$. Amphipods were present only in March and Planaria in November each with a frequency of occurrence of 1/12. The group amphipod was represented by a single species *Quadrivisio bengalensis*.

Station 4

Polychaetes were the most abundant and common group with a total density of 10119 contributing 43.93% of the benthic community. The density ranged from $21/m^2$ (October) to $1648/m^2$ (January) with an average of $843/m^2$ and the frequency of occurrence was 12/12. The seasonal averages showed maximum density of $892/m^2$ during monsoon followed by pre-monsoon ($887/m^2$) and post-monsoon ($751/m^2$).

Aphrodita alta (family – Aphroditidae), *Ancistrosyllis constricta* (family – Hesionidae), *Vanadis formosa* (family – Alciopidae), *Lycasits indica, Dendronereis aestuarina* and *Perinereis cavifrons* (family – Nereidae), *Nephthys dibranchis* (family – Nephthydidae), *Lumbrinereis impatiens* (family – Eunicidae), *Goniada emerita* and *Glycera alba* (family – Glyceridae), *Prionospio cirrifera* and *P. polybranchiata* (family – Spionidae), *Disoma orissae* (family – Disomidae) and *Capitella capitata, Notomastus latericeus, Heteromastus similis, Heteromastides bifidus, Mediomastus capensis, Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis* (family – Capitellidae) were the 20 species of polychaetes encountered during the study. The maximum frequency of occurrence of 10/12 was shown by

Lycasits indica, followed by *Dendronereis aestuarina* & *Prionospio polybranchiata* (9/12), *Heteromastides bifidus* (7/12), *Perinereis cavifrons* (4/12), *Notomastus latericeus* (3/12), *Nephthys dibranchis* and *Paraheteromastus tenuis* (2/12) and rest of the species were in the frequency of occurrence of (1/12). *Prionospio polybranchiata* showed the maximum density (4541) followed by *Dendronereis aestuarina* (2064), *Lycastis indica* (1567) and *Heteromastides bifidus* (834). The species with low densities were *Ancistrosyllis constricta, Goniada emerita, Capitella capitata, Heteromastus similis* and *Scyphoproctus djiboutiensis* each contributing $21/m^2$. *Ancistrosyllis constricta, Goniada emerita and Capitella capitata* occurred in January and *Heteromastus similis* and *Scyphoproctus djiboutiensis* in August and February respectively. *Aphrodita alta, Vanadis formosa* and *Disoma orissae* contributed $42/m^2$ to the polychaete population, which occurred only in November, August and July respectively.

Bivalves were the second dominant group numbering 8396 contributing 36.45% of the benthic community with an annual range of $63/m^2$ (August) to $2334/m^2$ (March) and an average of $700/m^2$. The frequency of occurrence was 10/12 and this group was not recorded during July and November. The seasonal averages indicated high values during pre-monsoon ($1261/m^2$) followed by post-monsoon ($620/m^2$) and monsoon ($219/m^2$).

Meritrix sp. (42), *Villorita cyprinoides* (7645), *Nucula* sp. (188), *Pendora flexosa* (479) and *Bivalve* sp. (42) were 5 species obtained during the study under the group bivalves. The frequency of occurrence of *Villorita cyprinoides* was 9/12, which contributed $2188/m^2$ in March. The least numerical abundance of $229/m^2$ was observed in September and was absent in July, August and November. *Nucula* sp. was observed in August ($21/m^2$), March ($146/m^2$) and May ($21/m^2$). The other 3 species such as *Meritrix* sp. ($42/m^2$), *Bivalve* sp. ($42/m^2$) and *Pendora flexosa* ($479/m^2$) were present only in May, August and January respectively.

Amphipods were the next abundant group with a density of 1988 contributing 8.63% of the benthic community with an annual range of $21/m^2$ (August) to $1067/m^2$ (January) and an annual average of $166/m^2$. This group occurred in July, August and from December to April with a frequency occurrence of 7/12. The mean value of $272/m^2$ was observed during post-monsoon followed by $204/m^2$during pre-monsoon and decreased to $21/m^2$ during monsoon.

Oligochaetes numbering 732 forming 3.18% of the benthos were the fourth in abundance and the density ranged between $21/m^2$ (June, August, January & April) and $313/m^2$ (March) with a mean value of $61/m^2$. The frequency of occurrence was 8/12 and was present during July to August and from January to March. The maximum density observed was during March ($313/m^2$) followed by May ($126/m^2$) and July ($125/m^2$). The minimum density was obtained in June, August, January and April. The seasonal averages showed that the pre-monsoon values ($136/m^2$) were high compared to monsoon ($42/m^2$) and post-monsoon ($5/m^2$).

Gastropods numbering 566 forming 2.46% of benthos formed the next dominant group and ranged between $21/m^2$ (October, November, January and April) and $188/m^2$ (February) with a mean value of $47/m^2$. The frequency of occurrence was 9/12 and this group was absent during July to September. The average density was high during pre-monsoon ($89/m^2$) and decreased in the succeeding seasons ($26/m^2$ each).

Solariella sp. and a Gastropod sp. were obtained during the study numbering 336 and 230 respectively. The densities ranged from $21/m^2$ (October, November, December and February) to $105/m^2$ (June) and $21/m^2$ (December, January & April) to $167/m^2$ (February) for the above species respectively with the corresponding frequency of occurrence 7/12 and 4/12.

Tanaidaceans ranked next in abundance contributing 564 specimens to the benthic density forming 2.45% of the benthic community with a mean value of $47/m^2$. The frequency of occurrence was 4/12; this group was present only in July ($210/m^2$), August ($208/m^2$), December ($42/m^2$) and January ($104/m^2$). The seasonal averages showed $105/m^2$ during monsoon, $37/m^2$ during post-monsoon and were absent during pre-monsoon.

Apseudes chilkensis and *A. gymnophobium* were the 2 species obtained under the group tanaidaceans. *Apseudes gymnophobium* numbering 417 were present in July (63/m^2), August (208/m^2), December (42/m^2) and January (104/m^2) with a frequency of occurrence 4/12. *Apseudes chilkensis* was present only in July contributing 147/m^2 to the benthic density.

Chironomid was the next group numbering 460 forming 1.99% of the benthic community with an annual average of 38/m^2. They were present during July to September and in November with the respective densities of 63/m^2, 334/m^2, 21/m^2 and 42/m^2. The frequency of occurrence was 4/12. The seasonal observations showed the average values were 105/m^{2}during monsoon, 11/m^2 during post-monsoon and were absent during pre-monsoon.

Decapods contributing 147 specimens to the benthic density formed 0.64% with a monthly mean value of 12/m^2. This group was present only in August and the seasonal average of 37/m^2 was observed during monsoon. The only representative of this group was crab.

Juvenile fishes and mysids numbering 42 and 21 forming 0.18% and 0.09% were the rare groups with an annual average of 4/m^2 and 2/m^2 respectively. Juvenile fishes were present in July and August and mysids only in August. Both these groups were present only during monsoon with an annual average of 10/m^2 and 5/m^2 respectively.

Station 5

Polychaetes were the most dominant group with a total of 6809 specimens contributing 82.94% of the benthic community with an average of 567/m^2. The frequency of occurrence was 12/12. The density of 1648/m^2 was observed during June followed by 1521/m^2 in December and 897/m^2 in July. The minimum density 21/m^2, 84/m^2 and 147/m^2 were observed during May, April and January respectively. The seasonal averages showed a high density of 856/m^2 during monsoon followed by 684/m^2 during post-monsoon and 163/m^2 during pre-monsoon.

Aphrodita alta (family – Aphroditidae), *Amphinome rostrata* (family Amphinomidae), *Ancistrosyllis constricta* (family – Hesionidae), *Lycastis indica, Perinereis cavifrons* and *Platynereis* sp. (family – Nereidae), *Nephthys dibranchis* (family – Nephthydidae), *Diopatra neapolitana* and *Lumbrinereis impatiens* (family - Eunicidae), *Prionospio pinnata, P. polybranchiata* and *Prionospio* sp. (family – Spionidae), *Cossura coasta* (family – Cossuridae), *Capitella capitata, Notomastus aberans, N. fauveli, Heteromastus similis, H. filiformis, Heteromastides bifidus, Mediomastus capensis, Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis* (family – Capitellidae) and *Pista indica* (family – Terebellidae) were the 23 species encountered during the study. The common species of this station were *Ancistrosyllis constricta* (10/12), *Nephthys dibranchis* (9/12) and *Prionospio polybranchiata* (9/12). Though the frequency of occurrence of *Notomastus aberans* was low (4/12) it dominated the group with a numerical abundance 1564 specimens during the study. The density of this species ranged between 84/m^2 (September and February) and 1146/m^2 (December) with an average density of 130/m^2. The common and second dominant species *Prionospio polybranchiata* was present except in August, March and May and showed its peak abundance (813/m^2) during June and minimum density (21/m^2) during July, January and April. A total of 1252 specimens were noticed during the investigation. The species *Nephthys dibranchis* with a total number of 1168 during the study, showed a density varying from 21/m^2 (September & January) and 354/m^2 (July). Density of the next abundant species *Ancistrosyllis constricta* ranged between 21/m^2 (November) and 229/m^2 (July) and showed a total number of 857 specimens. *Lycastis indica, Platynereis* sp., *Cossura coasta, Mediomastus capensis* and *Pista indica* showed minimum density of 21/m^2 followed by *Amphinome rostrata, Perinereis cavifrons* and *Capitella capitata* with a density of 42/m^2.

Tanaidaceans were the second in abundance with a density of 503 forming 6.13% of the benthic fauna with an annual average of 42/m^2. The frequency of occurrence was 5/12 with a maximum density of 230/m^2 in June followed by 189/m^2 in December. The low density of 21/m^2 was observed in July and October followed by 42/m^2 in September. The seasonal averages were 73/m^2 and 53/m^2 during monsoon, post-monsoon and no organisms were obtained during pre-monsoon.

Apseudes chilkensis with a frequency of occurrence of 2/12 and *A. gynmophobium* with a frequency of occurrence 4/12 were the 2 species of tanaidaceans observed during the investigation period. *Apseudes chilkensis* showed the total density of 126 and *A. gymnophobium* with a density of 377. *Apseudes chilkensis* was collected only in June (105/m^2) and July (21/m^2) where as *A. gymnophobium* were noticed in June (125/m^2), September (42/m^2), October (21/m^2) and December (189/m^2).

Oligochaetes were the third in abundance with the density of 417 contributing 5.08% of the benthic community with an annual average of 35/m^2. This group occurred only in June (375/m^2), July (21/m^2) and October (21/m^2) and the frequency of occurrence was 3/12. The monsoon and post-monsoon averages were 99/m^2 and 5/m^2 respectively where as the organisms were not encountered during pre-monsoon.

Decapods were the next abundant group contributing 3.30% of the benthic community with a total number of 271 with an annual average of 23/m^2. The frequency of occurrence was 3/12 with their occurrence only in June (187/m^2), September (21/m^2) and February (63/m^2). Prawn and crab with the numerical abundance of 21/m^2 and 250/m^2 contributed to the decapod population. Prawn occurred only in February (21/m^2) and crab showed the maximum density of 187/m^2 (June) followed by 42/m^2 (February) and 21/m^2 (September).

Amphipods and bivalves were the next groups in abundance with a total number of 63 forming 0.77% of the benthic community with a monthly mean value of 5/m^2. Monsoon and post-monsoon averages were 10/m^2 and 5/m^2 respectively for amphipods whereas the corresponding values for bivalves were 5/m^2 and 10/m^2. Both the groups were not obtained during pre-monsoon.

Grandidierella bonneri, G. gilesi and *Corophium triaenonyx* were the 3 species of amphipods occurred during June, July and October respectively each contributing 21/m^2.

Bivalve sp., *Villorita cyprinoides* and *Nucula* sp. each contributing 21/m^2 were the 3 species of bivalves obtained during the study. .

Mysids were the next group contributing 0,51% with a density of 42 and an annual average of 4/m^2. Mysids were obtained only in February with a frequency of occurrence of 1/12. The average during pre-monsoon was 4/m^2.

Gastropods and juvenile fishes contributing 21/m^2 forming 0.25% of the benthic community with an annual average of 2/m^2 were the least abundant groups. Gastropods were present only during July and juvenile fishes only in June and the average for monsoon was 5/m^2 for both the groups.

Station 6

Polychaetes were the most abundant group with a total number of 10027 contributing 75.70% of the benthic community with a monthly mean value of 836/m^2. The frequency of occurrence was 12/12. The high density of 2585/m^2 was observed during April followed by 1946/m^2 in August. The low density observed was 105/m^2 (February), 147/m^2 (January), 168/m^2 (June) and 273/m^2 (July). The seasonal averages showed maximum values during pre-monsoon (1010/m^2) followed by monsoon (874/m^2) and post-monsoon (623/m^2).

Aphrodita alta (family – Aphroditidae), *Ancistrosyllis constricta* (family – Hesionidae), *Syllis spongicola* (family – Syllidae), *Dendronereis aestuarina, Perinereis cavifrons* and Platynereidae (family – Nereidae), *Nephthys dibranchis* (family – Nephthydidae), *Lumbrinereis impatiens,* and *L. notocirrata* (family – Eunicidae), *Goniadopsis maskelensis* and *Glycera longipinnis* (family – Glyceridae), *Scolelepis indica, Prionospio cirrobranchiata, P. polybranchiata* and *Prionospio* sp. (family – Spionidae), *Magelona capensis* (family – Magelonidae), *Cossura coasta* (family – Cossuridae), *Capitella capitata, Notomastus aberans, N. latericeus, N. fauveli,* Heteromastus *similis, Heteromastides bifidus, Mediomastus capensis, Leiochrides africanus, Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis* (family – Capitellidae), *Owenia fusiformis* (family – Oweniidae) and *Pista indica* (family – Terebellidae) were the 29 species of polychaetes encountered during the study. The species with maximum frequency of occurrence was *Ancistrosyllis constricta* (10/12), followed by *Prionospio polybranchiata* (9/12), *Capitella capitata* (7/12), *Heteromastides bifidus* (7/12) and *Nephthys dibranchis* (6/12). The total number of *Prionospio polybranchiata* was 1501 followed by *Ancistrosyllis constricta* (1151), *Notomastus aberans* (1151) and *Paraheteromastus tenuis* (1003). *Ancistrosyllis constricta* showed the maximum density of 333/m^2 in April and minimum density of 42/m^2 in June, November and December. *Prionospio polybranchiata* showed the maximum density of 437/m^2 in October followed by 354/m^2 in September and minimum of 21/m^2 in November. The frequency of occurrence of *Notomastus aberans* was 3/12, the high density of 648/m^2 was observed in October and low value of 210/m^2 in September. *Paraheteromastus tenuis* also showed a high value of 625/m^2 in April whereas the low value was 21/m^2 in January. The minimum density of 21/m^2 was observed for species like *Syllis spongicola, Platynereis* sp., *Goniadopsis maskelensis, Owenia fusiformis* and *Pista indica.* This second minimum density of 42/m^2 was shown by *Dendronereis aestuarina* and *Lumbrinereis impatiens.*

Oligochaetes were the next abundant group forming 11.80% of the benthic population with a density of 1563 and an annual average value of 130/m^2. The occurrence of this group was only during July (896/m^2), September (625/m^2) and October (42/m^2). The seasonal averages during monsoon and post-monsoon were 380/m^2 and 11/m^2 respectively and the organisms were absent during pre-monsoon.

Tanaidaceans were the third abundant group constituting 857 to the benthic community forming 6.47% with a monthly mean value of 71/m^2. The maximum density of 312/m^2 (July) and 293/m^2 (August) were observed and the minimum density was 21/m^2 in March and May followed by 42/m^2 in June. The frequency of occurrence was 7/12. The seasonal observations showed that the average value of 188/m^2 during monsoon which reduced to 16/m^2 during post-monsoon and 11/m^2 during pre-monsoon.

Apseudes chilkensis and *A. gymnophobium* were the two species of tanaidaceans encountered during the study. *Apseudes chilkensis* showed a maximum density of 230/m^2 (August) and minimum of 21/m^2 (June, July & November) and the total density was 293 with the frequency of occurrence 4/12. *Apseudes gymnophobium* occurred more frequently (7/12) with maximum density of 291/m^2 in July followed by 105/m^2 in September. A minimum density of 21/m^2 was observed in June, March and May.

Gastropods were the next abundant group with a total number of 294 forming 2.22% of the benthic community with an annual average of 25/m^2. The frequency of occurrence was 6/12 with a maximum density of 126/m^2 in September followed by 63/m^2 in December. The low density of 21/m^2 was observed during July, November and January followed by 42/m^2 in August. The monsoon and post-monsoon averages were 47/m^2 and 26/m^2 respectively and no animals were observed during pre-monsoon.

Gastropods constituted by three species viz. Gastropod sp., *Littorina littorea,* and *Dentalium* sp. Out of these *Littorina littorea* occurred more frequently (3/12) followed by gastropod sp. (2/12) and *Dentalium* sp. (1/12). The maximum density of 84/m^2 was obtained for Gastropod sp. in September and the minimum density was 21/m^2 for three species except *Dentalium* sp. (42/m^2).

Amphipods with a total number of 252 with an annual average of 21/m^2 forming 1.90% of the benthic community were the next abundant group. The frequency of occurrence was 6/12 with a high density of 84/m^2in May and low density of 21/m^2 in June, July and December. The seasonal averages were very low during pre-monsoon (32/m^2), monsoon (11/m^2) and post-monsoon (21/m^2).

Grandidierella bonneri (63), *Quadrivisio bengalensis* (126) and *Eriopisa chilkensis* (63) were the three species obtained under the group amphipods. Out of these the maximum density of 84/m^2 was observed in May for *Quadrivisio bengalensis* followed by 42/m^2 (March) for *Eriopisa chilkensis*. All the other densities were minimum (21/m^2).

Decapods were the next abundant group with 210 specimens forming 1.59% of the benthic community with an annual average of $18/m^2$. Though the frequency of occurrence was 6/12 the maximum density reached upto $84/m^2$ in July followed by $42/m^2$ in June. The minimum density was $21/m^2$ in August, October, December and April. The seasonal averages during pre-monsoon, monsoon and post-monsoon were $5/m^2$, $37/m^2$ and $11/m^2$ respectively.

Penaeid prawns, *Acetes* sp. and crab constitute the decapod population. The frequency of occurrence of prawn was 5/12 with a maximum density of $42/m^2$ in June and July followed by $21/m^2$ in August, December and April. *Acetes* sp. and crab occurred only in one month with a density of $42/m^2$ (July) and $21/m^2$ (October) respectively.

Cumaceans and bivalves were the least dominant groups amounting 21 with an annual average of $2/m^2$ forming 0.16% of the benthic community. Both the groups were present only in October and the seasonal average for post-monsoon was $5/m^2$.

Station 7

Polychaetes numbering 17296 were the most dominant group with an annual average of $1441/m^2$ forming 85.80% of the benthic population. The high abundance is due to the occurrence of this group throughout the year. The high densities of $3331/m^2$ followed by $3124/m^2$ and $2860/m^2$ were observed during June, November and September respectively. The low densities were observed during July ($271/m^2$), October ($84/m^2$) and March ($356/m^2$). The pre-monsoon, monsoon and post-monsoon averages were $1020/m^2$, $1996/m^2$ and $1309/m^2$ respectively.

A total of 27 species belonging to 14 families were encountered during the study. The species include *Aphrodita alta* (family – Aphroditidae), *Ancistrosyllis constricta* (family – Hesionidae), *Scoloplos madagascariensis* (family – Orbiniidae), *Dendronereis aestuarina* and *Platynereis* sp. (family – Nereidae), *Nephthys dibranchis* (family – Nephthydidae), *Diopatra neapolitana, Lumbrinereis latreilli* and *L. impatiens* (family – Eunicidae), *Glycera longipinnis* (family – Glyceridae), *Prionospio pinnata, P. polybranchiata* and *Prionospio* sp. (family – Spionidae), *Magelona capensis* (family – Magelonidae), *Cossura coasta* (family – Cossuridae), *capitella capitata, Notomastus aberans, N. latericeus, N. fauveli,* Heteromastus *similis, Heteromastides bifidus, Mediomastus capensis, Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis* (family – Capitellidae), *Branchiomaldane vincenti* (family – Arenicolidae), *Owenia fusiformis* (family – Oweniidae) and *Pista indica* (family – Terebellidae). The species with the maximum frequency of occurrence was *Ancistrosyllis constricta* (9/12) followed by *Prionospio polybranchiata* (8/12), *Capitella capitata* (7/12), *Paraheteromastus tenuis* (7/12), *Nephthys dibranchis* (6/12), *Prionospio pinnata* (6/12) and *Heteromastides bifidus* (6/12). The species with high numbers were *Paraheteromastus tenuis* (4314) followed by *Prionospio pinnata* (2455) *Ancistrosyllis constricta* (2391), *Prionospio polybranchiata* (1669), *Capitella capitata* (1374) and *Prionospio* sp. (1063). Though the frequency of occurrence of *Paraheteromastus tenuis* was 7/12, the maximum density of 1999/m^2 was observed in June and minimum of 21/m^2 in July. *Prionospio pinnata* showed the frequency of occurrence of 6/12 and the maximum density was observed in April 1563/m^2 and minimum of 21/m^2 in July and December. *Ancistrosyllis constricta* showed the maximum density of 582/m^2 and 520/m^2 were observed in June and September respectively and the minimum density was 21/m^2 in December. *Prionospio polybranchiata* with the maximum density of 1166/m^2 in August, *Prionospio* sp. with 1063/m^2 in November, *Capitella capitata* with 621/m^2 in November and *Heteromastides bifidus* with 500/m^2 in November were the other abundant species, where all these species showed the minimum density of 21/m^2 except *Prionospio* sp. which occurred only in November. The species with minimum density (21) were *Diopatra neapolitana, Lumbrinereis impatiens, Notomastus fauveli, Branchiomaldane vincenti* and *Pista indica* followed by *Aphrodita alta* and *Platynereis* sp. with a density of 42.

Oligochaetes were the second dominant group with a density of 1271 constituting 6.30%of the benthic community with a monthly mean value of 106/m^2. The frequency of occurrence of oligochaetes was 4/12 with a maximum density of 1124/m^2 in August and minimum of 21/m^2 in July. The average value for monsoon was 318/m^2 and no animals were obtained during pre-monsoon and post-monsoon.

Tanaidaceans were the third dominant group with a total abundance of 774 forming 3.84% of benthic community with an annual average of $65/m^2$. Maximum density of $188/m^2$ was observed in June and November and minimum density of $63/m^2$ in July and the frequency of occurrence was 5/12. The averages for monsoon and post-monsoon were $147/m^2$ and $47/m^2$ respectively and no organisms were obtained during pre-monsoon.

Apseudes chilkensis (480) and *A. gymnophobium* (294) were the two species of tanaidaceans. *Apseudes chilkensis* showed the maximum density of $167/m^2$ in November followed by $146/m^2$ in July and $125/m^2$ in August. The minimum density ($42/m^2$) was in July. *Apseudes gymnophobium* showed the frequency of occurrence of 5/12 with the maximum density in September ($168/m^2$) and minimum in July and November ($21/m^2$).

Amphipods numbering 356 was the fourth group in abundance with an annual average of $30/m^2$ forming 1.76 of the benthic community. The frequency of occurrence was 5/12 with a high density of $146/m^2$ in June and low density was $21/m^2$ in July. The seasonal observations showed that the monsoon averages ($52/m^2$) were high compared to post-monsoon ($26/m^2$) and pre-monsoon ($11/m^2$).

Grandidierella bonneri (21), *Quadrivisio bengalensis* (209), *Eriopisa chilkensis* (42) and *Corophium triaenonyx* (42) were the 4 species under the group amphipods. *Grandidierella bonneri* and *Corophium triaenonyx* showed the frequency of occurrence 1/12 with a density of $21/m^2$ in July and $84/m^2$ in October respectively. *Quadrivisio bengalensis* showed the frequency of occurrence of 4/12 with maximum density of $125/m^2$ in June followed by $42/m^2$ in February and minimum of $21/m^2$ in September and October. *Eriopisa chilkensis* was present only in June ($21/m^2$) and September ($21/m^2$).

Decapods numbering 252 forming 1.25% of the benthic community with an average value of $21/m^2$. The frequency of occurrence was 5/12 where the maximum density was $63/m^2$ in June and September and minimum of $42/m^2$ in January, April and May. The seasonal averages for pre-monsoon, monsoon and post-monsoon were

$21/m^2$, $32/m^2$ and $11/m^2$ respectively. Prawn and crab were the representatives of this group with a frequency of occurrence of 4/12 each.

Prawn and crab showed the highest densities of $63/m^2$ each in July and September respectively and low density of $21/m^2$ was observed in January, April and May for both the species.

Isopods with a total number of 105 were the next dominant group constituting 0.52% with an annual average of $9/m^2$. Isopods occurred only in June, August and September with a density of $21/m^2$, $63/m^2$ and $21/m^2$ respectively. *Cirrolinia fluviatilis* was the only representative of this group.

Gastropods and bivalves numbering 42 forming 0.21% with a monthly mean value of $4/m^2$. Gastropods occurred in July and January with a density of $21/m^2$ in each month and bivalves with a density of $42/m^2$ in February. The seasonal observations showed the monsoon and post-monsoon average of $5/m^2$ for gastropods and a pre-monsoon average of $11/m^2$ for bivalves. Gastropod sp. and *Paphia papilliens* contributed $42/m^2$, each with a frequency of occurrence of 2/12 and 1/12 respectively.

Juvenile fishes was the last group numbering 21 in November forming 0.10% of the benthic community with a monthly mean average of $2/m^2$ and a post-monsoon average of $5/m^2$. This group was present only in November and hence the frequency of occurrence was 1/12.

Station 8

Polychaetes were the most abundant group with a density of 5484 forming 62.46 with a monthly mean value of $457/m^2$. The frequency of occurrence was 12/12 with maximum density of $1235/m^2$ in April, followed by $690/m^2$ in December and $648/m^2$ in June and July. The minimum density was $21/m^2$ in May followed by $168/m^2$ in September and $273/m^2$ in August. The pre-monsoon, monsoon and post-monsoon averages were $482/m^2$, $434/m^2$ and $455/m^2$ respectively.

Aphrodita alta (family – Aphroditidae), *Ancistrosyllis constricta* (family – Hesionidae), *Lycastis indica, Dendronereis aestuarina, Penereis cavifrons,* Platynereis sp. (family – Nereidae), *Nephthys dibranchis* (family – Nephthydidae), Diopatra *neapolitana,* (family – Eunicidae), *Glycera longipinnis, Glycera* sp. (family – Glyceridae), *Scolelepis indica, Prionospio cirrobranchiata, P. polybranchiata* and *Prionospio* sp. (family – Spionidae), *Disoma orissae* (family – Disomidae), *Capitella capitata, Notomastus aberans, N. latericeus, N. fauveli, Heteromastus similis, H. filiformis, Heteromastides bifidus, Mediomastus capensis, Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis* (family – Capitellidae), *Owenia fusiformis* (family – Oweniidae) and *Pista indica* (family – Terebellidae) were the 27 species of polychaetes encountered during the study. Out of these *Diopatra neapolitana* showed the maximum density of 1127 followed by P*rionospio* polybranchiata (900), *Heteromastides bifidus* (565) and *Mediomastus capensis* (544). The maximum frequency of occurrence was observed for *Prionospio polybranchiata* (9/12) followed by *Diopatra neapolitana* (8/12), *Mediomastus capensis* (6/12), *Lycastis indica* (5/12), *Heteromastus similis* (5/12), *Ancistrosyllis constricta* (4/12), *Perinereis cavifrons* (4/12), *Notomastus aberans* (4/12) and *Heteromastides bifidus* (4/12). *Diopatra neapolitana* showed the maximum density of 438/m^2 in June and minimum of 42/m^2 in September and April. *Prionospio polybranchiata* showed a maximum density of 355/m^2 in April and minimum of 21/m^2 in May. *Heteromastides bifidus* and *Mediomastus capensis* showed the maximum density of 252/m^2 (April) and 229/m^2 (January) respectively whereas the corresponding minimum densities were 21/m^2 in March and December. *Aphrodita alta, Glycera* sp., *Scolelepis indica, Disoma orissae, Notomastus latericeus, N. fauveli, Heteromastus filiformis* and *Pista indica* were the species with a density of 21 each.

Amphipods were the second group in abundance constituting 23.74% of the benthic community with a total density of 2084 and an annual average of 174/m^2. The frequency of occurrence was 6/12 with the maximum density of 1335/m^2 (July) and minimum of 42/m^2 (February). The monsoon averages (433/m^2) were high compared to post-monsoon (78/m^2) and pre-monsoon (11/m^2).

Melita zeylanica (21), *Grandidierella bonneri* (84), *G. gilesi* (21), *Quadrivisio bengalensis* (126), *Eriopisa chilkensis* (335), *Corophium triaenonyx* (1455) and Caprillidae (42) were the representatives of Amphipods. The maximum frequency of occurrence (4/12) was observed for *Quadrivisio bengalensis* and *Eriopisa chilkensis*. *Quadrivisio bengalensis* showed the maximum density of $42/m^2$ (July and November) and minimum of $21/m^2$ (August and December) whereas the corresponding values were $125/m^2$ (June) and $42/m^2$ (February) for *Eriopisa chilkensis*. *Corophium triaenonyx* showed the maximum density of $1188/m^2$ in July and minimum of $104/m^2$ in June and the frequency of occurrence was 3/12. *Grandidierella bonneri* and Caprillidae showed the frequency of occurrence of 2/12 and *Melita zeylanica* and *Grandidierella gilesi* were observed in November ($21/m^2$) and August ($21/m^2$) respectively.

Tanaidaceans were the third abundant group with a density of 605 forming 6.89% of the benthic community with an annual average of $50/m^2$. The frequency of occurrence was 4/12 with maximum density in June ($291/m^2$) and minimum in April ($21/m^2$). The seasonal averages were high during monsoon ($125/m^2$) compared to pre-monsoon ($5/m^2$) and post-monsoon ($21/m^2$).

Apseudes chilkensis (312) and *A. gymnophobium* (293) were the two species of tanaidaceans with the frequency of occurrence of 2/12 and 3/12 respectively. The maximum abundance was $291/m^2$ (June) and $188/m^2$ (August) respectively for the two species and the corresponding minimum values were $21/m^2$ in August and April.

Isopods were the fourth group in abundance contributing 3.80% to the benthic community with a maximum density of $334/m^2$ and a monthly mean value of $28/m^2$. The frequency of occurrence was 4/12 with a maximum of $146/m^2$ in July and August and $21/m^2$ in November and April. The seasonal averages showed the value of $73/m^2$ during monsoon and $5/m^2$ during both pre-monsoon and post-monsoon.

Cirrolinia fluviatilis and Anthuridae comes under isopods with corresponding total densities of 292 and 42, both showing the frequency of occurrence of 2/12.

Cirrolinia fluviatilis was present in July (146/m^2) and August (146/m^2) and Anthuridae in November (21/m^2) and April (21/m^2).

Decapods contributing 84 specimens were the next abundant group forming 0.96% to the benthic community with a monthly mean value of 7/m^2. The frequency of occurrence was 2/12 with a maximum of 63/m^2 in April and a minimum of 21/m^2 in November. The pre-monsoon and post-monsoon averages were 16/m^2 and 5/m^2 respectively.

Prawn (63) and crab (21) come under decapods each with a frequency of occurrence of 1/12 in April and November respectively.

Oligochaetes and bivalves contributed 42/m^2 to the benthic community forming 0.48% with an annual average of 4/m^2. Oligochaetes and bivalves showed the frequency of occurrence of 1/12 and 2/12 respectively. The seasonal variations showed post-monsoon average of 11/m^2 for Oligochaetes and monsoon and post-monsoon averages of 5/m^2 for bivalves.

Oligochaetes were present in November only. Bivalves were represented by two species, *Modiolus striatulus* (21/m^2) and *Paphia papilliens* (21/m^2) in August and October respectively.

Station 9

Polychaetes numbering 8668 were the dominant group contributing 74.49 of the benthic community with a monthly mean value of 722/m^2. The frequency of occurrence was 12/12 with a maximum density in September (2004/m^2) and February (1296/m^2). The minimum density of 63/m^2 was observed in January. The pre-monsoon, monsoon and post-monsoon averages were 657/m^2, 1013/m^2 and 486/m^2 respectively.

Sthenelais boa (family – Aphroditidae), *Ancistrosyllis constricta* (family – Hesionidae), *Lycastis indica, Dendronereis aestuarina, Perinereis cavifrons* and *Platynereis* sp. (family – Nereidae), *Nephthys dibranchis* (family – Nephthydidae),

)iopatra *neapolitana,* (family – Eunicidae), *Goniada incerta, Glycera benguellana* family – Glyceridae), *Prionospio polybranchiata* and *Prionospio* sp. (family – ;pionidae), *Capitella capitata, Notomastus aberans, N. latericeus, N. fauveli, Heteromastus similis, Heteromastides bifidus, Mediomastus capensis, Paraheteromastus tenuis, Scyphoproctus djiboutiensis* and *Pulliella armata* (family – Capitellidae) and *Maldane sarsi* (family – Maldanidae) were the 23 species of polychaetes encountered during the study. The species with high frequency of occurrence was *Dendronereis aestuarina* (10/12) followed by *Heteromastides bifidus* (9/12) and *Prionospio polybranchiata* (5/12). The maximum density was observed for *Heteromastides bifidus* (2232) and next in abundance was *Notomastus aberans* (1480), though the frequency of occurrence was 2/12. *Dendronereis aestuarina* showed the density of 1193 and *Prionospio polybranchiata* with a density of 625/m^2. The minimum density of 21/m^2 was observed for the species, *Sthenelais boa, Diopatra neapolitana, Glycera benguellana, Heteromastus similis* and *Maldane sarsi.*

Amphipods forming 14.36% of the benthic community with a density of 1671 and an annual average of 139/m^2 were the second abundant group. The frequency of occurrence was 8/12 with a maximum density in November (999/m^2) and minimum during June to August (21/m^2). The seasonal variations showed the maximum average during post-monsoon (281/m^2) followed by pre-monsoon (121/m^2) and monsoon (16/m^2).

Melita zeylanica (84), *Grandidierella bonneri* (189), *G. gilesi* (208), *Quadrivisio bengalensis* (1064) and *Eriopisa chilkensis* (126) were the 5 species of amphipods with the frequency of occurrence 2/12, 3/12, 3/12, 5/12 and 4/12 respectively. *Melita zeylanica* showed the minimum density of 42/m^2 in December and March. *Grandidierella bonneri* showed the density of 126/m^2 in April and minimum of 21/m^2 in March whereas *Grandidierella gilesi* showed the maximum density in November (145/m^2) and minimum in June (21/m^2). The maximum density of 854/m^2 (November) and minimum of 21/m^2 (August) was observed for *Quadrivisio bengalensis. Eriopisa chilkensis* showed high and low density of 63/m^2 (February) and 21/m^2 (July, December and March) respectively.

Bivalves were the third in abundance with a total density of 794 contributing 6.83% with an annual average of $66/m^2$. The frequency of occurrence was 4/12 with a maximum density in April ($668/m^2$) and minimum in February ($21/m^2$). Bivalves were present only during pre-monsoon period with an average of $199/m^2$.

Villorita cyprinoides (84) and *Pendora flexosa* (710) were the 2 species of bivalves with the frequency of occurrence 1/12 and 4/12 respectively. *Villorita cyprinoides* was present only in April and *Pendora flexosa* from February to May with the maximum density in April ($584/m^2$) and minimum in February ($21/m^2$).

Tanaidaceans were the fourth in abundance contributing 1.44% with a density of 168 and an annual average of $14/m^2$. The frequency of occurrence was 6/12 with maximum density of $42/m^2$ (November and December) and minimum of $21/m^2$ (June to August and March). The pre-monsoon, monsoon and post-monsoon averages were $5/m^2$, $16/m^2$ and $21/m^2$ respectively.

Apseudes chilkensis and *A. gymnophobium* showed the frequency of occurrence of 3/12 with the density of $63/m^2$ and $105/m^2$ respectively.

Isopods were the fifth group in abundance forming 0.90% of the benthic community with a total number of 105 and a monthly mean value of $9/m^2$. The frequency of occurrence was 3/12 with maximum density of $42/m^2$ in July and December and minimum of $21/m^2$ in August. The monsoon and post-monsoon averages were $16/m^2$ and $11/m^2$ respectively and the animals were absent during pre-monsoon. *Cirrolina fluviatilis* (21) and Anthuridae (84) represented the group isopods.

Insects with a frequency of occurrence of 2/12 and a density of 63 forming 0.54% of the benthic community with a monthly mean of $5/m^2$ were the sixth abundant group. The maximum density was $42/m^2$ in July and minimum of $21/m^2$ in September and the seasonal average for monsoon was $16/m^2$. Chironomids were the only representative of the group insect.

Oligochaetes, gastropods and Planaria contributed 42 to the total benthic density forming 0.36% with a monthly mean value of 4/m^2. The frequency of occurrence of the species was 2/12, 2/12 and 1/12 respectively. Oligochaetes were present in July (21/m^2), and December (21/m^2) and the seasonal averages for monsoon and post-monsoon were 5/m^2. Planaria were present only in December (42/m^2) with a post-monsoon average of 11/m^2. *Littorina littorea* and Gastropod sp. were the representatives of the gastropods and were present in April (21/m^2) and August (21/m^2) respectively.

Archiannelids and mysids represented with a total density of 21 forming 0.18% with a monthly mean value of 2/m^2. Archiannelids were present in August (21/m^2) and mysids in June (21/m^2), both showing an average of 5/m^2 during monsoon. *Polygordius* sp. was the only representative of Archiannelids.

Station 10

Polychaetes numbering 734 were the most abundant group contributing 56.59% with an annual average of 61/m^2. The frequency of occurrence was 3/12 with a maximum density of 608/m^2 in April followed by 105/m^2 in February and 21/m^2 in May. The pre-monsoon average was 184/m^2 and organisms were absent during the other seasons.

Dendronereis aestuarina (family – Nereidae), *Prionospio polybranchiata* (family – Spionidae), *Capitella capitata, Notomastus latericeus, Heteromastides bifidus* and *Paraheteromastus tenuis* (family – Capitellidae) were the 6 species of polychaetes encountered during the study. Out of these the first three species showed the frequency of occurrence. 2/12 and rest with 1/12. The maximum occurrences of first 2 species were 420/m^2 and 167/m^2 respectively in April and all others showed the density of 21/m^2. *Dendronereis aestuarina* showed the maximum density of 441/m^2 followed by *Prionospio polybranchiata* (188/m^2) and *Capitella capitata* (42/m^2).

Only one species of Amphipod namely, *Grandidierella bonneri* was observed during the study with a density of 21/m^2 in March.

Bivalves numbering 521 were the second dominant group forming 40.17% of the benthic community with a monthly mean value of 43/m^2. The frequency of occurrence was 1/12 and this group was present only in March and the pre-monsoon average was 130/m^2. *Pendora flexosa* was the only representative of bivalves with a density of 521/m^2 in March.

Amphipods and isopods, each contributing 21/m^2 was the least dominant group with a frequency of occurrence 1/12. Amphipods and isopods were observed during pre-monsoon and monsoon respectively with a seasonal average of 5/m^2 each. Anthuridae were the representative of isopods and *Grandidierella bonneri* represented the group amphipods.

Station 11

Polychaetes were the dominant group with the numerical abundance of 334 forming 88.83% of the benthic community with a mean value of 28/m^2. The frequency of occurrence was 1/12 and present only in January with an average of 84/m^2 during post-monsoon.

Dendronereis aestuarina (family – Nereidae) and *Prionospio polybranchiata* (family – Spionidae) were the 2 species of polychaetes with a density of 250/m^2 and 84/m^2 in January.

Insects numbering 42 were the other group constituting 11.17% of the benthic community with a mean value of 4/m^2. The seasonal variations showed an average of 11/m^2 during post-monsoon. *Hydroptila* sp. and larvae of insect numbering 21/m^2 each in December and January respectively represented the group insects.

Station 12

Polychaetes numbering 17194 were the dominant group constituting 99.63% with an annual average of 1433/m^2. The high abundance is due to the high occurrence of this group in all the months except June, August and September and hence the frequency of occurrence 9/12. The maximum density was observed during October ($6209/m^2$) followed by $5129/m^2$ (November). Minimum density of $147/m^2$ was observed in July. The pre-monsoon, monsoon and post-monsoon averages were 672, 37 and $3590/m^2$ respectively.

Only the family Capitellidae was encountered from this station *Capitella capitata, Heteromastus similis, Heteromastides bifidus, Branchiocapitella singularis* and *Scyphoproctus djiboutiensis* with a total density of 17005, 42, 21, 21 and 105 respectively were the 5 species of polychaetes recorded during the study. The more frequently occurred species was *Capitella capitata* (8/12) followed by *Scyphoproctus djiboutiensis* (2/12). All the other species occurred only in July. *Capitella capitata* was present from October to May with the maximum density of $6167/m^2$ in October and $5129/m^2$ in November. A minimum density of $292/m^2$ was observed in March. *Scyphoproctus djiboutiensis* showed the high abundance in July ($63/m^2$) and low in October ($42/m^2$).

Insects were the other group numbering 63 forming 0.37% of the benthic community with a mean value of $5/m^2$. A seasonal average of $16/m^2$ was observed during monsoon. Chironomids were the only representatives of insects.

Station 13

Polychaetes with a total abundance of 417 forming 86.88% of the benthic community with an annual average of $35/m^2$ were the most abundant group. The frequency of occurrence was 2/12 with high density in July ($354/m^2$) and low density in November ($63/m^2$). The fauna were absent during pre-monsoon and the averages during monsoon and post-monsoon were $89/m^2$ and $16/m^2$ respectively.

Dendronereis aestuarina (family – Nereidae), *Capitella capitata* and *Paraheteromastus tenuis* (family – Capitellidae) were the 3 species obtained with a numerical abundance of 21, 333 and 63 respectively. The first 2 species were present in July and third in November.

Insects numbering $63/m^2$ were the other group with a percentage composition of 13.12% and the annual average was $5/m^2$. This group was present in June and July and the average during monsoon was $16/m^2$. *Asellus aquaticus* present in June ($21/m^2$) and Chironomids in June and July with a density of $21/m^2$ each were the representatives of the group insects.

Station 14

Amphipods numbering 770797 with an annual average of $64233/m^2$ formed 92.69% of the benthic community were the most dominant group during the study period. The frequency of occurrence was 9/12 with a maximum density in October ($710417/m^2$) followed by a density of $53190/m^2$ in September. The low density was observed in June ($21/m^2$) followed by $42/m^2$ in March and $63/m^2$ in February and this group was absent in July, April and May. The seasonal averages showed the maximum value during post-monsoon ($177912/m^2$) compared to pre-monsoon ($26/m^2$) and monsoon ($14761/m^2$).

Grandidierella bonneri, (1554), *G. gilesi* (37478), *Quadrivisio bengalensis* (59146), *Eriopisa chilkensis* (19989) and *Corophium triaenonyx* (652630) were the 5 species of amphipods encountered during the study. The frequency of occurrence of the above species was 2/12,7/12, 4/12, 7/12 and 4/12 respectively. *Grandidierella bonneri* showed the peak abundance of $1470/m^2$ in September and minimum of $84/m^2$ in November. *Grandidierella gilesi* showed the maximum abundance of $29167/m^2$ in October followed by $7540/m^2$ in September. The minimum density was $21/m^2$ in February. *Quadrivisio bengalensis, Eriopisa chilkensis* and *Corophium triaenonyx* showed their high abundance in October and the corresponding values were $56250/m^2$, $18750/m^2$ and $606250/m^2$ and the density decreased to $270/m^2$, $21/m^2$ and $292/m^2$ in November respectively.

Polychaetes were the second dominant group with a density of 8921 forming 1.07% of the benthic community with an annual average of $743/m^2$. They occurred throughout the year with a maximum density of $2792/m^2$ in October and minimum density of $63/m^2$ in December. The pre-monsoon, monsoon and post-monsoon averages were $142/m^2$, $954/m^2$ and $1135/m^2$ respectively..

Lepidonotus sp. and *Sthenelais boa* (family – Aphroditidae), *Ancistrosyllis constricta* (family – Hesionidae), *Dendronereis aestuarina, Perinereis cavifrons* and *Platynereis sp.* (family – Nereidae), *Marphysa mossambica, Diopatra neapolitana, Lumbrinereis simplex, L. polydesma* and *L. impatiens* (family – Eunicidae), *Glycera longipinnis* (family – Glyceridae), *Prionospio pinnata* and *P. polybranchiata* (family – Spionidae), *Capitella capitata* and *Heteromastides bifidus* (family – Capiellidae), *Pista indica* and *Polycirrus coccineus* (family – Terebellidae) were the 18 species of polychaetes encountered during the study. The species with maximum frequency of occurrence was *Diopatra neapolitana* (8/12) followed by *Ancistrosyllis constricta* (5/12) and these two species showed the maximum density of 4334 and 1709 respectively. The species with minimum density (21) were *Lepidonotus* sp. *Dendronereis aestuarina, Lumbrinereis polydesma, Glycera longipinnis, Heteromastides bifidus, Pista indica* and *Polycirrus coccineus. Ancistrosyllis constricta* showed the maximum density of $1042/m^2$ in October and minimum of $21/m^2$ in February and March where as the corresponding values for *Diopatra neapolitana* was in July ($1041/m^2$) and November ($21/m^2$). *Capitella capitata* showed a maximum density of $1042/m^2$) in October and minimum of $21/m^2$ in January and February.

Tanaidaceans were the fourth abundant group numbering 8584 forming 1.03% of the benthic community with a mean value of $715/m^2$. The frequency of occurrence was 4/12 with a maximum abundance of $8396/m^2$ in October and minimum of $21/m^2$ in June and January. The seasonal observation showed that the monsoon and post-monsoon averages were $5/m^2$ and $2141/m^2$ respectively and animals were absent during pre-monsoon.

Apseudes chilkensis (84) and *A. gymnophobium* (8479) were the 2 species of tanaidaceans with frequency of occurrence 2/12 and 4/12 respectively. Both the species of tanaidaceans showed the high abundance in October and the values were $63/m^2$ and $8333/m^2$ respectively. The minimum density observed was $21/m^2$ for both the species.

Isopods (41501) ranked third in abundance forming 4.99% of the benthic community with a monthly mean value of 3458/m^2. Isopods showed the frequency of occurrence of 5/12 with maximum abundance of 35210/m^2 in September followed by 4250/m^2 in August. The seasonal observation showed the monsoon and post-monsoon averages of 9870/m^2 and 505/m^2 respectively.

Cirrolinia fluviatilis with the frequency of occurrence 5/12 and with the density 41501 was the only species of isopod. It showed the high abundance in September (35210/m^2) followed by 4250/m^2 (August) and low density of 21/m^2 in June.

Mysids were the fifth abundant group with a density of 1042 forming 0.13% of the benthic community with an annual average of 87/m^2. They were present only in October and the post-monsoon average was 261/m^2.

Bivalves were the sixth group in abundance forming 0.04% of the benthic community contributing 294 and the annual average was 25/m^2. The frequency of occurrence was 5/12 with a maximum density of 147/m^2 in July and 21/m^2 in October and March. The pre-monsoon, monsoon and post-monsoon averages were 16/m^2, 53/m^2 and 5/m^2 respectively.

Cardium sp., *Meritrix* sp. and *Paphia papilliens* were the three species of bivalves. *Cardium* showed the density of 105/m^2 in July followed by 63/m^2 in June and 21/m^2 in October and March. The other two species were present in May (42/m^2) and July (42/m^2) respectively.

Gastropods were the seventh abundant group numbering 188 forming 0.02% of the benthic community with a monthly mean value of 16/m^2. The frequency of occurrence was 2/12 with maximum density (146/m^2) in January and minimum (42/m^2) in February. The pre-monsoon and post-monsoon averages were 11/m^2 and 37/m^2 respectively.

Dentalium sp. and *Solariella* sp. were observed during the study. The *Solariella* sp. was present in January (146/m^2) and February (21/m^2) and the *Dentalium* sp. in February (21/m^2) only.

Decapods numbering 126 were the eighth group in abundance forming 0.015 % of the benthic community with a monthly mean value of 11/m^2. The frequency of occurrence was 4/12 with high abundance of 42/m^2 (January and February) and low value of 21/m^2 (August and September). All the three seasons showed the averages of 11/m^2.

Prawn (42/m^2) and Crab (84/m^2) were the representatives of decapod with the frequency of occurrence 1/12 and 3/12 respectively.

Insects and fishes contributing 42/m^2 and Cumaceans contributing 21/m^2 to the benthic density were the rare groups in occurrence. The first 2 groups showed the frequency of occurrence 2/12 and the third 1/12.

Benthic productivity in terms of density and biomass was very low in the upstream stations, which located near the industrial complex. Maximum number of 1020064 specimens with a biomass of 462771.17g was collected from station 3 during the investigation. This was contributed by a single species of gastropod. Second peak in density (831558) was observed at barmouth with a variety of faunal groups. Though stn. 12 was located near the effluent discharge point in the northern limb, accounted a total number of 17257, which is mainly due to the presence of a single species of polychaete, *Capitella capitata*. The total number at other stations varied from 1297 (stn. 10) to 23035 (stn. 4). Spionid worm *Prionospio polybranchiata* and the bivalve *Villorita cyprinoids* contributed the high density at station 4.

No definite pattern of variation was observed between seasons in the different stations. Seasonal averages showed high values during pre-monsoon at stns. 3 and 4. Stations 5 to 9 recorded high numbers during monsoon and stns. 12 and 14 showed high numbers during post-monsoon. Organisms were absent at station 1 during monsoon, Stn. 2 during pre-monsoon and post-monsoon, stn. 10 during post-monsoon, station 11 during pre-monsoon and monsoon and station 13 during pre-monsoon.

A total of 14 groups were encountered during the study and the number of groups at different stations varied from 1 (stn. 1) to 11 (stns. 9 & 4). The number of groups encountered at other stations was 2 groups at stns. 2, 11,12 and 13; 4 groups at station 10; 6 groups at stns. 3; 8 groups at stns. 6 & 8, 9 groups at stns. 5 & 7 and 10 groups at stn. 4.

A total of 91 species / genus / families belonging to 14 groups were encountered during the study. Polychaetes formed the dominant and common group constituted by 54 species from 19 families. Second dominant group amphipods contributed 7 species. Only 2 species were noticed under tanaidaceans and isopods. Three species were recorded under decapods, one species under Mysids and one species under Cumaceans. Gastropods and bivalves were represented by 5 and 8 species and insects were represented by 4 species. Rare occurrence of juvenile fishes and flat worms were also noticed.

Polychaetes dominated at all stations except at stns. 3 & 14, where gastropods and amphipods dominated respectively. Station 6 recorded maximum number (29) of polychaete species followed by station 7 and 8 (27). Stations 5, 4 and 9 showed 20 to 23 species, barmouth registered 18 species and 9 species were recorded from stn.13. In all other stations the species diversity was less varying from 1 to 6.

The spatial distribution of 54 species of polychaetes varied from station to station. The species *Capitella capitata* was noticed at all the stations except stn. 11. The next common species recorded from 10 stations were *Dendronereis aestuarina, Prionospio polybranchiata* and *Heteromastides bifidus. Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis* were observed in 9 and 8 stations respectively. *Ancistrosyllis constricta, Perinereis cavifrons* and *Heteromastus similis* were seen in 7 stations. *Platynereis* sp., *Nephthys dibranchis, Notomastus latericeus* and

Mediomastus capensis were encountered from 6 stations. *Aphrodita alta, Lycastis indica, Diopatra neapolitana, Lumbrinereis impatiens, Prionospio* sp., *Notomastus aberans, N. fauveli,* and *Pista indica* were recorded from 5 stations. *Glycera longipinnis* was found in 4 stations. Species viz. *Prionospio pinnata, Disoma orissae, Cossura coasta,* and *Owenia fusiformis* were collected from 3 stations. *Sthenelais boa, Scolelepis indica, Prionospio cirrobranchiata, Magelona capensis, Heteromastus filiformis* and *Branchiocapitella singularis* were noticed in 2 stations. *Lepidonotus* sp., *Amphinome rostrata, Vanadis Formosa, Syllis spongicola, Scoloplos madagascariensis, Marphysa mossambica, Lumbrinereis simplex, L. polydesma, L. latreilli, L. notocirrata, Goniada emerita, Goniada incerta, Goniadopsis maskellensis, Glycera alba, G. benguellana, Glycera* sp., *Prionospio cirrifera, Leiochrides africanus, Pulliella armata, Branchiomaldane vincenti, Maldane sarsi* and *Polycirrus coccineus each* were collected from one station only.

Oligochaetes were noted at 6 stations whereas *Polygordius* sp. was recorded from one station only.

Maximum representation of amphipods was by *Grandierella bonneri* occurring at 8 stations followed by *Quadrivisio bengalensis* at 7 stations. *Eriopisa chilkensis* and *Grandidierella gilesi* were recorded from 6 and 5 stations. *Corophium triaenonyx* and *Melita zeylanica* were noticed in 4 and 3 stations respectively. Caprillid sp. was seen in one station only.

Both species of tanaidaceans (*Apseudes chilkensis* and *A. gymnophobium)* were recorded from 7 stations each.

The isopod *Cirrolinia fluviatilis* was collected from 4 stations and Anthurid sp. from 3 stations.

Among decapods, penaeid prawn was recorded from 5 stations, crab from 6 stations and *Acetes* sp. only from one station. Cumaceans and mysids were recorded from 2 and 4 stations respectively.

Of the 5 species of gastropods, gastropod sp. was recorded from 4 stations. Others were seen only in 1to 3 stations.

Bivalves were represented by 8 species of which *Villorita cyprinoides* was collected from 4 stations. Bivalve sp., *Pendora flexosa* and *Paphia papilliens* were noticed in 3 stations. Others were found only in 1 or 2 stations.

Insects were noticed in 5 stations and juvenile fishes in 4 stations. Flat worms were observed in one station only.

3.3.4 Statistical inferences (Figs. 3.50 – 3.56 & Tables 3.6 – 3.13)

Community structure

Diversity was least at station 1, showing the presence of a single species. At station 2 with 3 species occurring only in July showed low richness of 2.39. Lower diversity of 1.50 was noticed at station 3. Species richness measured by Margalef varied between 0.67 (April) and 9.02 (December), at station 4, between 1.13 (January) and 9.75 (July, August) at station 5, between 2.40 (April) and 8.47 (July and September), at station 6, between 2.38 (May) and 12.47 (September) at station 7, between 1.42 (May) and 11.20 (November) at station 8, between 3.42 (January) and 9.10 (July) and March at station 9, and between 1.50 (July) and 9.51 (November) at station 14. The seasonal average richness of the 14 stations varied from 1.65 (station 3) to 7.60 (station 6) except stations 1, 2, 10 and 13. The variability of the richness factor was least (31.46%) at station 6 and maximum (60. 25%) at station 3. At stations 4 to 9 the range for richness index was between 5.19 (station 5) and 7.60 (station 9).

Species concentration factor measured by Simpson's index was very low at station 3. The range for the index was 0.01 (February) to 0.28 (August) at station 3, 0.16 (October) to 0.87 (February) at station 4, 0.55 (December) to 0.85 (September) at station 5. 0.56 (February) to 0.91 (November) at station 6, 0.33 (May) to 0.82 (November) at station 7, 0.49 (May) to 0.91 (November) at station 8, 0.49 (September) to 0.89 (December and March) at station 9. It varied between 0.22 (July) and 0.88 (November, February to March). The average distribution of concentration factor was least (0.61) at station 4 and highest (0.80) at station 6. The variability over seasons was maximum (39.05%) at station 14 and minimum (13.45%) at station 6. At stations 3 and 11 very high values (142.76% and 228.19%) were noticed. The distribution showed a normal pattern for the index with bi modes, at station 6 (0.80) and at station 8 (0.75).

Species diversity index was < 1 at stations 3 and 14. The lowest and highest values for12 months varied from 0.01 (February) to 0.90 (August) at station 3, 0.50 (October) to 3.28 (February, January) at station 4, 1.5 (April) to 3.21 (June) at station 5, 1.37 (February) to 3.65 (November) at station 6, 1.50 (May) to 4.85 (March) at station 7, 1.00 (May) to 3.63 (November) at station 8, 1.50 (June) to 3.42 (December) at station 9, 1.09 (January) to 2.00 (December) at station 11, 0.33 (November) to 3.09 (January, February) at station 14. The temporal distributional variability of diversity was higher at stations 4 to 9. Seasonal average of species diversity was least (2.04) at station 4 and maximum (2.84) at station 6 with very high variability (127.03%) at station 3 (234.95%) at station 11 with a dispersion ranging between 22.63% (station 6) and 38.95 % (stations 4 and 5).

Species dominance index recorded a wider range at station 3 (0.06) in May to 5.48 in July at station 4 was between 0.55 (May) and 1.33 (December) at station 5, between 1.47 (April) and 0.95 (August) at station 6, between 0.42 (May) and 1.13 (October), at station 7, between 0.37 (May) and 1.19 (August), at station 8, between 0.33 (May) and 1.19 (October) at station 9, between 0.52 (May) and 1.17 (November) and between 0.43 (May) and 2.22 (October) at station 14.. The temporal average distribution of species dominance in the effluent discharge area varied between 0.67 (station 5) and 0.88 (station 6) except at station 1 (0.23 with 127.01%) and station11 (0.01 with 234.62%) and station 14 (1.30) with 43.82% seasonal variation. Species dominance index was distributed with peak value (0.83) at station 4 and a second peak (0.88) at station 6 and reduced to 0.81 (station 9) with a small gradient from station 6 up to station 9.

On comparing the various seasons for species evenness index high values were observed at stations 5, 6, 8 and 14. At station 3 the value ranged from 0.01

(February) 0.21 (August). At station 4 the values ranged between 0.32 (October) and 1.99 (February). Station 5 showed a higher range, (0.63) (December) to 2.23 (January) at station 6 the evenness in the distribution was comparatively high with minimum evenness (0.80) in July and maximum evenness (2.89) in November. In the late pre-monsoon and early post-monsoon the benthic species were distributed with more uniformity. At station 7, low evenness in the distribution was observed with a range of 0.45 (April) to 1.71 (October and March). At station 8, high evenness in distribution was observed in early post-monsoon in October (2.29) and November (2.63) and to some extent in monsoon period (June) (2.02) and August (2.13) with dominance in July (0.66). Evenness index varied between 0.66 (July) and 2.63 (November). During February (1.97) to May (1.72) the uniformity in the distribution remained steady indicating no changes in the environmental conditions. At station 9 the range for evenness distribution was between 0.44 (June) and 2.54 (March). The steady trend in distribution was observed during December (2.28) to May (1.86) with a peak value during March (2.54) and low value (0.96) in April. At station 14 there was a clear-cut change in the environmental conditions as indicated by low uniformity during June to October and the values ranged between 0.15 and 0.52 (August) and nearly 4 times uniformity during November to May with a range of 1.75 (May) to 2.61 (February). The statistical distribution of Heip's equitability coefficient showed a steady increase from station 3 (0.07) to station 6 (1.92), thereafter decreased to 1.06 at station 7. The high value (1.75) at station 8 decreased gradually. The Heip's value was spatially distributed with highest variation (86.72%) at station 3 and least variability (30.31%) at stations 6 and station 8.

Niche breadth

At station 1, *Capitella capitata* ($\overline{X} = 5/m^2$, C.V = 238.05%) has moderate correlation with sand (r = 0.40) and it had a niche breadth of 3.54.

Of the 3 species at station 2, *Capitella capitata* $\overline{X} = 4/m^2$, C.V = 331.66%) had a niche breadth of 1.41. This species showed high correlation with high organic matter (r = 0.59) and moderate correlation with clay (r = 0.42). *Branchiocapitella* *singularis* and *Littorina littorea* ($\overline{X}$ = 2/m^2, C.V = 331.66%) have a niche breadth of 1.91 and 1.16. These were controlled by the same parameters at the same level.

Station 3 with 14 species had maximum niche breath (6.32) for *Lycastis indica* ($\overline{X}$ = 162/m^2, C.V = 126.79%) and was moderately controlled by suspended load (r = 0.40) and for *Prionospio polybranchiata* the niche breadth was 6.16 ($\overline{X}$= 51/m^2, C.V = 114.94%) and for gastropod sp.($\overline{X}$ = 84042/m^2, C.V = 198.25%) having high correlation with salinity (r = 0.79) and temperature (r = 0.59) had only low niche breadth (3.83). *Villorita cyprinoides* ($\overline{X}$ = 188/m^2, C.V = 197.33%) having very low correlation with ammonia (r = 0.1641) had a niche breadth of 2.64 indicated that at this station higher niche breadth was followed by lower abundance and low variability.

Station 4, with 40 species the niche breadth varied between 1.18 (*Nucula* sp. $\overline{X}$ = 188/m^2, C.V = 197.33%) and 7.33 (*Villorita cyprinoides,* $\overline{X}$ = 637/m^2, C.V = 99.11%) followed by 6.08 (*Prionospio polybranchiata,* $\overline{X}$ = 378/m^2, C.V = 112.21%), 6.03 (*Heteromastides bifidus,* $\overline{X}$ = 70/m^2 C.V = 114.12%) and 6.00 (Gastropod sp., $\overline{X}$ = 28/m^2, C.V = 123.73%). *Villorita cyprinoides* was highly correlated with dissolved oxygen (r = 0.80) ammonia (r = 0.59) and nitrite (r = 0.56). *Prionospio polybranchiata* was highly correlated with nitrite (r = 0.71). About 10% of the species had niche breadth > 5.11 and their average abundance ranged between 7/m^2 (Perinereidae, C.V = 141.42%) and 172/m^2 (*Dendronereis aestuarina,* C.V. 145.45%) and the latter was highly related to dissolved oxygen (r = 0.48), silt (r = 0.45) and suspended load (r = 0.69). *Lycastis indica* in this group showed high correlation with particulate organic carbon (r = 0.56). The rest of the species had niche breadth < 4.34 indicating high abundance and low seasonal variation and their abundance was controlled by nutrients.

Of the 37 species at station 5, 4 were moderately abundant and showed a niche breadth between 1.41 (*Diopatra neapolitana,* $\overline{X}$ = 16/m^2) with high temporal variation and 8.05 (*Ancistrosyllis constricta,* $\overline{X}$ = 71/m^2, C.V = 90.19%). The latter was highly correlated with nitrate (r = 0.77) dissolved oxygen (r = 0.61) and organic matter (r = 0.46). Nearly 50% of the species have niche breadth more than 4.34. Low variation was obtained for *Nephthys dibranchis*, which was highly correlated with nitrate (r = 0.57), clay (0.55) and dissolved oxygen (r = 0.54). In this station also low seasonal variation and high seasonal average resulted in high niche breadth.

At station 6, with 44 species the niche breadth ranged between 1.52 (*Scolelepis indica,* $\overline{X}$ = 12/m^2, C.V = 331.66%) and 8.04 (*Ancistrosyllis constricta,* $\overline{X}$ = 96/m^2, C.V = 91.92%) and moderately related to water quality and sediment characteristics. Nearly 50% of the species occurring at this station had a niche breadth >4.34 and their average abundance varied between 2/m^2 (*Platynereis* sp.) and 125/m^2 (*Prionospio polybranchiata)* and were controlled by suspended load (r = 0.56). *Paraheteromastus tenuis* ($\overline{X}$ = 84/m^2) showed relationship with silt (r = 0.50), salinity and temperature (r = 0.37) and showed a niche breadth of 2.84. Oligochaete sp. with an abundance (130/m^2) showed relation with suspended load (r = 0.66) and very low niche breadth of 2.28. Generally in this region higher average abundance, higher seasonal variation and lower niche breadth were noticed.

At station 7, with 40 species, *Ancistrosyllis constricta* ($\overline{X}$ = 200/m^2) was highly related with nitrite (r = 0.53) and sand (r = 0.51). *Prionospio pinnata* ($\overline{X}$ = 204/m^2) was highly dependent on temperature (r = 0.49) and salinity (r = 0.40). *Capitella capitata* ($\overline{X}$ = 115/m^2) and *Paraheteromastus tenuis* ($\overline{X}$ = 359/m^2) were controlled by nitrite (r = 0.58) and suspended load (r = 0.47), *Oligochaete* sp. ($\overline{X}$ = 106/m^2) showed correlation with silt (r = 0.59) and suspended load (r = 0.46). The niche breadth of the above species ranged between 1.69 (Oligochaete sp.) and 6.98 (*Ancistrosyllis constricta*). In this station it was observed that the abundant species with low seasonal variation had high niche breadth.

Station 8 with 44 species of which, *Diopatra neapolitana* ($\overline{X}$ = 94/m^2) with low seasonal variation was highly correlated with nitrate (r = 0.51). *Prionospio polybranchiata* ($\overline{X}$ = 75/m^2) was highly affected by nitrate (r = 0.91), ammonia (r = 0.49) and temperature (r = 0.56). *Heteromastides bifidus* ($\overline{X}$ = 47/m^2, C.V = 195.44%) depended on nitrite (r = 0.62), *Mediomastus capensis* ($\overline{X}$ = 45/m^2) were controlled by organic matter content (r = 0.42) and sand (r = 0.55) and the maximum abundant *Corophium triaenonyx* ($\overline{X}$ = 121/m^2, C.V = 268.55%) was controlled by nitrate (r = 0.73), particulate organic carbon (r = 0.05) and more associated with silty sediment (r = 0.30). The niche breadth ranged between 1.34 (*Prionospio cirrobranchiata*) and 6.55 (*Prionospio polybranchiata*).

Of the 40 species at station 9, *Prionospio polybranchiata* ($\overline{X}$ = 52/m^2, C.V = 162.80%), *Pendora flexosa* ($\overline{X}$ = 59/m^2, C.V = 269.55%), *Quadrivisio bengalensis* (x = 81/m^2, C.V = 262.12%), *Dendronereis aestuarina* ($\overline{X}$ = 99/m^2, C.V = 84.65%), *Notomastus aberans* ($\overline{X}$ = 123/m^2, C.V = 316.57%) *and Heteromastides bifidus* ($\overline{X}$ = 186/m^2, C.V = 113.92%) *were* abundant and their niche breadth were 4.05, 2.06. 2.22, 8.09, 1.26 and 6.34 respectively. The niche breadth ranged between 1.23 (*Nephthys dibranchis*) and 8.09 (*Dendronereis aestuarina*). Except the abundant species the niche breadth showed an increasing trend with high abundance and low variability. At this station the species of increasing abundance was highly correlated with ammonia (r = 0.60) and sand (r = 0.58), with nitrite (r = 0.89), with salinity (r = 0.35), with ammonia (r = 0.90) and clay (r = 0.18), with nitrite (r = 0.58) and suspended load (0.55) and silt (r = 0.53) respectively.

At station 11 with 4 species, all rare had low niche breadth (1.32) for Dendronereis *aestuarina* ($\overline{X}$ = 121/m^2, C.V = 331.66%) and *Prionospio polybranchiata* ($\overline{X}$ = 7/m^2, C.V = 331.66%) both having high correlation with salinity (r = 0.83) and organic matter (r = 0.63) and only the former with silt (r = 0.70).

Station 14, the reference station showed 37 species of which the *Grandidierella gilesi* ($\overline{X}$ = 3123/m^2), *Quadrivisio bengalensis* ($\overline{X}$ = 4929/m^2), *Eriopisa chilkensis* ($\overline{X}$ = 1666/m^2), *Corophium triaenonyx* (X = 54386/m^2), *Apseudes gymnophobium* ($\overline{X}$ = 708/m^2) and *Cirrolinia fluviatilis* ($\overline{X}$ = 3458/m^2) have a coefficient of variation between 259 and 324%. The first three species were controlled by clay (r = 0.72, 0.68 and 0.68) and the last species by suspended load (r = 0.83). In this station niche breadth varied between 1.09 (Mysid sp., $\overline{X}$ = 87/m^2)

and 5.62 (*Diopatra neapolitana*, $\overline{X} = 361/m^2$ and C.V. = 117.98%). All abundant species have very low niche breadth indicating an inverse relation between species abundance and niche breadth.

Predictive regression model

In the effluent discharge area the 14 stations were classified into 6 groups depending on the distance from the discharge sites on both limbs. The 6 groups were (1) stations 1, 2 and 3 (2) stations 4 and 5 (3) stations 6 and 7 (4) stations 8 and 9 (5) stations 10, 11, 12 and 13 and (6) station 14.

Stations 1, 2 and 3

The most important parameter combinations were nitrite, phosphate, silt and clay. These were taken from, among the 256 combinations of the 8 parameters viz., temperature, nitrite, ammonia, phosphate, organic matter, sand, silt and clay ; which predict the benthic density of these stations with 69.01% explained variability using the model

$$Y = 0.4672 - 0.3332\,X1 + 0.4154\,X2 - 0.7805\,X_3 - 0.2375\,X_4 - 0.2055\,X_1\,X_2 - 0.8168\,X_1.X_3 + 0.021469\,X1\,X_4 - 0.3545\,X2\,X3 + 0.3101\,X2\,X_4 + 0.2448\,X3\,X4$$

where Y = total benthic density X_1 = nitrite X_2 = phosphate, X_3 silt, X_4 clay and these parameters were transformed into log (x + 1) and standardised as $Z = (X\text{-}mean)/\sigma$

Y is also the standardised log transformed total benthic density $F\,(10,\ 25) = 8.7943$, $P = < 0.05$). The relatively important parameters were ranked as (nitrite * silt) > - silt > (+phosphate) > (+prostate * silt) > (-nitrite) > (+phosphate * clay) > (+silt * clay) > -clay > (-nitrite * phosphate) > (+nitrite * clay). Of these the first two were limiting factors and the third controlling factor for benthic production in these stations. The standard error and test statistic for the significance of these parameters along with 95% confidence interval given as below -Lower Confidence Limit (LCL), Upper Confidence Limit (UCL).

Parameters	Relative importance	Standard error	Statistic 't'	95% confidence interval	
				LCL	UCL
$X_1 * X_3$	-0.8168	0.2067	-3.9524	(-1.2426	-0.3911)
X_3	-0.7805	0.1235	-6.3201	(-1.0349	-0.5261)
$X_2 *$	0.4154	0.2098	1.9804	(-0.0167	0.8475)
$X_2 * X_3$	-0.3541	0.2600	-1.3617	(-0.8898	0.1816)
X_1	-0.3332	0.2196	-1.5173	(-0.7857	0.1192)
$X_2 * X_4$	0.3101	0.2065	1.5013	(-0.1154	0.7356)
$X_3 * X_4$	0.2448	0.2269	1.0787	(-0.2227	0.7123)
X_4	-0.2375	0.1082	-2.1944	(-0.4604	-0.0145)
$X_1 * X_2$	-0.2055	0.1108	-1.8555	(-0.4337	0.0227)
$X_1 * X_4$	0.2147	0.2208	0.0972	(-0.4334	0.4763)

All the model parameters, particularly the first three were highly significant ($P = < 0.05$) and the last one was statistically insignificant and hence need not be considered in the future prediction for benthic density in this area.

Stations 4 and 5

Depending on the high correlation between the total benthic density and parameters viz. Salinity, ($r = 7.6$ at stn. 4 and – 0.57 at stn. 5), phosphate ($r = 0.71$ at stn. 4), nitrite ($r = 0.49$ at stn. 4, 0.62 at stn. 5), ammonia ($r = 0.37$ at stn. 4), organic matter ($r = 0.40$ at stn. 4), sand, ($r = 0.38$ at stn. 5) and suspended load ($r = -0.38$ at stn. 4 and 0.85 at stn.5), the above parameters and their first order interaction effect were considered the best as possible combinations. The best set of parameters obtained was salinity (X_1), phosphate (X_2), ammonia (X_3), organic matter (X_4), sand (X_5) and suspended load (X_6). These parameters were log transformed and normalised to predict the log transformed normalised values of total benthic density from the model,

$$Y = - 0.5844 - 0.3929 X_1 - 0.2308 X_2 + 0.01928 X_3 + 0.3593 X_4 + 0.4747 X_5 + 0.1863 X_6 + 1.3124 (X_1 X_2) - 0.7312 (X_1 X_3) - 0.7012 (X_1 X_4) + 0.03154 (X_1 X_5) + 1.1155 (X_1 X_6) - 0.0022 (X_2 X_3) - 1.1449 (X_2 X_4) + 0.7016 (X_2 X_5) + 0.8534 (X_2 X_6) + 0.0101 (X_3 X_4) + 0.1973 (X_3 X_5) - 0.2158 (X_3 X_8) - 0.6025 (X_4 X_5) - 0.8246 (X_4 X_6) + 0.3534 (X_5 X6).$$

This model explained about 97.37% of the spatial and seasonal variability in the benthic density. $F(21, 2) = 41.5773$, $P < 0.05$). The model parameters were ranked according to the relative importance as (salinity * phosphate) > (phosphate * organic matter) > (salinity * suspended load) > (phosphate * suspended load) > (organic matter * suspended load) > salinity * ammonia) > (phosphate * ammonia) > (phosphate * sand) > (salinity * organic matter) > (organic matter * suspended) load) > (sand) > (salinity) > (organic matter) > (sand * suspended load) > (ammonia * suspended load) > (ammonia * sand) > (suspended load) > salinity * sand) > (ammonia) > (ammonia * organic matter) > (phosphate * ammonia). Of these the first, third and fourth were the leading and, controlling factors while second, fifth and sixth were the leading limiting factors. The significance of the parameters, standard error and 95% confidence interval were given below.

Parameters	Relative importance	Standard error	Statistic 't'	95% confidence interval	
				LCL	UCL
$X_1 * X_2$	1.3124	0.1551	8.4524	(0.6443	1.9805)
$X_2 * X_4$	-1.1449	0.3019	-3.7926	(-2.4439	0.1541)
$X_1 * X_6$	1.1155	0.2679	4.1639	(-0.0374	2.2683)
$X_2 * X_6$	0.8534	0.2378	3.5885	(-0.1699	1.8768)
$X_4 * X_6$	-0.8246	0.3320	-2.4839	(-2.2532	0.6039)
$X_1 * X_3$	-0.7312	0.1787	-.40914	(-1.5002	0.0378)
$X_2 * X_5$	0.7016	0.1541	4.5539	(0.0387	1.3646)
$X_1 * X_4$	-07012	0.1885	-3.7202	(-1.5122	0.1098)
$X_4 * X_5$	-06025	0.1056	-5.7057	(-1.0569	-0.1481)
X_5	0.4747	0.2259	2.1013	(-0.4974	1.4468)
X_1	-0.3929	0.0778	-5.0518	(-0.7276	-0.0582)
X_4	0.3593	0.1872	1.9194	(-0.4462	1.1648)
$X_5 * X_6$	0.3534	0.2484	1.4229	(-0.7154	1.4222)
X_2	-02508	0.1196	-1.9300	(-0.7453	0.2838)
$X_3 * X_6$	-0.2158	0.2283	-0.9453	(-1.1981	0.7665)
$X_3 * X_5$	0.1973	0.4477	0.4408	(-1.7291	2.1238)
X_6	0.1863	0.1177	1.5833	(-0.3201	0.6928)
$X_1 * X_5$	0.0315	0.1988	0.1587	(0.8239	0.88700
X_3	0.0192	0.1742	0.1107	(-0.7303	0.7689)
$X_3 * X_4$	0.0101	0.1366	0.0742	(-0.5777	0.5980)
$X_2 * X_3$	-0.0022	0.1138	-0.0191	(-0.4421	0.4877)

The table shows that first 14 factors are highly significant and indicated that even if the last 4 factors are deleted the significance of the model will be retained since these are not significantly important ($P > 0.05$).

Stations 6 and 7

For predicting the benthic density in these two stations the parameters temperature, (r = 0.26 at stn. 6 – 0.43 at stn. 7), nitrite (r - -0.23 at stn. 6, 0.39 at stn. 7), ammonia (r= - 0.37 at stn. 7), organic matter (r =-0.47 at stn. 6, - 0.72 at stn. 7), particulate organic carbon (r = 0.24 at stn. 6, - 0.37 at stn. 7), sand (r =-0.45 at stn. 6, 0.32 at stn. 7), and clay (r= 0.33 at stn. 6, - 0.24 at stn. 7) were selected depending on the comparatively high correlation of these parameters with total benthic density. The model was based on log transformed and standardised values of both Y (benthic density) and X_1 – X_6 (parameters) is

$Y = 0.2044 - 0.1856\ X_1 - 1.2628\ X_2 - 0.2820\ X_3 + 0.1962\ X_4 + 0.6552\ X_5 - 0.3772\ X_6 - 0.9734\ (X_1\ X_2) + 0.6044\ (X_1\ X_3) + 0.6997\ (X_1\ X_4) - 1.0140\ (X_1\ X_5) - 2.4074\ (X_1\ X_6) + 1.9202\ ((X_2\ X_3) + 0.5902\ (X_2\ X_6) + 0.0349\ (X_2\ X_5) - 0.5076\ (X_2\ X_6) - 0.1511\ (X_3\ X_6) + 1.0031\ (X_3\ X_5) - 1.883\ (X_3\ X_6) + 0/6229\ (X_4\ X_5) + 0.1360\ (X_4\ X_6) - 0.1896\ (X_5\ X_6)$. Where X_1 = temperature, X_2 ammonia, X_3 organic matter and X_4 particulate organic carbon, X_5 sand and X_6 clay.

This model could explain about 93.4% of the spatial as well as temporal variation in the benthic density distribution. The relatively most important parameters were (temperature * clay) > (ammonia * organic matter) > (sand * clay) > (ammonia) > (organic matter * clay) > (temperature * sand) > (organic matter * particulate organic carbon) > (temperature * ammonia) > (temperature * particulate organic carbon) > (sand) > (particulate organic matter * sand) > (temperature * organic matter) > (ammonia * particulate organic carbon) > (ammonia * clay) > (clay) > (organic matter) > (particulate organic carbon) > (temperature) > (particulate organic carbon * clay) > (organic matter * particulate organic carbon) > (ammonia * sand). In this arrangement the first 6 factors except factor 2 are limiting the benthic production in these stations. The significance of the model in terms of parameters is as follows, along with their 95% confidence interval.

In the table given below all the parameters are significant ($P < 0.05$) in predicting the benthic production. This further concludes that even if the last three parameters are removed (not significant, $P > 0.05$). The prediction efficiency of the model will not be affected.

Parameters	Relative Importance	Standard Error	Statistic 't'	95% confidence interval LCL	UCL
$X_1 * X_6$	-2.4074	0.1497	-16.0812	(-3.0516	-1.7632)
$X_2 * x_3$	1.9202	0.1220	15.7440	(1.3954	2.4450)
$X_5 * X_6$	-1.8960	0.0002	-8881.0620	(-1.8969	-1.8951)
X_2	-1.2628	0.1253	-10.0798	(-1.8019	-0.7237)
$X_3 * X_6$	-1.1883	0.2385	-4.9818	(-2.2147	-.01619)
$X_1 * X_5$	-1.0140	0.1439	-7.0468	(-1.6332	-0.3948)
$X_3 * X5$	1.0031	0.2228	4.5019	(0.0443	1.9619)
$X_1 * X_2$	-0.9734	0.1439	-6.7650	(-1.5925	-0.3542)
$X_1 * X_4$	0.6997	0.1618	4.3257	(0.0037	1.3958)
X_5	0.6552	0.1371	4.7809	(0.0655	1.2450)
$X_4 * X5$	0.6229	0.2567	2.4262	(-0.4815	1.7274)
$X_1 * X_3$	0.6044	0.1206	5.0097	(0.0853	1.1235)
$X_2 * X_4$	0.5903	0.2517	2.3453	(-0.4927	1.6732)
$X_2 * X_6$	-0.5076	0.2569	-1.9753	(-1.6132	0.5981)
X_6	-0.3772	0.1000	-3.7737	(-0.8074	0.0529)
X_3	-0.2820	0.0769	-3.6644	(-0.6131	0.0491)
X_4	0.1962	0.1300	-1.5091	(-0.3633	0.7557)
X_1	-0.1856	0.0988	-1.8794	(-0.6105	0.2393)
$X_4 * X_6$	-0.1511	0.3001	0.4531	(-1.1552	1.4272)
$X_3 * X_4$	0.1360	0.1772	-0.8527	(-0.9138	0.6115)
$X_2 * X_5$	0.0349	0.1713	0.2042	(-07020	0.7720)

Stations 8 and 9

In this area depending on the linear correlation between total density and parameters (water quality and sediment characteristics) temperature ($r = -0.38$ at stn. 8), salinity ($r = -0.34$ at stn. 8), phosphate ($r = -0.27$ at stn. 8, $r = -0.26$ at stn. 9), nitrate (0.51 at stn. 8), organic matter ($r = -0.36$ at stn. 8), silt ($r = 0.33$ at stn. 8, $r = -0.21$ at stn. 9), and clay ($r = -0.39$ at stn. 8) were selected for the model. The log transformed standardised values of the above parameters could predict the log transformed standardised values of the total benthic density from the model.

$Y = -1.4590 + 1.2281\,X_1 - 1.6099\,X_2 + 0.1765\,X_3 - 1.2721\,X_4 + 0.8327\,X_5 - 0.5115\,X_6 + 3.8638\,(X_1 X_2) + 1.0819\,(X_1 X_3) + 0.9653\,(X_1 X_4) + 0.3995\,(X_1 X_5) - 1.3168\,(X_1 X_6) + 1.7265\,(X_2 X_3) - 2.0713\,(X_2 X_4) + 1.2682\,(X_2 X_5) + 1.5218\,(X_2 X_6) - 0.9336\,(X_3 X_4) - 4.7751\,(X_3 X_5) - 1.0872\,(X_3 X_6) + 0.7972\,(X_4 X_5) + 1.4801\,(X_4 X_6)$

+ 1.2521 (X_5 X_6) were X_1 temperature, X_2 salinity, X_3 phosphate, X_4 nitrate, X_5 silicate, X_6 clay.

This model explained about 90.44% of the spatial and temporal variation in the benthic density. The significance of the model in terms of the model parameters, test statistic 't' and 95% confidence interval for the regression coefficient are as follows:

Parameters	Relative Importance	Standard Error	Statistic 't'	95% confidence interval	
				LCL	UCL
$X_3 * X_5$	-4.7751	0.3577	-13.3489	(-6.3144	-.3.2359)
$X_1 * x_2$	3.8637	0.1797	21.5026	(3.0906	4.6370)
$X_2 * X_4$	-2.0713	0.4147	-4.9944	(-3.8559	-0.2867)
$X_2 * X3$	1.7264	0.2496	6.9184	(0.6527	2.8003)
X_2	-1.6499	0.3977	-430486	(-3.3211	0.1012)
$X_4 * X_6$	1.4800	0.5638	2.6253	(-0.9458	3.9060)
$X_2 * X6$	1.5218	0.3846	3.9570	(-0.1331	3.1767)
$X_1 * X_6$	-1.3168	0.3349	-3.9316	(-2.7580	0.1244)
X_4	-1.2721	0.2879	-4.4183	(-2.5111	-0.0332)
$X_2 * X_5$	1.2682	0.2218	5.7181	(0.3139	2.2225)
$X_5 * X_6$	1.2521	-	-	-	-
X_1	1.2281	0.2524	4.8655	(0.1420	2.3142)
$X_1 * X_3$	1.0891	0.3249	3.3298	(-0.3162	2.4800)
$X_3 * X_6$	-1.0872	0.3801	-2.8599	(-2.7228	0.5485)
$X_1 * X_4$	0.9653	0.4849	1.9906	(-1.1214	3.0519)
$X_3 * X_4$	-0.9336	0.3550	-2.6302	(-2.4610	0.5938)
X_5	0.8327	0.3281	2.5376	(-0.5793	2.2446)
$X_4 * X_5$	0.7972	0.4406	1.8094	(-1.0986	2.6931)
X_6	-0.5115	0.2370	-2.1583	(-1.5313	1.5083)
$X_1 * x_5$	0.3995	0.2649	1.5083	(-0.7403	1.5394)
X_3	0.1765	0.2770	0.6370	(-1.0157	1.3686)

Among these parameters all except the last one were statistically significant, removing any one of the above, except the last one will lead to reduction in the prediction efficiency of the model.

Stations 10, 11, 12 and 13

In these stations as in the earlier cases depending on the benthic density and parameter correlation, the factors – temperature X1 (r = 0.68 at stn. 10, -0.58 at stn. 12), salinity X2 (r = 0.92 at stn. 10, 0.82 at stn. 11), dissolved oxygen X3 r = -086 at stn. 10, - 0.48 at stn. 11), nitrite X4 (r= 0.71 at stn. 10, 0.35 at stn. 12), nitrate X_5

Parameters	Relative importance	Standard Error	Statistic 't'	95% confidence interval	
				LCL	UCL
$X_2 \cdot X_9$	-75.5328	0.6270	-120.4442	(-78.2220	-72.8257)
$X_1 \cdot X_3$	61.3857	7.1454	8.5909	(30.6391	92.1324)
$X_2 \cdot X_8$	60.4538	1.4154	42.7123	(54.3634	66.5441)
$X_3 \cdot X_4$	-57.1674	32.9175	-1.7367	(198.8112	84.4765)
$X_1 \cdot X_2$	53.6143	0.5918	90.6016	(51.0680	56.1607)
X_2	-44.2595	1.6537	-26.7634	(-51.3756	-37.1435)
$X_2 \cdot X_4$	-38.1823	1.1731	-32.5492	(-43.2300	-33.1346)
$X_2 \cdot X_7$	-36.6789	2.2162	-16.5507	(-46.2150	-27.1427)
X_8	-21.7513	9.5245	-2.2837	(-62.7354	19.2328)
X_1	18.0000	4.4571	4.0386	(1.1786	37.1792)
X_7	16.7284	2.9822	5.6061	(3.8861	29.5509)
X_9	-13.3117	0.5147	-25.8629	(-15.5265	-11.0970)
X_6	12.8483	10.4285	-1.2320	(-57.7223	32.0256)
$X_5 \cdot X_7$	-12.5576	5.9851	-2.0981	(-38.3117	13.1965)
$X_2 \cdot X_5$	-12.4846	3.1586	-3.9526	(-26.0761	1.1069)
$X_6 \cdot X_7$	11.2913	16.3500	0.6906	(-59.0628	81.6453)
$X_1 \cdot X_6$	6.6908	1.1856	5.9435	(1.5892	11.7923)
$X_5 \cdot X_8$	-4.9509	20.0707	-0.2467	(-91.3149	81.4132)
X_3	3.5471	0.6312	5.6199	(0.8312	6.2630)
$X_4 \cdot X_8$	3.3711	4.5271	0.7446	(-16.1090	22.8511)
$X_3 \cdot X_6$	-2.9261	2.7697	-1.0565	(-14.8442	8.9919)
X_5	1.9871	7.2262	-0.2750	(33.0815	29.1072)
$X_7 \cdot X_9$	1.7544	49.4145	-0.0355	(-214.3848	210.8761)
$X_1 \cdot X_5$	1.6651	14.0604	0.1184	(-58.8369	62.1671)
$X_5 \cdot X_9$	-1.5893	7.3267	-0.2169	(-33.1160	29.9373)
$X_2 \cdot X_3$	1.5199	0.9863	1.5411	(-2.7239	5.7638)
$X_5 \cdot X_6$	1.4.00	2.4593	-0.5693	(-11.9822	9.1521)
$X_4 \cdot X_6$	-1.3640	3.3497	-0.4072	(-15.7779	13.0499)
$X_1 \cdot X_7$	1.2967	5.5650	-0.2330	(-25.2431	22.6497)
X_4	1.1532	5.5576	-0.2057	(-25.0574	22.7709)
$X_4 \cdot X_7$	1.0736	6.9020	0.1556	(-28.6256	30.7729)
$X_3 \cdot X_5$	1.0309	2.1588	0.4775	(-8.2586	10.3204)
$X_1 \cdot X_8$	-0.9550	0.3690	-2.5885	(-2.5427	0.6326)
$X_6 \cdot X_9$	0.9389	25.1515	0.0367	(-109.0091	110.8868)
$X_6 \cdot X_8$	0.8479	34.7593	0.0244	(-148.7213	150.4171)
$X_3 \cdot X_7$	-0.8379	3.5121	-0.2386	(-15.9503	14.2746)
$X_1 \cdot X_4$	0.8213	1.0939	0.7508	(-3.8858	5.5284)
$X_1 \cdot X_9$	-0.7742	2.1543	-0.3594	(-10.0441	8.4958)
$X_4 \cdot X_5$	-0.6378	1.0554	-0.6049	(-5.1752	3.8996)
$X_2 \cdot X_6$	-0.5516	1.6166	-0.3412	(-7.5078	6.4047)
$X_7 \cdot X_8$	-0.4145	24.2120	0.2069	(-4.9040	5.39940)
$X_3 \cdot X_9$	-0.2477	1.1972	-0.0171	(-104.5989	103.7700)
$X_4 \cdot X_9$	0.1894	6.9668	0.0272	(-29.7887	30.1675)
$X_8 \cdot X_9$	-0.1991	0.0001	-1397.9550	(-0.1997	-0.1985)
$X_3 \cdot X_8$	-0.0386	1.8913	0.0204	(-8.1767	8.0995)

($r = 0.44$ at stn. 10, 0.85 at stn. 13), ammonia X6 ($r = 0.35$ at stn. 10, -0.33 at stn. 11), organic matter X_7 ($r = 0.46$ at stn. 10, 0.63 at stn. 11, 0.34 at stn. 12), particulate organic carbon X_8 ($r = -0.31$ at stn. 12, 0.64 at stn. 13), and clay X_9 ($r = 0.51$ at stn. 12) were selected for the model. The standardised values of the parameters could predict the standardised values of the total benthic density explaining 80.48% of the spatial and temporal variability from the model.

$Y = -11.4984 + 18.00\ X_1 - 44.2596\ X_2 + 3.5471\ X_3 - 1.1432\ X_4 - 1.9871\ X_5 - 12.8483\ X_6 + 16.7185\ X_7 - 21.7513\ X_8 - 13.3117\ X_9 + 53.6143\ (X_1 X2) + 61.3857\ (X_1 X_3) + 0.8213\ (X_1 X_4) + 1.6651\ (X_1 X_5) + 6.6908\ (X_1 X_6) - 1.2967\ (X_1 X_7) - 0.9550\ (X_1 X_8) - 0.7742\ (X_1 X_9) + 1.5199\ (X_2 X_3) - 38.1823\ (X_2 X_4) - 12.4846\ (X_2 X_5) - 0.5516\ (X_2 X_6) - 36.6789\ (X_2 X_7) + 60.4538\ (X_2 X_8) - 75.5248\ (X_2 X_9) - 57.1674\ (X_3 X_4) + 1.0309\ (X_3 X_5) - 2.9261\ (X_3 X_6) - 0.8378\ (X_3 X_7) - 0.3858\ (X_3 X_8) + 0.2477\ (X_3 X_9) - 0.6378\ (X_4 X_5) - 1.3640\ (X_4 X_6) + 1.0736\ (X_4 X_7) + 3.3711\ (X_4 X_8) + 0.1894\ (X_4 X_9) - 1.4000\ (X_5 X_6) - 12.5576\ (X_5 X_7) - 4.9509\ (X_5 X_8) - 1.5893\ (X_5 X_9) + 11.2913\ (X_6 X_7) + 0.8479\ (X_6 X_8) + 0.9388\ (X_6 X_9) - 0.4145\ (X_7 X_8) - 1.7544\ (X_7 X_9) - 0.1991\ (X_8 X_9)$ in which the parameters (X_1 to X_9) were as listed earlier, the significance of the model parameters, their standard error test statistic 't' and 95% confidence interval are given below.

From the above table indicated that the first 12 parameters were statistically significant and if any one of these factors was removed, the precision of the estimates of the total benthic productivity will be affected. The last few parameters will not affect the predicted estimate significantly if they have been removed from the model.

Station 14

The parameters considered at this station are nitrite X_1 ($r = -0.15$), ammonia X_2 ($r = -0.09$), sand X_3 ($r = -0.51$) and clay X_4 ($r = 0.69$) for the best prediction model using standardised values of the total benthic density. The individual effects and their first order interaction effects could predict the density using the model.

$Y = 2.2020 - 5.2994 X_1 + 8.3132 X_2 + 7.3095 X_3 + 3.4061 X_4 - 1.0688 (X_1 X_2) - 11.7805 (X_1 X_3) + 3.4061 X_4 - 1.0688 (X_1 X_2) - 11.7805 (X_1 X_3) - 0.6899 (X_1 X_4) - 2.3468 (X_2 X_3) + 17.6227 (X_2 X_4) + 7.0840 (X_3 X_4)$ with 99.99% of variability being explained. Other models were also obtained with almost more than 86% variability being explained. In these models ammonia was the common parameter and nitrite, phosphate and clay were the other important parameters. $F (10, 1) = 161469.92$, $P < 0.001$). The significance of the model parameters could be given as $(X_2 X_4) > (X_1 X_3) > X_2 > X_1 > (X_3 X_4) > X_3 > X_4 > (X_2 x_3) > (X_1 x_4)$. The significance of the parameters is given below:

Parameters	Relative Importance	Standard Error	Statistic 't'	95% confidence interval	
				LCL	UCL
$X_2 * X_4$	12.0289	0.0049	364.2758	(17.0080	18.2374)
$X_1 * X_3$	-11.7791	0.0340	-346.7262	(-12.2122	-11.3488)
X_2	8.3112	0.0240	346.5547	(8.0075	8.6170)
X_1	-5.2989	0.1116	-456.6577	(-5.4469	-5.1520)
$X_3 * X_4$	-5.0482	0.0193	367.6162	(6.8392	7.3289)
X_3	4.6206	0.0184	396.5729	(7.0753	7.5436)
X_4	-2.4273	0.0075	452.4594	(3.3104	3.5017)
$X_2 * X_3$	1.6725	0.0049	-474.7174	(-2.4096	-2.2840)
$X_1 * X_4$	1.1629	0.0071	-97.0990	(-0.7802	-0.5996)
$X_1 * X_2$	-1.0688	0.0017	-637.2543	(-1.0901	-1.0475)

All the parameters were significant for predicting the benthic density.

Similarity between stations and months

At station 3, > 90% similarity was observed between June and other months and also between February and other months. A lesser degree of similarity but has been observed between December and other months. During September to December similarity was only 40 to 80% so also during March to April (25 to 50%).

Based on presence/ absence of species June to November showed < 50% similarity. But February to March showed 40 to 80% common species. This area was dominated by Gastropod sp. ($\overline{X} = 84042/m^2$), Lycastis *indica* ($\overline{X} = 162/m^2$) and *Dendronereis aestuarina* ($\overline{X} = 150/m^2$) and *Villorita cyprinoides* ($\overline{X}$ =

188/m^2), the Gastropod sp. was highly correlated with salinity (0.79) and temperature (0.59).

At station 4 high similarities was obtained between months August to December and January to May (70 to 90%). But less similarity was observed between the months of pre-monsoon (40 to 60%). At this station *Villorita cyprinoides* (X = 637/m^2), *Prionospio polybranchiata* ($\overline{X}$ = 378/m^2), *Lycastis indica* ($\overline{X}$ = 131/m^2) and *Dendronereis aestuarina* ($\overline{X}$ = 172/m^2) were abundant *Villorita cyprinoides* was highly correlated with dissolved oxygen (r = 0.80), ammonia (r = 0.59) and nitrite (r = 0.56). *Prionospio polybranchiata* showed high correlation with nitrate (r = 0.71). *Dendronereis aestuarina* was highly dependent on dissolved oxygen (r = 0.48), silt (r = 0.45) and suspended load (r = 0.68) where as *Lycastis indica* was dependent on particulate organic carbon (r = 0.57), sand (r = 0.32) and phosphate (r = 0.34). Depending on the presence/ absence of species, only April and February showed about 63% similarity. Very low similarity was observed between May and other months (< 25%) and October with July and August (< 10%).

At station 5 high similarities was observed between the months, June to December and March to May (> 70%). Very low similarity was observed between February and August to October (< 60%). Maximum similarity was observed between May and June to December (> 90%). Based on the common number of species, it was noticed that very low value of similarity was obtained between seasons at this station. This station was dominated by the *Notomastus aberans* ($\overline{X}$ = 130/m^2), *Prionospio polybranchiata* ($\overline{X}$ = 104/m^2) and *Notomastus latericeus* ($\overline{X}$ = 97/m^2), which were seasonally distributed with high variation. *Notomastus aberans* had high correlation with ammonia (r = 0.33, C.V. > 200%), *Prionospio polybranchiata* with suspended load (r = 0.95), nitrite (r – 0.80) and sand (r = 0.35). *Nephthys dibranchis* with nitrate (r = 0.57), clay (r = 0.55) and dissolved oxygen (r = 0.54).

At station 6 which was dominated by the species 5 having moderate correlation with temperature (r = 0.25), silt (r = 0.28) and clay (r = 0.20), Prionospio *polybranchiata* ($\overline{X}$ = 125/m^2) showed high correlation with suspended load (r = 0.56), *Notomastus aberans* ($\overline{X}$ = 95/m^2) which was related with suspended load (r = 0.39) and Oligochaete sp. ($\overline{X}$ = 130/m^2) which was controlled by suspended load (r = 0.66) and *Paraheteromastus tenuis* ($\overline{X}$ = 84/m^2) which was dependent on silt (r = 0.50), salinity (r = 0.36) and temperature (r = 0.38) showed high similarity between months (> 90%) except between March and April (54%) and March and May (51%). Based on the presence/ absence of common species January and February showed the least similarity with other months of the study period (< 10%).

At station 7, where *Ancistrosyllis constricta* ($\overline{X}$ = 199/m^2), *Prionospio pinnata* ($\overline{X}$ = 205/m^2), ($\overline{X}$ = 139/m^2), *Paraheteromastus tenuis* ($\overline{X}$ = 360/m^2) and Oligochaete sp. ($\overline{X}$ = 106/m^2) which were highly correlated with nitrite (r = 0.05), biological oxygen demand (r = 0.53), ammonia (r = 0.26), nitrate (r = 58) and silt (r = 0.59) and which were highly heterogeneously distributed (C.V. > 100.98%) showed a pattern similar to that of station 6 for similarity based on abundance of species, with May and April having highest similarity with other months of the year (> 70%). The highly dissimilar periods were September and January (< 60%). But based on the presence/ absence of species it showed a similarity < 40% between months except that of August with September (64%).

At station 8 where the *Diopatra neapolitana* ($\overline{X}$ = 94/m^2), *Prionospio polybranchiata* ($\overline{X}$ = 75/m^2) and Corophium *triaenonyx* ($\overline{X}$ = 121/m^2) which were distributed moderately high variation (C.V. > 134%) over months and which showed high correlation with nitrite (r = 0.79), nitrite (r = 0.91), nitrite (r = 73) respectively and with temperature (r = 0.56), sand (r = 10.55) and particulate organic carbon (r = 0.50) also respectively showed high season wise similarity (> 75%) between months except that between September and December (< 62%). But the chance for common occurrence of species was very poor during September and October with other months (< 24%).

Station 9 which was the dwelling place for *Dendronereis aestuarina* ($\overline{X}$ = 99/m^2), *Prionospio polybranchiata* (X = 52/m^2), *Notomastus aberans* ($\overline{X}$ = 123/m^2), *Heteromastides bifidus* ($\bar{X}$ = 186/m^2), *Quadrivisio bengalensis* ($\bar{X}$ = 89/m^2) and which were distributed with lesser variation (C.V. > 84%) compared to other moderately abundant species (C.V. > 200%) and which were controlled by the water quality parameters ammonia (r = 0.40), with ammonia (r = 0.66) and sand (r =0.58), with clay (r = 0.18) with nitrite (r = 0.48), with suspended load (r = 0.55), silt (r = 0.53) and salinity (r = 0.35) showed high similarity for abundance of common species between January and other months, from June to December (> 95%). But December showed less similarity with from February to May (< 68%). But the presence of common species was very low (< 10%) between January and other months of the year.

At station 10 highly abundant species were *Dendronereis aestuarina* ($\bar{X}$ = 37/m^2) and *Pendora flexosa* ($\bar{X}$ = 43/m^2) both with high variations (C.V. > 310%). Former are highly correlated with nitrite (r = 0.89) and temperature (r = 0.46) and latter with salinity (r = 0.85) and nitrate (0.84) respectively. At station 11 abundant species was *Dendronereis aestuarina* ($\bar{X}$ = 21/m^2) with high variation (C.V. 331.66%) and highly controlled by salinity (r = 0.83), organic matter (r = 0.64) and silt (r = 0.70). At station 12 the abundant species was *Capitella capitata* ($\bar{X}$ = 1417/m^2) was highly correlated with clay (r = 0.50). Station 13 was dominated by *Capitella capitata* ($\bar{X}$ = 28/m^2) with high variation (C.V. 330%) and controlled by nitrate (r = 0.89), particulate organic carbon (r = 0.71) showed high similarity (>98%) between all the months except at station 12 where months December to May showed very low similarity for the species commonness based on abundance (<60%). Presence/ absence showed a reverse structure for the seasonal similarity indicating the high variation in the environmental conditions due to effluent discharge.

Station 14 which was the reference station with 37 species of which the most abundant *Grandidierella gilesi* ($\bar{X}$ = 31/m^2), *Quadrivisio bengalensis* ($\bar{X}$ = 49/m^2), *Eriopisa chilkensis* ($\bar{X}$ = 17/m^2) and Caprillid sp. ($\bar{X}$ = 54385/m^2) and *Cirrolina fluviatilis* ($\bar{X}$ = 3458/m^2) with variability (C.V > 300%) having high correlation with clay (r = 0.68) for the first four and with suspended load (r = 0.84) for the last showed high seasonal similarity (> 98%) based on abundance of common species except June and July (< 20%) and April and May (< 60%). Based on presence/ absence of common species a value (< 30%) was obtained except that between August and September (~ 69%) and October and November (59%)

Factor analysis

Q-mode factor analysis was applied only to stations 3, 5, 6, 7, 8, 9, 12 and 14 because in other stations either low number of species were observed or species were obtained only in few months.

In station 3, the months except August and November were grouped in factor 1 which had high even value and formed the differential factor group explaining 53.41% of the variation in the seasonal variation in benthic density. In area 5, for factor groups, containing the months, January, March, May in the factor 1, November and December in the factor 2, July to September in the factor 3 and June in the factor 4, explaining about 74.875% of the seasonal variation in the benthic density. High positive loading was obtained for factors 1 and 2 while high negative loading for factor 3. In station 6, four-factor groups having all positive loadings except the first one, which had wider range with negative loadings were obtained. These factor groups provided 54.05% of the seasonal information on benthic density in area 6. In stations 3 and 5, there was a certain amount of continuity in the seasonal variation where as in station 6, changes were noticed between December and May, particularly in January and February of the same characteristic and March and April of another unique nature of this station which affected the benthic production.. At station 7, four factor groups obtained had high negative factor loading of which the first two explain nearly twice that of factor groups 3 and 4. This grouping showed that during June, September and January, April and May the distribution of benthic species were similar. During August and November the pattern of distribution was different from that of the factors 1 and 2. Thus further highlights the fact that during July, October, December and also February and March were different from what was observed during peak monsoon and early post-monsoon period.

At station 8 out of the 5 factor groups obtained only the first four were statistically significant. But these 4 factor groups could not provide with the maximum information on the seasonal distribution of benthos in the station. May (factor 1) was different from that of July and December (Factor 2) and so also from that of October and January. In July and August benthic distribution was different from that of other months. This grouping further showed that in this station if distribution of benthos present different uniquely characterised pattern and it was likely to be different from that of other seasons of the year. The first 5 factor groups together explained about 54.21% of the seasonal variability in its distribution.

At station 9 Q-mode analysis presented 4 statistically significant factor groups with few months being grouped into a factor group. At this station also the 4 factor groups together provided only 47.85% of the seasonal variation in its distribution. This grouping showed significant changes during June, August, September and October, which were different from other months.

In station 12 a unique characteristic for the benthic distribution was observed and this pattern remained almost in the same trend during August to March and this group explained about 79.99% of the over all seasonal distribution in this station. In station 14, three factor groups were obtained. These three groups explained about 57.35% of the seasonal variability. Similar pattern was observed during June, July and April. During August to October benthic density was same. During January to March different pattern was observed. The first three factor groups were the differential factor groups explaining about 57.35% of the seasonal variability.

3.4 DISCUSSION

3.4.1 Water quality

The study of the hydrographical parameters of the estuarine environment is of great importance to characterise the general features, distribution pattern and relative abundance of nutrients. The studies are also significant with regards to water management and pollution control. The hydrographical conditions in an estuary mainly depend on the intrusion of seawater and the influx of freshwater from rivers.

The coagulation and precipitation of dissolved solids and evaporation of water also have profound effect on the hydrographical conditions of an estuary.

The concentration of pollutants were found diminished gradually with distance from the discharge point, mainly due to the dilution of the effluents by the receiving water and by the natural purification processes. Thus the pattern of variation in temperature, salinity and oxygen, controlled by the impact of rainfall and river discharge has been similar to other estuaries and backwaters along the southwest coast of India.

Industrial effluents particularly from fertilizer plants contain large quantities of nutrient elements like nitrogen and phosphorus mainly in the form of inorganic salts such as nitrite, nitrate, ammonia and phosphate and related compounds. Wide variation in the concentration of the above compounds in an aquatic system can affect the quality of water and make it harmful to the biota.

Temperature

Temperature is a factor of prime importance in the physical environment of organisms. This has a universal influence controlling the activities and distribution of animals and plants. The temperature of estuaries affect the physical properties of water such as density, vapour pressure, surface tension, viscosity, solubility, diffusion of gases etc., and temperature causes stratification in water. The distribution of temperature in estuarine region depends on the flow of freshwater from rivers (Sankaranarayanan and Qasim, 1969), the mixing of tidally influenced seawater (Ramamirthan and Jayaraman, 1963) and processes like exchange of heat from atmosphere and other localised phenomena.

The temperature showed an increasing trend from downstream to upstream stations in the southern limb and this may be due to the intrusion of comparatively cooler water from open ocean by the tidal cycle. Towards the northern limb the values were found to be fluctuating from downstream to upstream in different months. The influx of freshwater into the estuarine system is not the sole factor influencing the water temperature in the estuary but the influx of cold water from the sea may be also a significant factor (Sankaranarayanan and Qasim, 1969). The seasonal average was high during pre-monsoon compared to monsoon and post-monsoon for the entire study area. Kumaran and Rao (1975), Balakrishnan and Shynamma (1976), Joseph (1988) and Sivadasan (1996) have reported high water temperature during pre-monsoon in the Cochin estuary.

The vertical gradient was very less for the entire study area (0.5°C to 1.3°C) and this may be due to the shallow nature of the estuary as reported by Qasim and Gopinathan (1969).

Salinity

Salinity is considered as an important parameter in the investigation of the process of mixing of seawater with freshwater in estuaries. Wide fluctuations in the salinity values were observed in estuaries from almost marine conditions to strictly freshwater conditions. Salinity in estuaries usually depends on the intrusions of seawater through barmouth, discharge of freshwater from rivers, isolated rainfall and evaporation etc.

Towards the southern limb even-though the intrusion of seawater extends during pre-monsoon period, such effects are not seen in the other seasons (> 0.05). This condition is most pronounced at stns. 1 and 2. Towards downstream at stn. 3 & 4 the salinity was increased from January onwards. At stn. 5, which is nearest to the harbour entrance a stray value of 11.98 for surface and 31.71 for bottom during August may be due to the tidal effect. A gradual increase in salinity was observed as the season progressed and the higher values were recorded during pre-monsoon periods (11.14 to 25.43).

Towards the northern limb, a distinct seasonal pattern was observed for salinity distribution. The results revealed that almost freshwater conditions prevailed from stn. 10 onwards except in one or two months. At stations 8 and 9 except in the monsoon months the values were found to be high and this may be due to the intrusion of seawater during the tidal cycles.

In the sewage area, which is inside the estuary except during monsoon, the values were high with the salinity reaching up to 23.56 and 21.18 at stations 6 & 7 respectively in March. The barmouth also showed high values, which is due to the tidal rhythms.

The results of the present study is well comparable with the observations made by Haridas *et al.* (1973), Balakrishnan and Shynamma (1976), Sivenkutty (1977), Gopakumar (1991) and Maqbool (1993). The wide fluctuations in salinity of tropical estuaries are due to extreme condition of draught and monsoon affecting the estuarine environment. Nair *et al* (1983) have reported that a distinct seasonal pattern of salinity in Ashtamudi estuary with highest value during pre-monsoon and declining values from estuarine mouth to the riverine zone. Nair *et al.* (1988) observed very large spatial variations of salinity in the three areas of study in Cochin backwaters ranging from 0.24 to 31 X 10^{-3}, controlled by tidal and monsoonal flow and shallowness of the area.

Like temperature, during the pre-monsoon months the salinity also showed a vertical homogeneity. In the shallow regions of the estuary the water offers little resistance to mixing and therefore the salinity stratification remains less sharp (Sankaranarayanan and Qasim, 1969).

The extreme drop in salinity with nearer freshwater conditions observed during monsoon is due to the dilution by large amount of freshwater influx while the differences in the surfaces and bottom salinity is due to the out flowing riverine waters giving a two layered structure (Dehadrai and Bhargava, 1972 and Nasnolkar *et al.* 1996).

pH

Many of the life processes are dependent on the hydrogen ion concentration in the surrounding medium. The pH of the medium depends on factors like photosynthetic activity, discharge of industrial effluents, nature of dissolved materials, rain fall etc. Variations in pH due to chemical and other industrial discharges renders a stream unsuitable not only for recreational purposes but also for the rearing of fish and other aquatic life (Webb, 1982).

The industrial effluents discharged into the aquatic system may significantly lower or elevate the pH of water depending on the nature of the effluents. The pH of water affects the treatment processes and can contribute to the corrosion of distribution lines and household plumbing fixtures. Under extreme conditions the survival of the biota becomes a serious problem. The tolerance range for most organisms is quite narrow and critical (George, 1979). Close monitoring of pH values enable to identify zones of pollution and other quality conditions of water (Clarks *et al.*, 1977).

In the southern limb, a wide range (6.49 to 8.96) in pH was observed in the water column and this may be due to the effect of discharge of effluents from the chemical factories at Ambalamedu. The low variation in pH at stns. 5 to 7 may be due to the influence of seawater intrusion.

Towards the northern limb also wide range of fluctuation was seen between the pH values and this also may be attributed to the intermittent discharge of industrial effluents. The pH > 8 at the effluent discharge sites (stations 1, 2 and 13) may be due to discharge of some alkaline effluents around these stations. Stations 11& 12 showed erratic fluctuation during certain months probably due to localised influence of effluents (Saraladevi *et al.*, 1979).

Dissolved Oxygen

Dissolved oxygen content of water is a vital water quality parameter and is linked with the health of aquatic life. It is considered that dissolved oxygen level in coastal water should not fall below 2.8 ml/l for prolonged periods for the health of an ecosystem. Solubility of atmospheric oxygen in freshwater is low, only 10.66ml/l at 10°C and 7.13ml/l at 30°C under atmospheric pressure. The depletion of oxygen content in water leads to undesirable obnoxious odours under anaerobic conditions and damage to aquatic life. Adequate amount of dissolved oxygen is essential for the survival of fish and other aquatic organisms. The dissolved oxygen is dependent upon temperature. The decomposition of organic waste and oxidation of inorganic waste may reduce the dissolved oxygen to extremely low levels, which may prove harmful to organisms in the aquatic environment. The amount of dissolved oxygen in natural water depends upon temperature, salinity, turbulence of water and atmospheric pressure. Johannessen and Dahl (1996) have reported decline in dissolved oxygen as a result of increased nutrient load.

A desired limit of 5.0 mg/l (3.4 ml/l) of dissolved oxygen has suggested by Hart (1974). The minimum acceptable limit of dissolved oxygen for fish life is 3ml/l. Rate of depletion of oxygen has been used to investigate the quality of water bodies.

The amount of dissolved oxygen in surface water is usually greater than that in bottom water. This may be attributed to the partial utilization of dissolved oxygen by organic rich sediments. Oxygen can diffuse in surface waters to support aerobic processes. The variation in the amount of dissolved oxygen is also attributed to the seasonal and tidal fluctuations of both surface and bottom waters (Vijayan *et al.*, 1976).

Dissolved oxygen content of the present study showed wide fluctuations with tide and with varying rate of tidal flow. The low oxygen may be due to the decomposition of organic matter present at the bottom. Near the fertilizer factory the lower oxygen concentration observed during the period may be due to high microbiological activity (Nair *et al.*, 1988).

The high dissolved oxygen values noted during the present study were well comparable with the findings of Dehadri (1970 a & b) in the Mandovi and Zuari esturies, Rajendran (1974) and Chandran & Ramamorthy (1984) in Vellar estuary and Saraladevi (1986) in Cochin estuary.

Biological Oxygen Demand (BOD_5)

The importance of BOD_5 in the assessment of pollution of an environemnt is emphasised by Reish (1959), Monultty (1961) and Pauli Bagge (1969) and it is dependent on the amount of suspended/ dissolved organic matter in the water. A water body with a BOD_5 of 8.0 mg/l is considered to be moderately polluted (Martin, 1970). Remani (1979) noted an inverse correlation between dissolved oxygen and $(BOD)_5$ in the retting yard of Cochin backwaters holding oxygen-depleted waters. In general low BOD_5 values (<5 mg/l) were noticed throughout the investigation period and this may be indication of the removal rate of organic load (Bhargava 1977). The noted low values could be due to the strong semidiurnal tidal flushing and consequent dilution. Low BOD_5 values were reported in the industrial area which receive inorganic and combined effluents (Saraladevi, 1986). The present low levels observed in this area can thus in fact be due to efficient break down of organic matter in presence of high oxygen content, tidal dilution and significant contribution from inorganic sources to the total waste load discharged.

Nitrite-N

The concentration of various forms of nitrogen in an estuary at a given time is controlled by factors like input rates, the inter conversion reactions occurring within the water column, incoming tides, freshwater discharge, de-nitrification, deposition etc. Nitrite can reach the aquatic system through effluents from industries and certain biologically purified waters, which may also contain certain large amount of nitrites. Levels of nitrite concentration in estuaries ranged between 0.5 to 6.0 µmol/l and is very high when compared to sea water where it is < 0.1µmol/l. Nitrite is unstable in the presence of oxygen and hence occurs mainly as an intermediate form between ammonia and nitrate.

The NO_2^-N values were found to be high in the southern limb (2.39 to 42.22 µmol/l) compared to northern limb (0.0 to 7.54µmol/l). In the sewage area the values were in the range of 0.25 to 3.11µmol/l. At stn. 5, which is in the down stream of southern limb the values fall within the range of 0.98 and 11.29 µmol/l. The barmouth also showed low values in the range of 0.00 and 1.63 µmol/l. The annual range for the entire study area varied between 0.00 and 42.22µmol/l. The pre-monsoon values were high compared to monsoon and post-monsoon values in the southern and northern limb. Station 5, the sewage discharge site and barmouth showed high seasonal average during monsoon compared to pre-monsoon and post-monsoon.

Segar and Hariharan (1989) have reported that the increase in concentration of nitrite may be attribute to the bacterial decomposition of planktonic detritus and the variation in the concentration of nitrite may be due to the variation in the quantum of effluent discharged.

The differences in seasonal variations may be contributed by the variation in the phytoplankton excretion, oxidation of ammonia and reduction of nitrate of which the latter is reported to be dominant (Rajendran and Venugopalan, 1975). The high values of nitrite may be due to the higher values of ammonia and may be due to the effluent discharge coupled with phytoplankton abundance during the preceding month.

The higher nitrite concentration at almost all stations appeared to be due to the death and decay of plankton and due to the nitrifying bacteria (Rajendran and Venugopalan, (1977a & b). However, increase of nitrite in the subsurface layers could be due to the increased bacterial activity, which is expected in a silty-clay substratum compared to sandy substrate.

Nitrate-N

Like nitrite, the southern limb and northern limb of Cochin backwaters showed high nitrate values during pre-monsoon compared to monsoon and post-monsoon. At stn. 5, the sewage discharge site and barmouth monsoonal averages were high compared to pre-monsoon. The annual range in concentration in nitrate was between 7.00 and 2216.10 µmol/l in the southern limb 15.08 and 1019.34 µmol/l at stn. 5, 0.00 and 1010.65µmol/l in the sewage discharge site, 0.00 and 1798.35 µmol/l in the northern limb and 0.00 and 451.23 µmol/l in the barmouth.

Nitrate ion concentration with abnormally high values indicates external additions of some effluents rich in nitrogenous compounds into the estuary, by the agricultural run off and municipal sewage.

Among the three inorganic forms of nitrogen, nitrate-nitrogen was the most abundant at all stations, perhaps due to the fact that nitrate is thermodynamically the most stable oxidation level of nitrogen in the presence of oxygen in seawater (Rajendran and Venugopalan, 1977b) and could accumulate if left unutilized. Oxidation of available ammonia and the fluctuations in the input of effluents in the proximity of the effluent discharge point may be another reason for the increase in nitrate concentration. High values of nitrate at all stations during April and May could be attributed to oxidation of ammoniacal form of nitrogen to nitrite and subsequently to nitrate. The peak concentrations were preceded by higher concentrations of ammonia. The oxidation of ammonia to nitrite and then to nitrate may take place photo-chemically or chemically in this surface layer or biologically in and near the bottom (Cooper, 1937). The high values of nitrate-nitrogen might have been due to bacterial oxidation rather than the photochemical oxidation of the high level to ammonia.

Ammonia -N

Ammonia occurs in 2 forms, the toxic un-ionised ammonia and the non-toxic ammonium ions in equilibrium, which is pH and temperature dependent. Ammonia is the first inorganic product formed during regeneration of nitrogen from organic compounds. By the death and decay of organisms the ammonia increases in the estuarine water and it was shown to be the most preferred form of nitrogen for planktonic assimilation and it inhabits the utilization of other forms such as nitrite and nitrate in its presence.

The maximum concentration of ammonia was observed in the southern limb (167.56µmol/l), which decreased towards downstream. At stn. 5 the maximum value was 119.57µmol/l in the surface in May. In the sewage discharge site the values were low and ranged between 0.0 and 24.30 µmol/l. Northern limb showed a range of 0.0 to 116.06µmol/l and the values ranged between 0.50 and 22.62 µmol/l in barmouth.

The seasonal values showed that the monsoon values were low compared to pre-monsoon and post-monsoon, except in the sewage area and barmouth. The values at the effluent discharge site in the southern limb were low compared to the values reported by Venugopal *et* al. (1980), Nair *et* al. (1988) and Aravindakshan *et al.* (1992) in this area. Nasnolkar *et al.* (1996) reported high nitrate values during monsoon (8.14 to14.10µmol/l) and low values during post-monsoon (0.84 to 4.16µmol/l) in the Mandovi estuarine waters of Goa. The higher values recorded along the area is perhaps due to its proximity to the point of discharge of effluents and to biodegradation of urea, Segar and Hariharan (1989). Higher concentrations in the water could be partly due to death and subsequent decomposition of phytoplankton and partly due to terrigeneous input during this season (monsoon). The irregular monthly fluctuations of ammonia concentrations could be related to the proximity of the effluent discharge point and the variations of the rate of discharge of the effluents.

Phytoplankton production appears to influence the ammonia concentrations. The high concentration of ammonia at stations located near the effluent discharge point may be due to the oxidation of ammonia which is reported to be slow in relatively polluted waters (Rajendran *et al.*, 1980). The excretion by planktonic organisms also induces higher levels of ammonia.

Phosphate-P

Phosphorus is a major nutrient regulating the growth and production of phytoplankton and its concentration helps to predict the total biomass of phytoplankton. The most important form of phosphorus involved in the biogeochemical processes in estuaries is the phosphate, find in various dissolution, precipitation, adsorption, and desorption processes. Estuarine sediments are rich in phosphorus, which may be liberated to overlying waters under favourable conditions. The riverine process of precipitation is also common under suitable conditions and hence the hydrographical conditions have important effect on the productivity of these waters.

Dissolved inorganic phosphate exists in different form like $H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-} and their relative concentrations in aquatic system are pH dependent.

Rivers are the major sources of phosphorus input to estuaries. The riverine influx of phosphorus in estuaries may be substantially modified by precipitation or dissolution causing changes in the concentration of phsophorus. The weathering of insoluble calcium and ferric phosphate rock and land drainage especially from agricultural run off also delivers phosphorus to estuaries. The external sources bringing phosphorus to estuaries are from domestic sewage and industrial effluent particularly from fertilizer plants producing phosphate fertilizers. A concentration range of 1.6 to 32.0µg at/l has been reported for agricultural drainage.

Phytoplankton take up phosphates and nitrates in relatively constant proportion and release these elements during their composition. Abundant phosphate availability in water stimulates undesirable plankton bloom, a phenomenon generally known as eutrophication.

Phosphate concentrations were high in the southern limb, (1.36 to 150.70µmo/l) compared to other stations. The ranges were 1.59 to 32.72µmo/l at stn. 5, 0.51 to 43.99µmo/l for sewage discharge area, 0.15 to 30.98µmo/l in the northern limb and 0.23 to 32.86 µmo/l at barmouth.

The pre-monsoon values were high compared to monsoon and post-monsoon except at stn. 5, where the monsoon values were higher.

The low values of phosphate during monsoon period were explained by the combined effect of dilution of estuarine water by riverine fresh water containing low phosphate and removal by adsorption caused by the influx of silt laden fresh water. The low salinity during monsoon by the increase in river discharge favours the removal of phosphorus from the overlying water by sedimentary particle. The high values in the southern limb may be due to the influence of industrial effluent from the plant producing phosphate fertilizers, the phosphate leaching from land drainage and agricultural run off as observed by Sankaranarayanan and Qasim (1969) and Nair *et al.* (1988). The values at Thevara (stn. 4) showed that the influence of the discharge of phosphate into the aquatic system get diluted towards downstream.

High concentration of phosphate was followed by an abundance of phytoplankton and presumably the subsequent decrease in the concentration of phosphate may be due to its utilisation by phytoplankton.

During pre-monsoon, however, the overlying water show high values of dissolved phosphate, which can be attributed to the leaching of phosphate from sediments to the overlying water. The post-monsoon season shows increases in sediment phosphate with a corresponding decrease in dissolved phosphate in the overlying water.

Chlorophyll `a'

Chlorophyll is the green pigment in plants that provides most of the plants` colour and supports the process of photosynthesis. The measurement of photosynthetic pigments, particularly chlorophyll `a' is used to estimate phytoplankton productivity and biomass. The standing crop of phytoplankton indicates the availability of food for animals at the primary stage.

Indiscriminate disposal of sewage and industrial wastes have been a major cause for the nutrient enrichment in coastal waters resulting in a decrease in diversity and an increase in biomass promoting some opportunistic algal species to dominate and suppress others (Kimor, 1991 and Dederen, 1992). Increasing nutrients in the estuary therefore have been stimulating excessive growth of a few tolerant phytoplankton leading to generally higher values of chlorophyll as suggested by Neelam and Ramaiah (1998). Besides implying the influence of sewage pollution on phytoplankton species composition and diversity, observation during this study serves to delineate their ability to adapt and proliferate under eutrophicated conditions.

In general stations in the southern limb registered high chlorophyll a compared to other areas. Maximum value of 151.83 mg/m^3 was noticed at stn. 2 surface. Seasonal averages showed high values during pre-monsoon and post-monsoon. The seasonal distribution of chlorophyll `a' shows high values in the coastal waters off Cochin during pre and post-monsoon (>15) seasons where as during monsoon it is very less (<3). The observations show higher concentration in and around Cochin waters (Sarupriya and Bhargava, 1998). The phytoplankton abundance noticed during the study may be due to the effect of nitrogenous effluents discharged near this area. However nutrient requirement is known to differ with the phytoplankton and that high concentrations of nutrients alone may not be conducive for substantial increase in productivity (Qasim, 1973a). Since the rate of regeneration of nitrogen is slower than that of phosphorus, the readily available ammoniacal form of nitrogen could have been responsible for high phytoplankton production.

Particulate Organic Carbon

An assessment of particulate organic carbon provided a more meaningful estimation of the available energy to the next trophic level where herbivore grazing is proposed to control phytoplankton within the limits set by nutrient concentration. POC concentrations in estuaries tend to be higher at the head of the estuary and decrease downstream owing to mixing with coastal water, which generally has lower concentrations of organic matters.

The particulate and dissolved organic carbon (POC and DOC) together constitutes a minor fraction of total organic carbon of seawater, but they are very important components in the transformation of carbon. Particulate organic carbon occurs in degradable and refractory (non-degradable) forms, the latter is mainly constituted by carbon present in humic material. Further POC can be of living or non-living (detrital) nature where the latter fraction may contain the refractory substance that result either from recycled marine matter or from terrestrial sources. The particulate humic material (PHM) is a measure of the extent of organic matter humification and aggregation in the water column before reaching the bottom and the addition of humic material through other sources like terrestrial inflow in the water column.

The temporal and spatial variations in POC and PHM depend on the nature and extend of primary and secondary producers. No definite pattern was observed in the temporal and spatial distribution of POC and the values were comparatively high in the southern limb. Seasonal variation showed that the values were moderate and more or less comparable during pre and post- monsoon periods and monsoonal averages were low in all stations. Satyanarayana *et al.* (1994) reported high POC during pre and post-monsoon periods in the coastal waters of Vishakapatnam, which is attributed to the high phytoplankton production and dinoflagellate bloom. The POC values noticed in the present study was higher than the reported values for the estuarine complex of the northern limb and in the Cochin barmouth (Saraladevi *et al.*, 1989) and in the mouths of the 4 estuaries viz. Kallai, Beypore, Korapuzha and Mahi (Saraladevi, unpublished).

Suspended solids

The estuarine waters are relatively turbid due to the influence of tidal currents and monsoonal flow. Human interferences however contribute significant amounts, which are difficult to quantify. Major contribution under the above came from industrial and domestic wastes as well as agricultural runoff.

The increased turbulence during monsoon and the high particulate mater normally associated with the run off, results in substantial increase in the suspended matter and the values exceeding 200 mg/l are commonly observed. Saraladevi (1989) reported a higher value of 252 mg/l in the northern limb of Cochin backwaters.

Attenuation coefficient / "K" value

Generally higher attenuation values were expected in the monsoon months especially during flood conditions, due to the likely increase in turbidity of the water and low intensity of solar radiation (Saraladevi, 1989). During the other seasons, variation in "K' values were rather erratic and followed no definite seasonal pattern due to dominance of clear neritic water and the prevalence of higher solar radiation (Chandran and Ramamoorthy, 1984). Tropical estuaries are generally characterized by a wide range of light attenuation coefficient in contrast to temperate estuaries (Thayer, 1971).

The results of the present study showed the "K" value ranging between 1.5 to 15 in July and 1.88 to 5.0 in October is well comparable with the values reported by Saraladevi (1989). Rest of the months showed low values ranging between 0.86 and 3.0. Chandran and Ramamoorthy (1984) reported very low attenuation coefficient (1.4) in Vellar estuary during summer when the estuary was dominated by clean neritic water and high (17.0) during monsoon owing to the heavy water flow. Although no definite tidal variation in light attenuation was noticed, the values were generally higher during low tides. In Goa estuaries, Bhattathiri and Devassy (1977) noticed a range of 4.8 to 7.5 in "K" values. Qasim *et al.* (1968) also observed a reduction in the light penetration during monsoon, the attenuation coefficient varying from 0.6 to 3.0 which is very low compared to the present observation and this may be due to the ongoing changes in the system.

3.4.2 Sediment characteristics

Sediments are the indicators of the quality of water overlying and hence their study is useful in the assessment of environmental pollution. The nature and extent of fluctuation in the composition of sediments can indicate the extent of stress on shallow aquatic environments. The sediments in the estuaries indicate the balance between the erosional and depositional forces of the ecosystem. The supply and source of these materials and the sites of deposition mainly depends on the type of estuaries, river discharge, currents, wave action and tidal regime. Organic carbon content in the sediments of the estuarine and riverine systems is of considerable interest as a potential food for the benthic fauna. Generally the state of preservation depends partly on its texture as well as microbial and redox potential of the sediment. Variation in colour and texture of sediments were brought about by changes in the grain size and state of oxidation of organic matter.

The grain size distribution described for a given habitat may be very different from those within the ambit of the organism. In addition to grain size other proposed causative factors include organic content, microbial content, food supply and trophic interaction but no single mechanism has been able to explain pattern observed across many different environments. (Paul And Cheryl, 1994). Over the last few decades, many studies have correlated infaunal invertebrate distribution with sediment grain size, leading to the generalization of distinct association between animals and specific sediment types.

Grain size co-varies with the sedimentary organic matter content, pore water chemistry and microbial abundance and composition; all of which are influenced by the near-bed flow regime. The variables could directly or indirectly influence distribution. The mechanisms proposed by Sanders (1958) to account for observed association between infauna and sediments was that differences in food supply resulted in the domination of sandy habitats by suspension feeders and muddy habitat by deposit feeders. Paul and Cheryl (1994) stated that organic content of bottom sediments might be a more likely crucial factor than sediment grain size in determining the infaunal distribution because organic matter in sediments is a dominant source of food for deposit feeders and indirectly for suspension feeders.

Grain size distribution

The floor of Cochin backwaters exhibits sediments of different textural types with a mixture of sand, silt and clay of different combinations. Such differing combination of sediments from one place to another and back associated with the tidal currents was reported by Murty *et al.* (1976). Such transport of the bed load material becomes more pronounced during the monsoon, which shows varying types of sediments compared to that of the post-monsoon. The sediments of the sand-silt-clay type and still finer ones indicated the prevailing low energy conditions as reported by Satyanarayana Murty and Rao (1959) in the Visakhapatnam shelf sediments, while the presence of sandy sediments indicate high energy zone associated with high turbulence (Nasnolkar *et al.*, 1996).

Organic matter

The shallow nature, higher temperature and oxygenated environment seem to encourage oxidation of organic matter (Macnae, 1969). Total organic carbon of the sediment has a major role in keeping the fertility of soil and thereby flourishing the biological productivity.

No distinct seasonal distribution pattern was perceived in organic carbon, during the present study, indicating the constant and eternal supply of detritus, irrespective of seasons, which give substantial flux of organic residues to the sediments by the decomposition process. The concentration of organic carbon at each station depends upon the sediment textural characteristics. Organic carbon increases with increasing finer fraction and decreases with the increasing coarser fraction in the sediments. One of the features of organic carbon in the sediments is that its concentration increases, as the particle size of the sediments decrease (Bordovisky, 1965).

In an aquatic system, the sediment acts as the storage reservoir of nutrient materials in waters. The replenishment of these nutrients in time of need and their consequent removal greatly helps in the biological cycle of the system. Such an exchange of nutrients depends upon the characteristics of the sediments and the hydrographic features of the estuary (Pomeroy, *et al.*, 1965).

The regeneration and mineralisation processes at the sediment–water interface greatly enhance the primary production by releasing nutrients (Martin, 1970). The observed peak values of organic carbon in the monsoon months could be attributed to the influx of land run off containing considerable amount of terrigenous matter. The dead planktonic matter in the estuary sinks to the bottom and get oxidised and on settling its decomposition releases organic matter into the interstitial water, part of which is then diffused into the overlying water (Martin, 1970).

During the present study the effluent discharge points showed the maximum organic matter values of 10.58% in the southern limb and 9.75% in the northern limb, which are higher than the values 6.91% reported by Aravindakshan *et al.* (1992) and Saraladevi *et al.*, (1992). In Cochin backwaters, Sankaranarayanan and Panampunnayil (1979) reported an increase in organic carbon during the southwest monsoon. According to the authors the organic matter varied between 1.28 and 6.62% and these values are well comparable with the values obtained in the present study except some high values in the effluent discharge points.

The planktonic production of the backwater is reported to be about 195g/m^2/year and the zooplankton grazers leave a considerable surplus of unconsumed basic food, which sinks to the bottom and becomes part of the sediment. Plant and animal matter brought in from land through run off and deposited in sediments are an important component of organic matter in estuarine sediments. Materials generated within the system (autochthonous) and those from the adjacent ecosystems also contribute the prevailing organic content of sediments. Associated with the freshwater run off the silt in colloidal suspension containing large quantities of soil humates is brought into the estuary and the humic substance precipitates and settles in the region before contribution from the system. Therefore, the seasonal variation in the organic carbon content in the sediments may be related to organic production in the overlying water, the humic material brought in from land and also to the oxidation of organic matter by organisms living on the bottom (Sankaranarayanan and Panampunnayil, 1979).

The present values are higher than the reported values for Mandovi and Zuari estuaries (Nasnolkar, 1996) and lower than the values reported by Remani *et al.* (1981) in the retting yard of Cochin backwaters, Nair *et al.* (1983) and Bijoy Nandan (1994) for the retting zones of Ashtamudy estuary.

The anoxic conditions and the higher proportion of the fine grained material capable of holding larger amount of organic matter might be responsible for the enrichment in the retting zones. Sediments of the retting z ones though rich in organic content and energy, the adverse effect of retting pose several problems to benthic communities resulting in low diversity (Bijoy Nandan, 1994).

The energy content of the present study varied from 12.96 to 2286.79 J/g, which is lower than the reported values (224.0 to 7949.4 J/g) for retting yards of Cochin backwaters by Remani *et al.* (1981) and the values (699.78 to 5134.30 J/g) of the retting zones of Ahstamudi estuary given by Bijoy Nandan and Abdul Aziz (1996).

In general water quality of the study area revealed fluctuating values for all the parameters due to the intermittent release of the effluents from the factories located upstream in both limbs of Cochin backwaters throughout the investigation period. Salinity steadily increased towards downstream stations, due to tidal influence. PH values varied from acid to alkaline. High nutrient content, suspended load, chlorophyll and POC were registered near the effluent site. Sankaranarayanan *et al* (1986) and Saraladevi *et al* (1986) reported variations in the different hydrographic and water quality parameters in the northern limb of Cochin backwaters and noticed a gradient of stress, which diminished towards downstream. Unnithan *et al* (1977) and Venugopal *et al* (1980) reported fish mortality due to high ammonia content in the Periyar and Chitrapuzha rivers respectively. Venugopal *et al.* (1980) also observed blooms of phytoplankton and diatoms in Chitrapuzha probably induced by abundant nutrient supply from the effluents.

3.4.3 Bottom fauna

The fauna of a tropical estuary comprises of marine, brackish and freshwater species. The estuary being a transition zone between the more stable marine and freshwater environments, the animals inhabiting this biotope have to be highly accomodative to cope with the stress brought about by the wide fluctuations in physical and chemical features especially salinity of the water column and sediment characteristics.

Daniel (1990) while examining the tropical coastal systems observed that widest variations in richness and diversity occur in these habitats in view of the gamut amount of habitats and environmental conditions.

The distribution pattern of benthic fauna exhibited considerable variation both qualitatively and quantitatively at different stations of the study area round the year. The results revealed a progressive reduction in number of taxa/species from the mouth of the estuary to upstream stations. Abundance of the fauna near barmouth region is attributed to favourable condition for the marine and estuarine life as observed by Desai and Krishnankutty (1967a). They also noticed a progressive decrease in the annual population from the lower part of backwaters towards the upper reaches.

The differences in biomass and density in estuaries is often attributed to seasonal variation, migration, food availability, reproduction, recruitment etc. (Harkantra *et al.*, 1980). Enrichment of coastal waters due to riverine flow and land run off also seem to be factors contributing to richness of the fauna in the nearshore regions (Parulekar, 1973). Alternative pathways for utilization of excess basic food material available in Cochin backwaters have also been suggested (Qasim, 1973b).

During the study a remarkable reduction in benthic density and diversity was delineated at the effluent discharge site. Only the polychaete species, *Capitella capitata* was collected from stn.1 and occurred only in October and April. Station 2 recorded two species of polychaetes viz. *Capitella capitata* and *Branchiocapitella singularis* and a single gastropod species *Littorina littorea* during July. Bottom fauna was completely absent during rest of the months. In the northern limb at stn. 11 two species of polychaetes *Dendronereis aestuarina* and *Prionospio polybranchiata* and insect larvae were encountered during December and January. At stn. 12 five species of Capitellidae viz. *Capitella capitata, Heteromastus similis, Heteromastides bifidus, Branchiocapitella singularis* and *Scyphoproctus djiboutiensis* were recorded. Of these *Capitella capitata* was found in higher numbers varying from 520 to 6167/m^2 during October to May and absent during rest of the months. The insect chironomid was also recorded from this station during June. In the upstream station (stn. 13) three species of polychaetes viz. *Dendronereis aestuarina*, *Capitella capitata* and *Paraheteromastus tenuis* and two species of insects viz. *Asellus aquaticus* and *Chironomid* sp. were noticed during January and November. Of the above listed species *Capitella capitata* was found to be an indicator of organic pollution as proposed by earlier workers like Gaufin and Tarzwell (1952), Reish (1959), Wass (1967), Ganapati and Raman (1970), Remani *et al.* (1983) and Saraladevi (1986). The species *Dendronereis aestuarina* that occurred at all stations can be considered as a pollution resistant species. Others, which were present in few numbers, can be treated as tolerant species (Saraladevi, 1986).

The Spionid worm *Prionospio polybranchiata*, a selective deposit feeder recognised as an indicator of retting yard and sewage pollution (Remani *et al.*, 1983 and Bijoy Nandan, 1994) was recorded during the present study from 10 stations (stns. 3 to 10 &14) and the frequency of occurrence was high at stns. 3 to 8 and appeared only once at stns. 10, 11 and 14 in lower densities and completely absent at stns.1, 2, 12 & 13.

Low diversity and higher population density of a few organisms denote some major stress condition, which eliminate many species but promote survival of a few. Contrary to this high diversity and a little relative dominance of species characterise areas of relative environmental stability. Low diversity and lower number of fauna at the upstream stations during the study indicate the prevalence of stress condition and the effect was reduced slowly towards downstream because of dilution and hence an increased species diversity. Ganapati and Raman (1973) and Zingde *et al.* (1980a) stated that though the effect of industrial effluents are not apparent in the beginning, the cumulative effect of continued discharge will endanger the safety of aquatic life and can reach the human body through food chain. The effluents from the Gwalior Rayon factory adversely affected not only the fish but also the whole fauna of the Chaliyar river (Nirmala *et al.* 1976). Nair *et al.* (1984) noted the maximum occurrence of benthic macrofauna in the station close to the sea and minimum at station near the effluent discharge point of Punalur paper mills. Compared to other areas in Cochin backwaters, a decline of bottom fauna in the effluent discharge site of the southern limb was reported by Aravindakshan *et al.* (1992). Pillai *et al.* (2000) observed a reduction in the total benthic biomass, density and faunal groups in the vicinity of the marine outfall point of a Petroleum Refinery off Chitrapur, Mangalore compared to the reference site.

The faunal composition exhibited a different picture in the sewage discharge area in having high benthic faunal density and diversity. The increaseing dominance of polychaetes in this region suggests that the environment is getting more organic load by sewage discharge as observed by Vijayakumar *et al.* (1991). Of the nine groups encountered from this area, polychaetes represented by 29 species dominated and contributed to more than 75% of the bottom fauna. A total of 53 species belonging to different groups were recorded from the sewage area. This result agrees with the observation of Remani (1979).

Predictable temporal and spatial changes in benthic community structure and composition occur in response to changes in pollution (Clark, 1989) from sewage and industrial discharges (Pearson and Rosenberg, 1978). The effluents include waste materials and solutions that have high concentrations of various nutrients that may stimulate primary production and thus increases the availability of organic material in the ecosystem. Assemblages of benthic macro-invertebrates form a characteristic response gradient with distance from sources of organic input or enrichment (Daniel and William, 1980). The station closest to the effluent discharge point lacks any macrofauna due to hypoxic or anoxic condition and the polluted zone generally is characterised by a few tolerant species such as *Capitella capitata*. In this station the total number of individuals are high due to exploitation of enhanced organic material by these species. Beyond these polluted zone is a normal and unaffected zone with more species and generally with a more even distribution of individuals among species. The primary factor influencing this pattern is believed to be oxygen gradient and presence of toxic substances. It is well documented that different major taxa (polychaetes, amphipods and molluscs) have very different response pattern to disturbances in the soft mud. Polychaetes tend to be initial macrobenthic colonists after a disturbance and later the major taxing inhabiting the most stressed habitat. The increased density by an individual species may be due to increased recruitment, increased fecundity or decreased mortality / resillience.

The presence of large numbers of gastropod sp. at stn. 3 and the commercially important bivalve species, *Villorita cyprinoides* at stn. 4 contributed to the high biomass noticed at these stations. The spatial distribution of bivalves suggests that an increase in salinity is more conducive than the substratum. This observation is in conformity with that of Chandran *et al.* (1982) from Vellar estuary and Prabhadevi *et al.* (1996) from Kayamkulam backwaters.

The other advantage of Cochin estuary to the benthos is its relatively shallow depth by which suspended food particles are readily made available for them through sinking as well as through downward transport by turbulent water movements as noted by Wolff *et al.* (1976).

Temporal and spatial variations in the different environmental parameters noticed here are thus reflected in the qualitative and quantitative distribution of the bottom fauna.

In general the study revealed stress and localised impact of industrial waste on the biota, predominance of stress tolerant species and low diversity in the vicinity of the effluent discharge. Then studies on impact of environmental parameters on the distribution of macrobenthos thus indicate the quantum of endurance warranted by the infauna to tide over the wide range of environmental stress. Low diversity and lower number of benthic fauna at near discharge site upstream stations can be attributed to the stress caused by cumulative toxic effects of effluents.

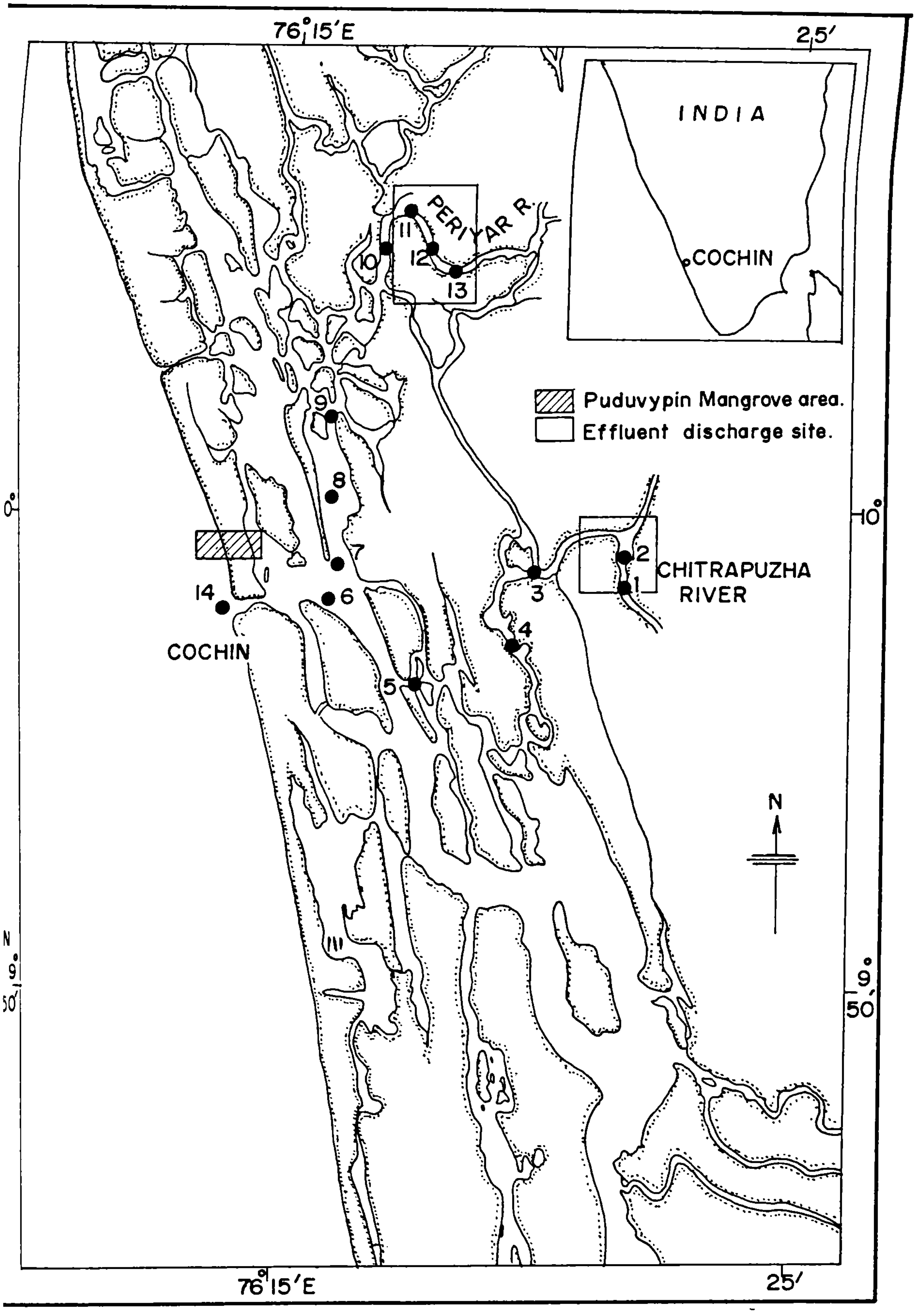


Fig.3.1. Location of sampling stations.

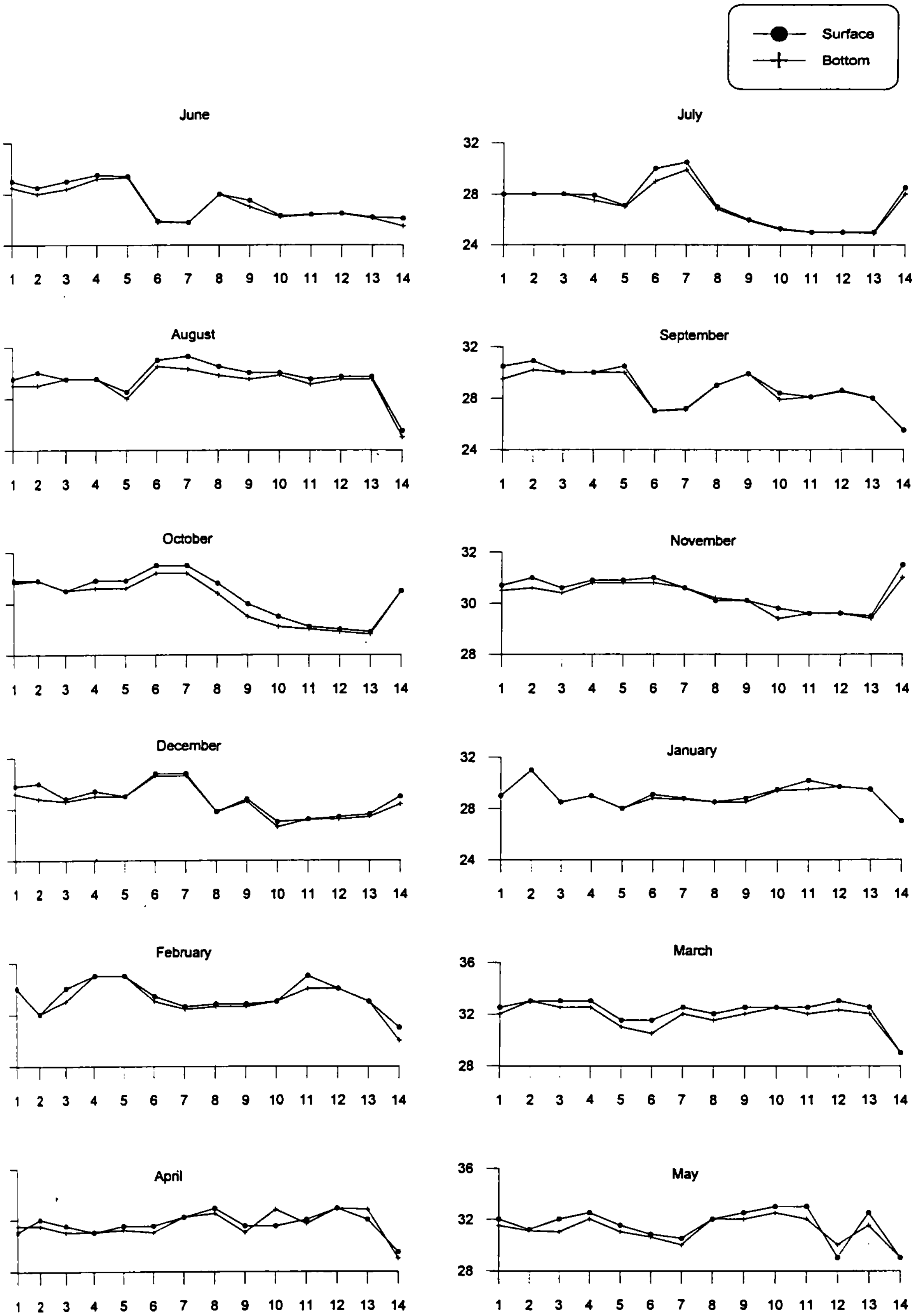


Fig. 3.2. Distribution of Temperature at stations 1 to 14

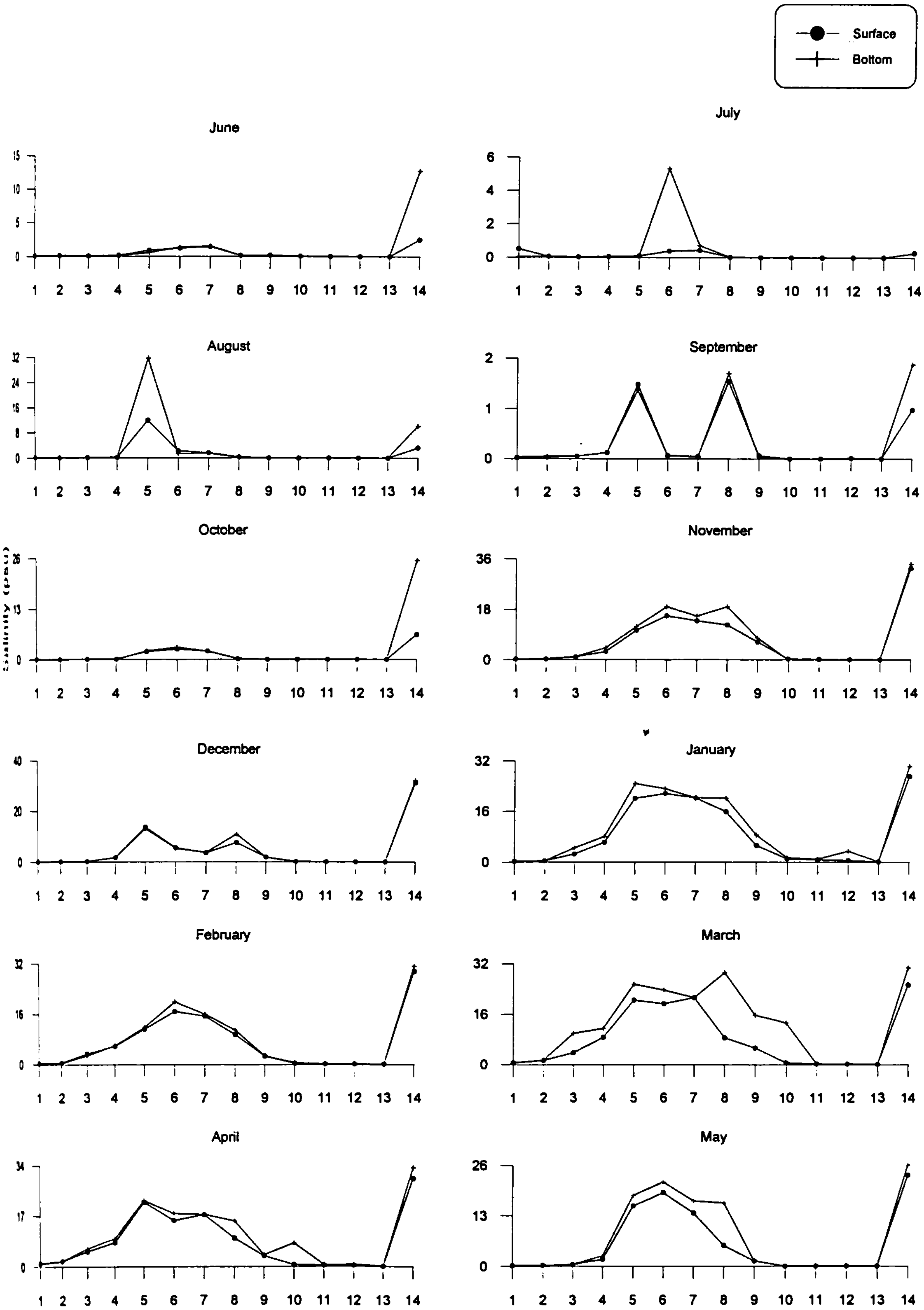


Fig. 3.3. Distribution of Salinity at stations 1 to 14

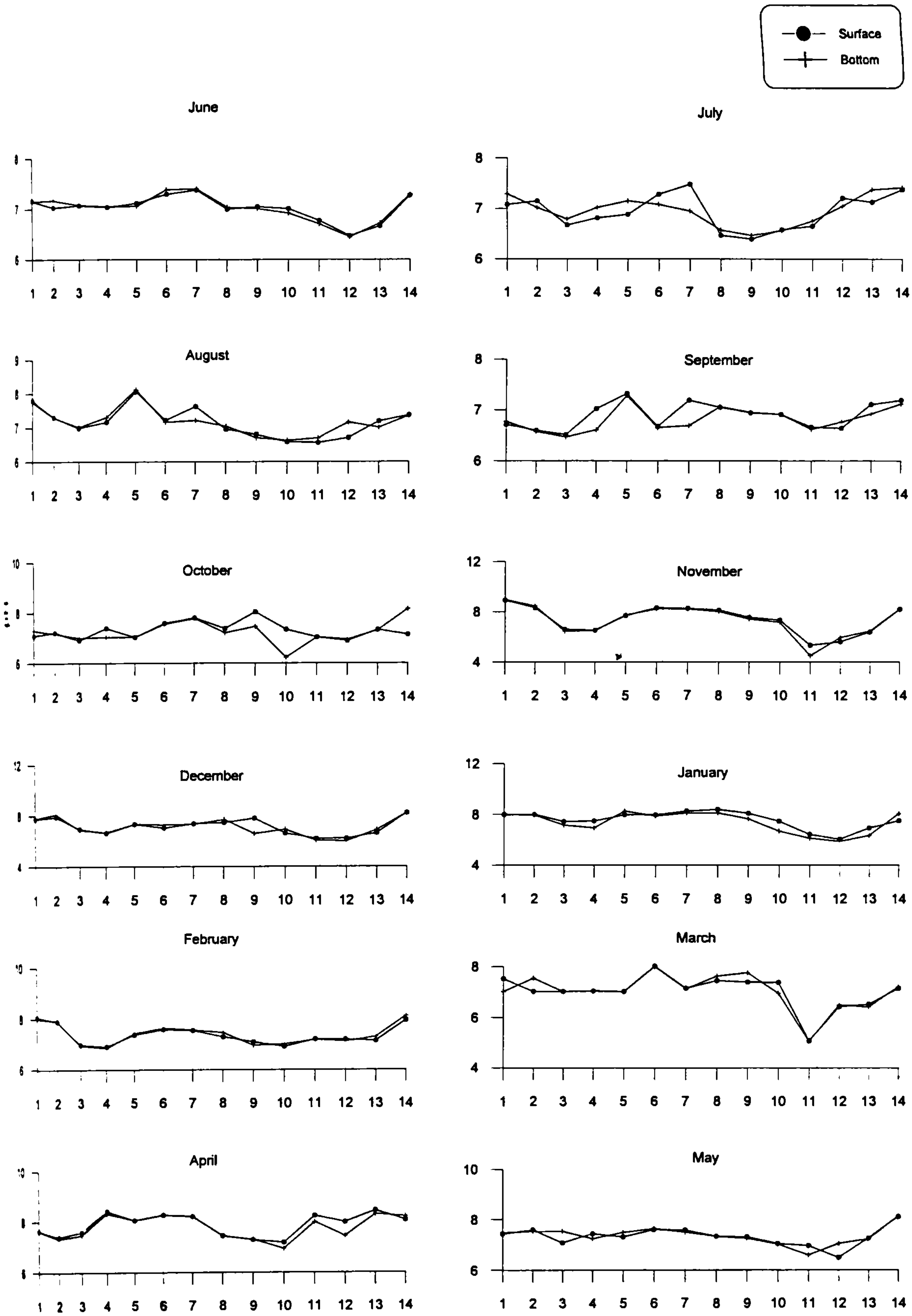


Fig. 3.4. Distribution of pH at stations 1 to 14

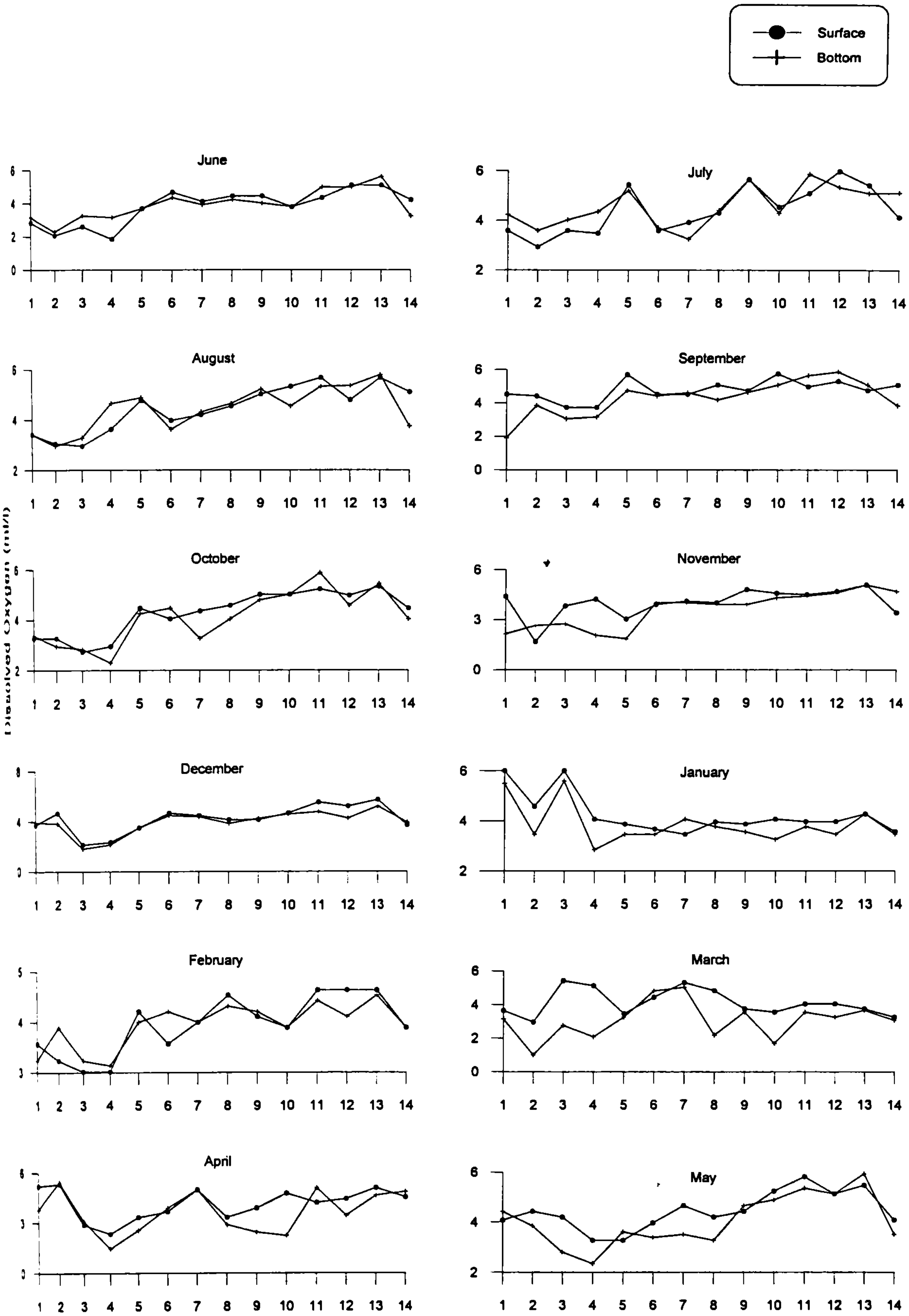


Fig. 3.5. Distribution of Dissolved Oxygen at stations 1 to 14

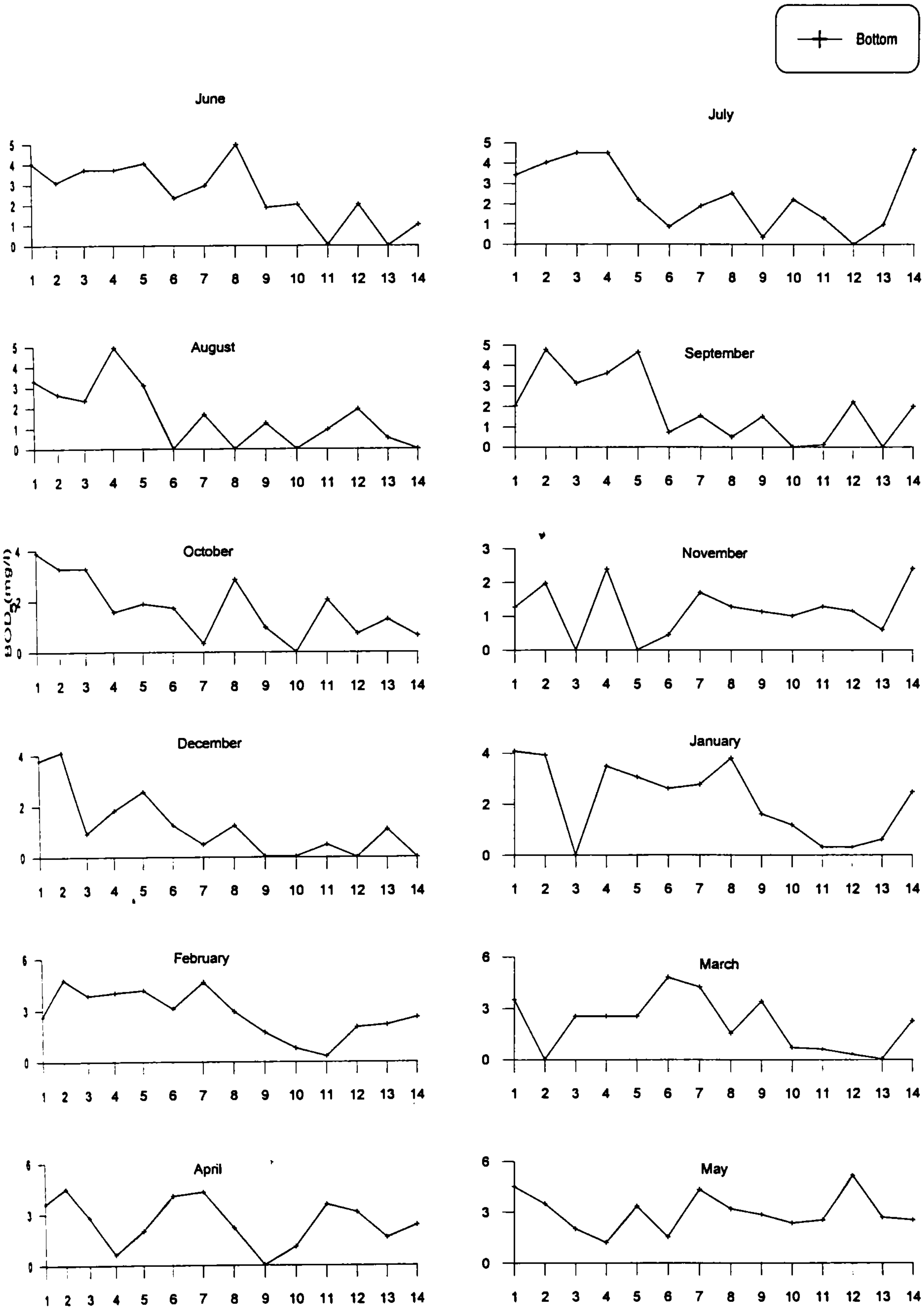


Fig. 3.6. **Distribution of Biochemical Oxygen Demand at stations 1 to 14**

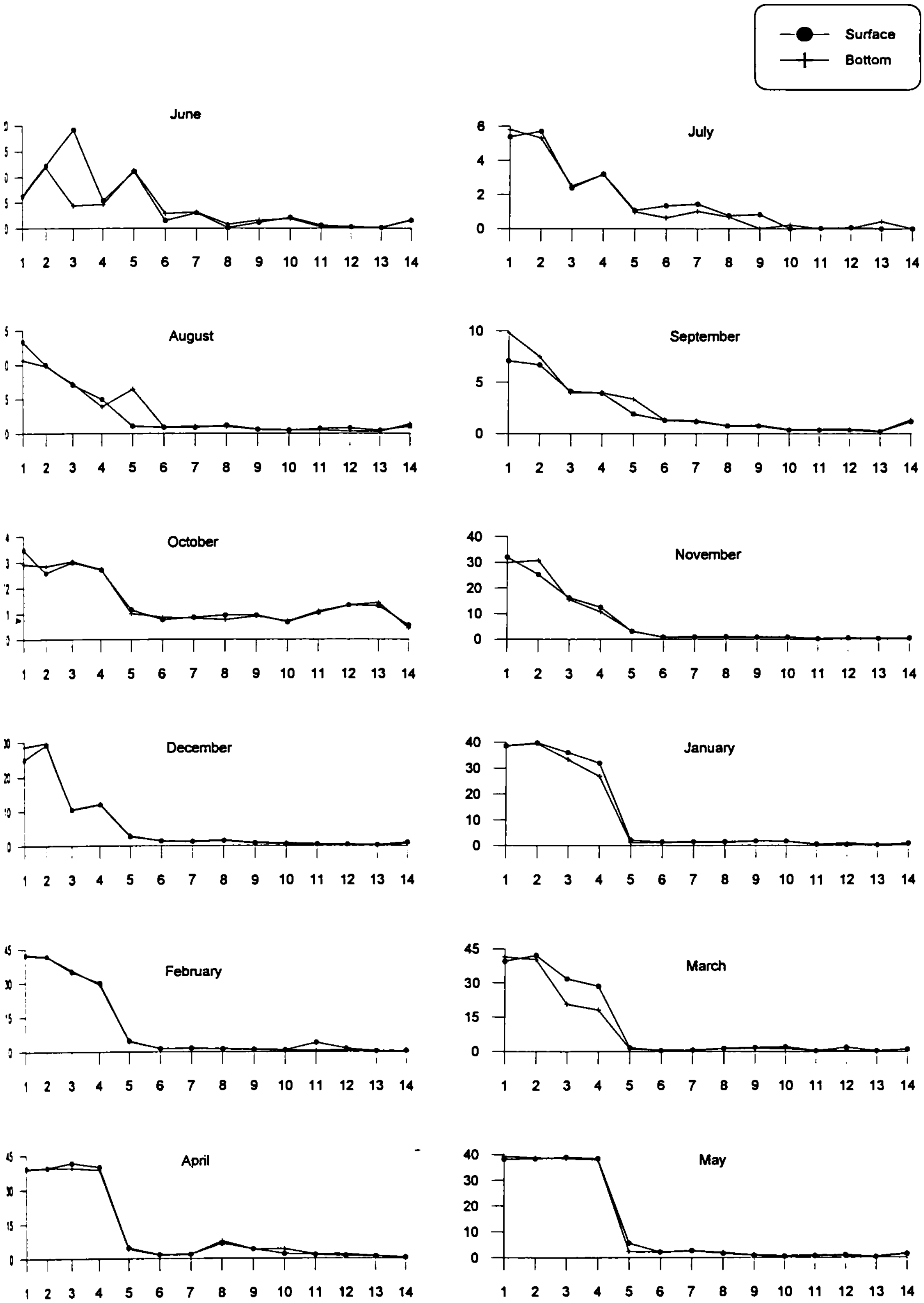


Fig. 3.7. Distribution of Nitrite at stations 1 to 14

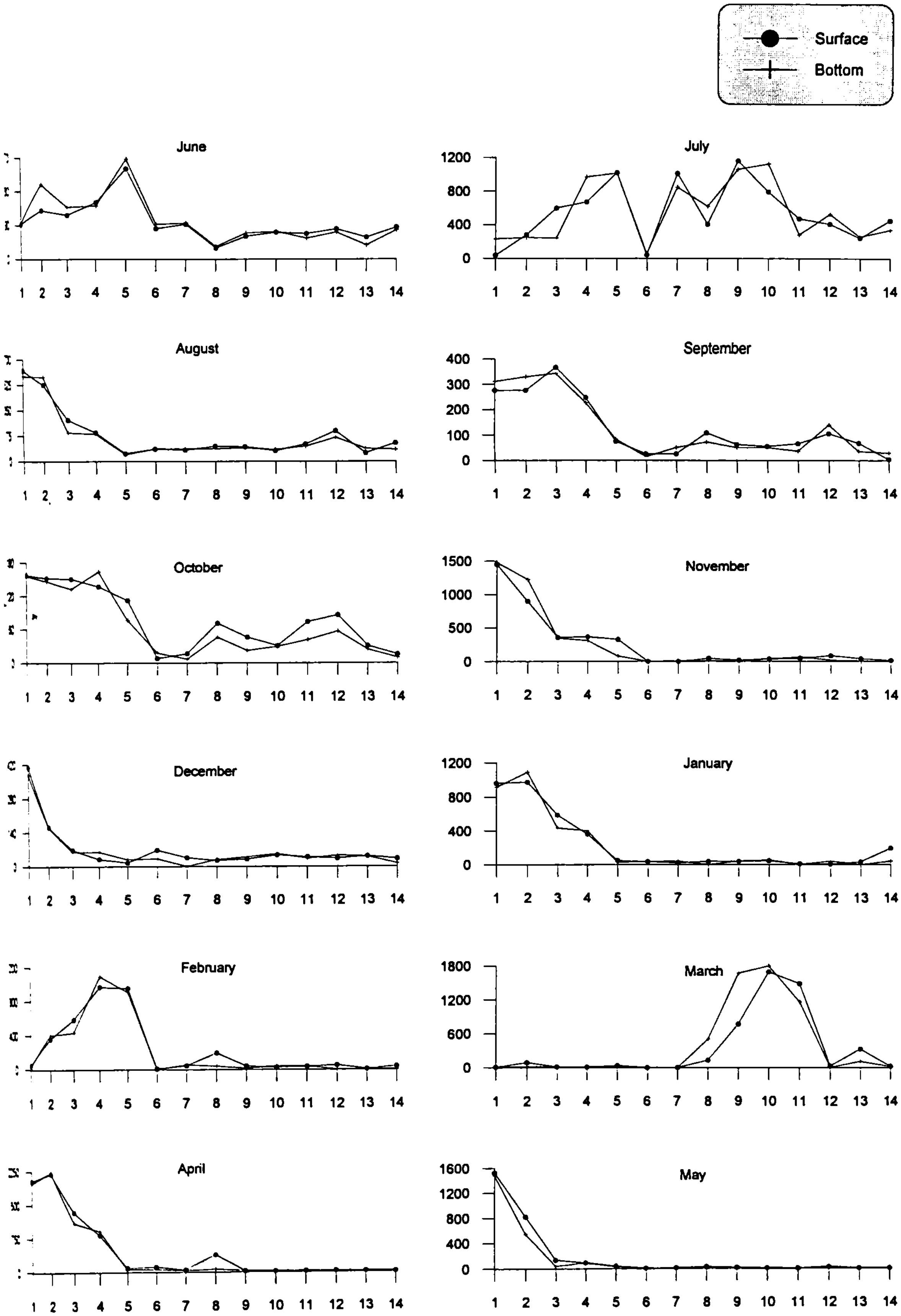


Fig. 3.8. Distribution of Nitrate at stations 1 to 14

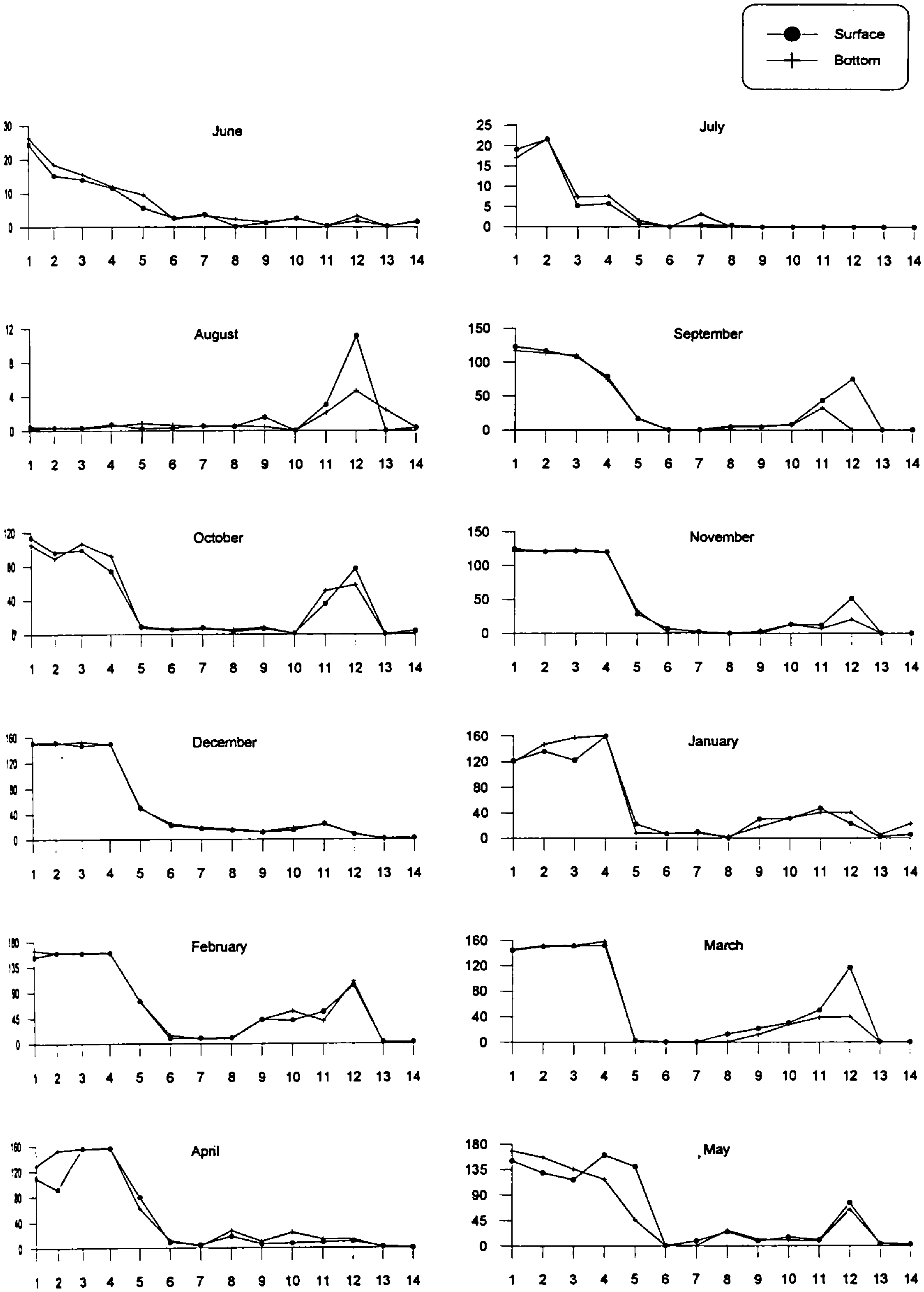


Fig. 3.9. Distribution of Ammonia at stations 1 to 14

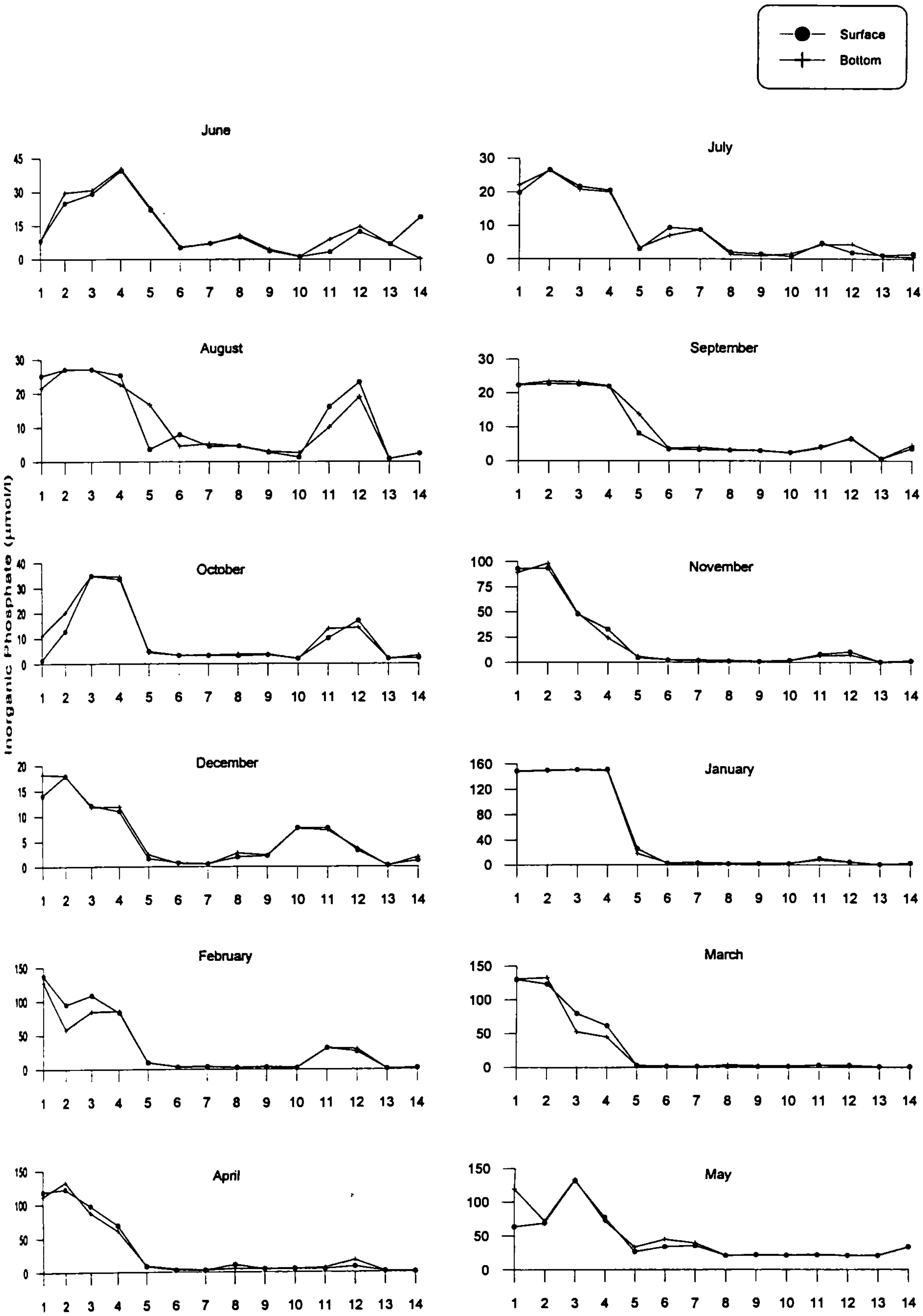


Fig. 3.10. Distribution of Inorganic Phosphate at stations 1 to 14

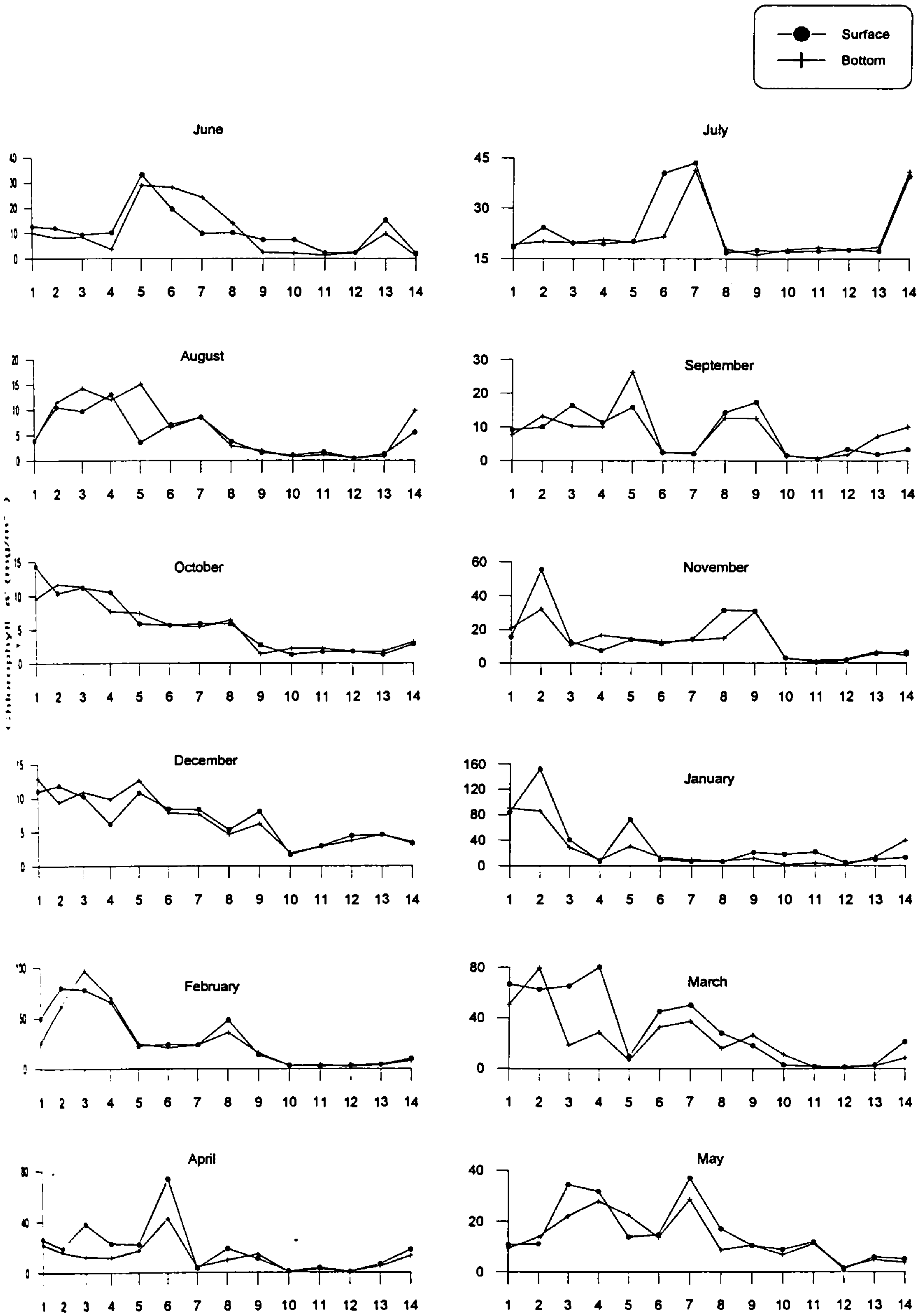


Fig. 3.11. Distribution of Chlorophyll 'a' at stations 1 to 14

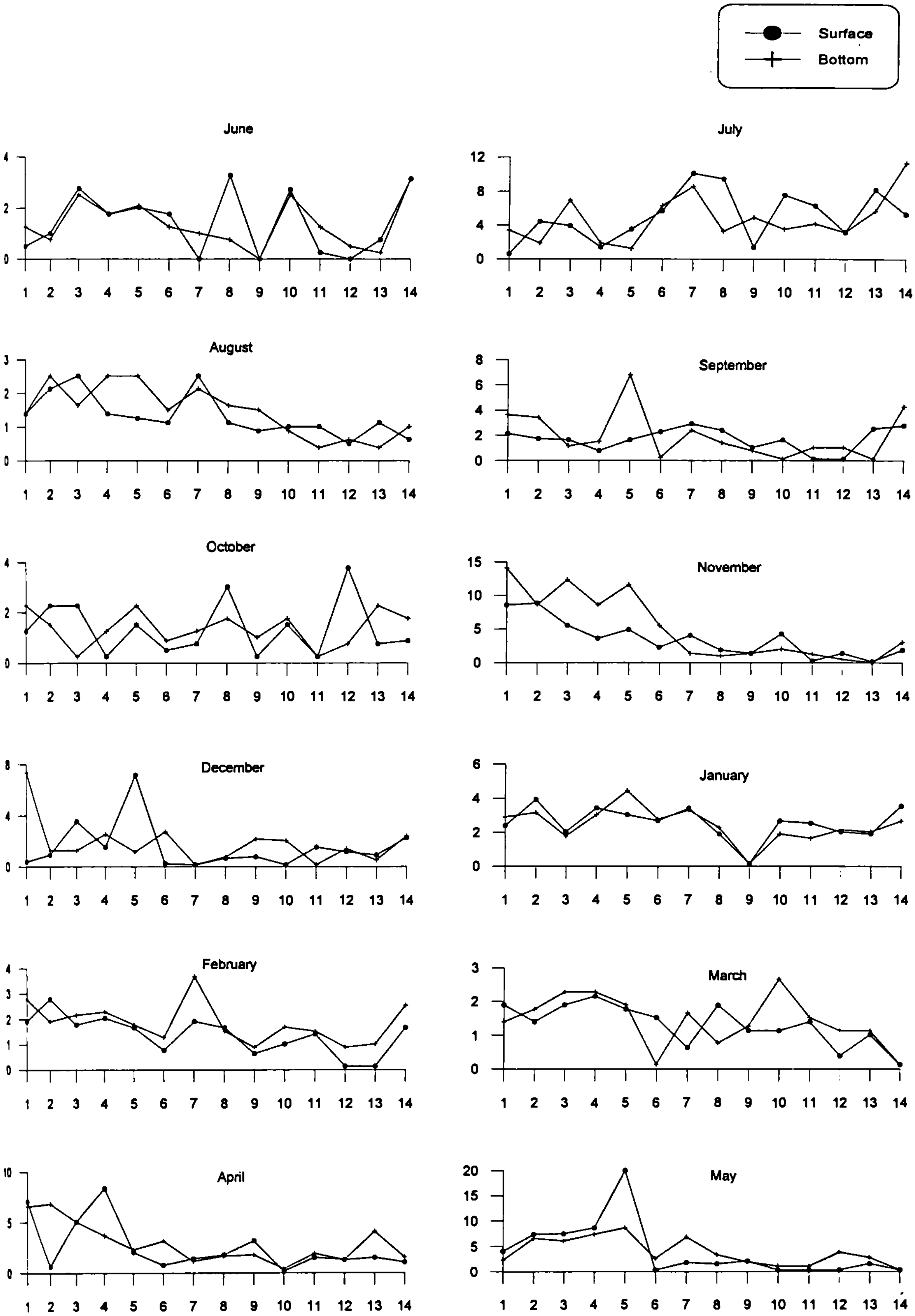


Fig. 3.12. Distribution of Particulate Organic Carbon at stations 1 to 14

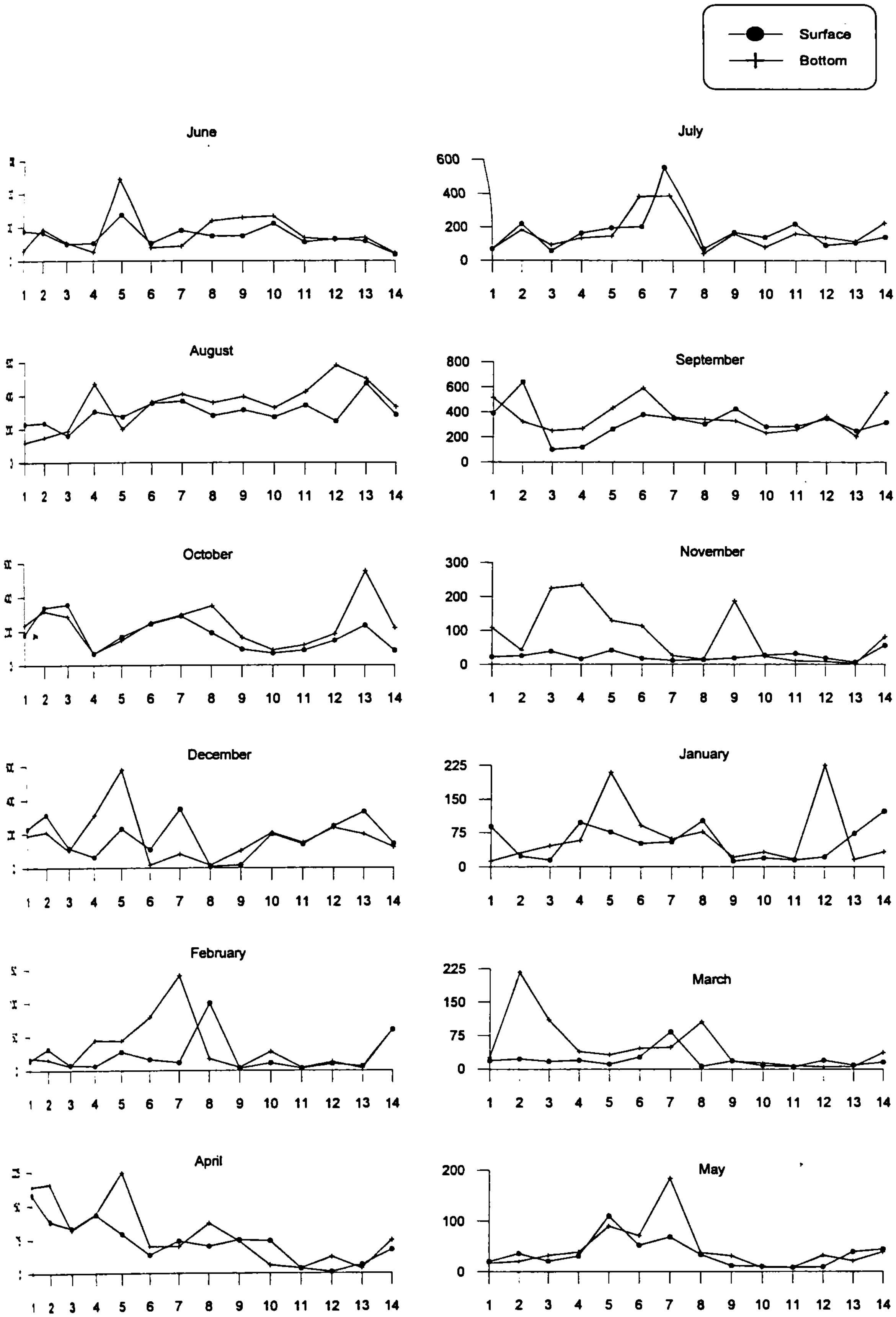


Fig. 3.13. Distribution of Suspended load at stations 1 to 14

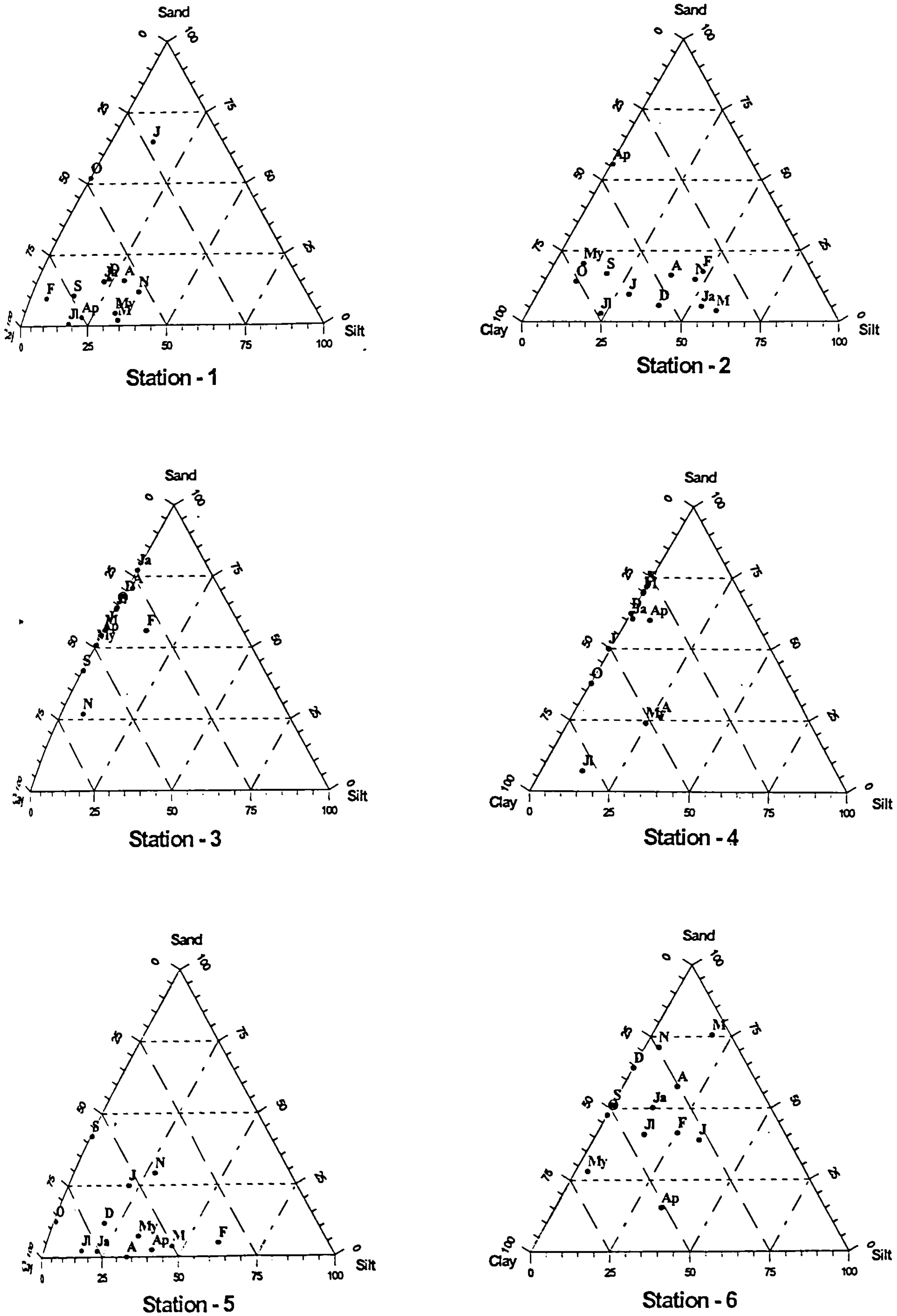


Fig. 3.14. Grain size distribution at different stations

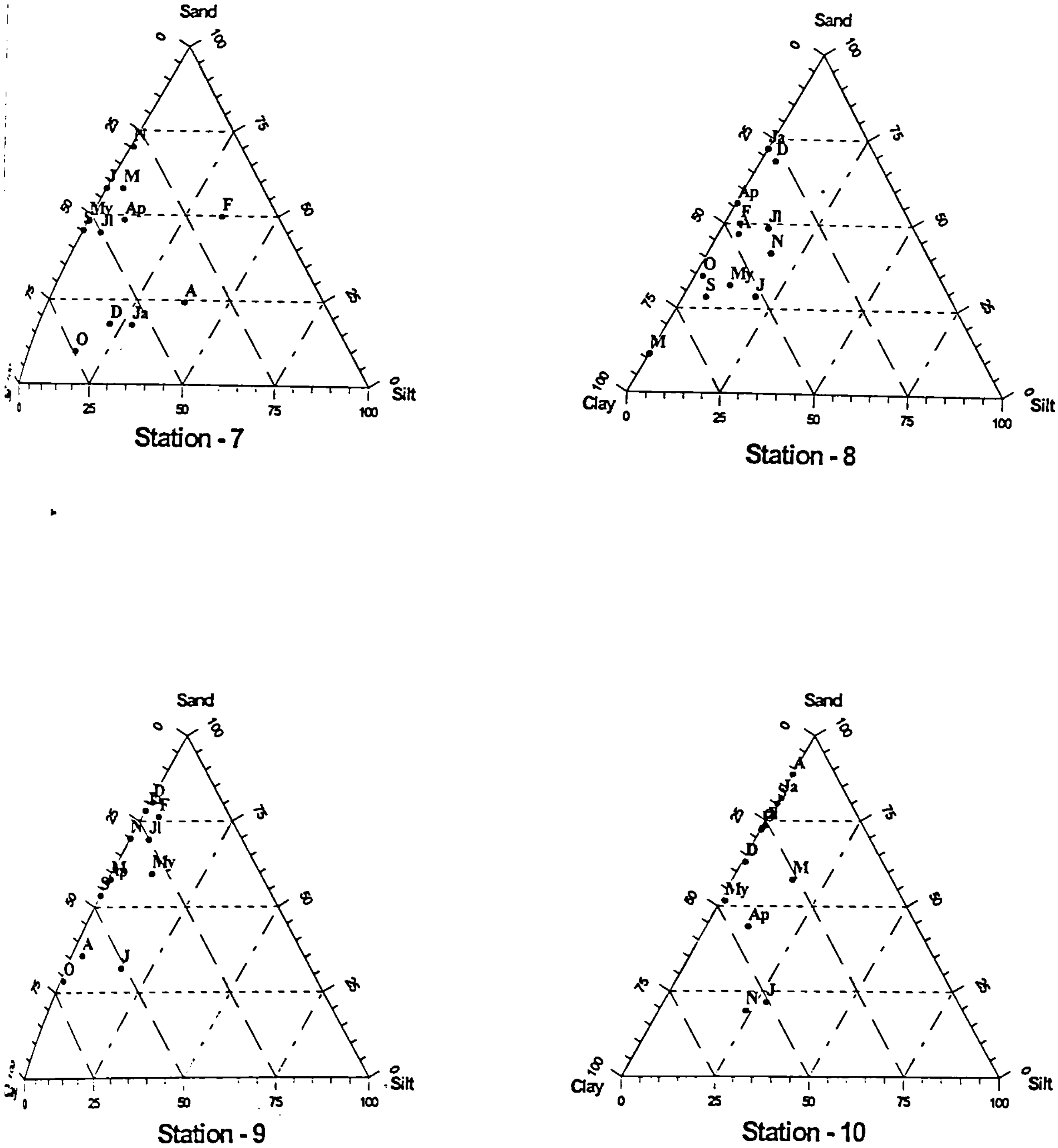


Fig. 3.15. Grain size distribution at different stations

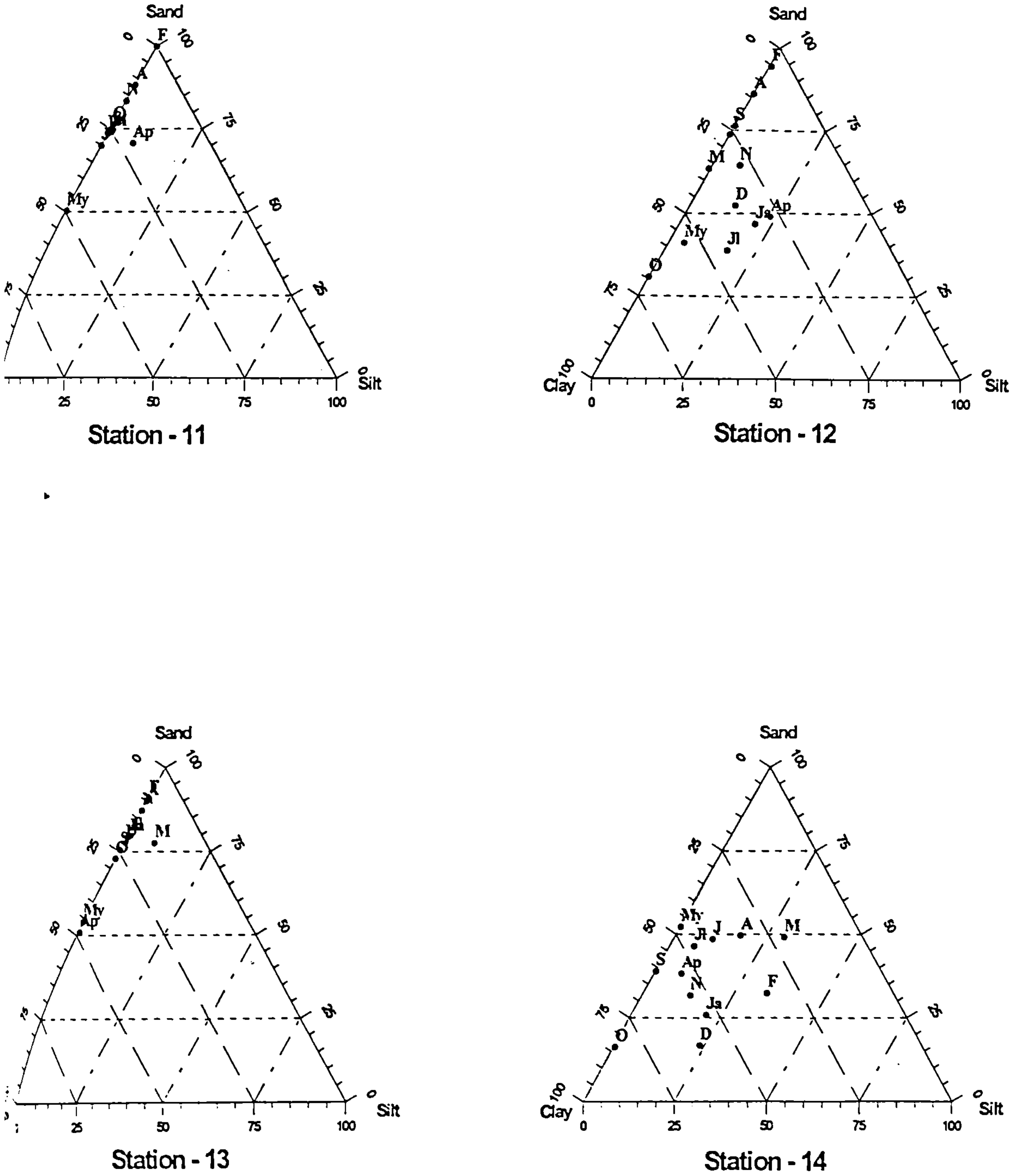


Fig. 3.16. Grain size distribution at different stations

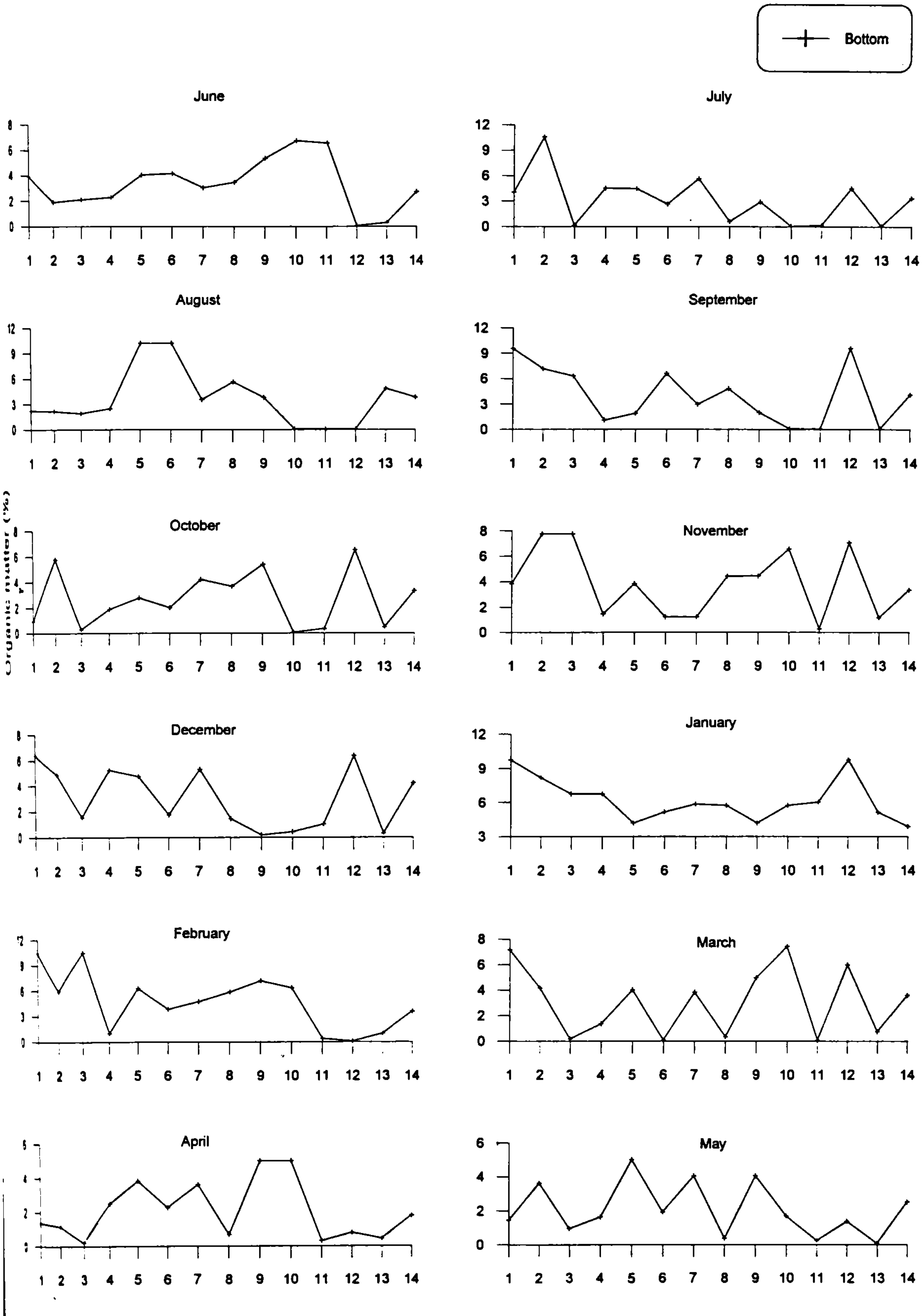
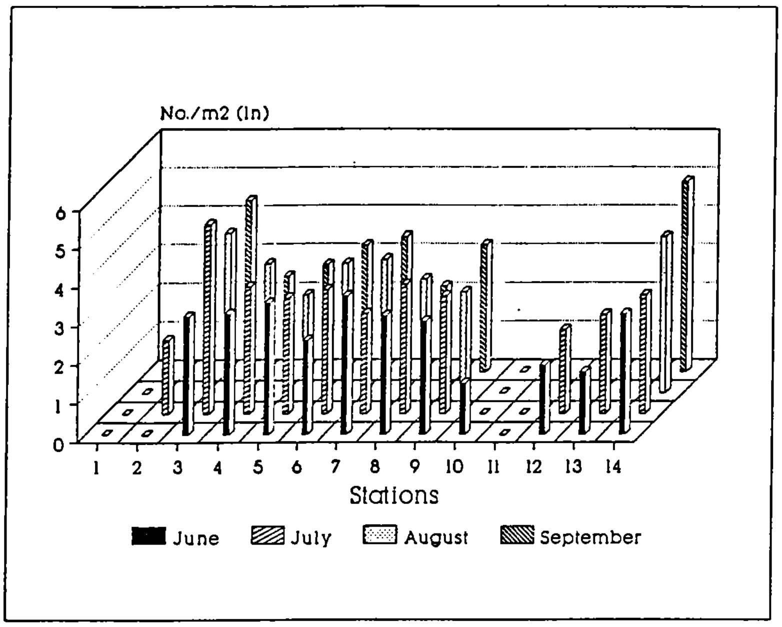
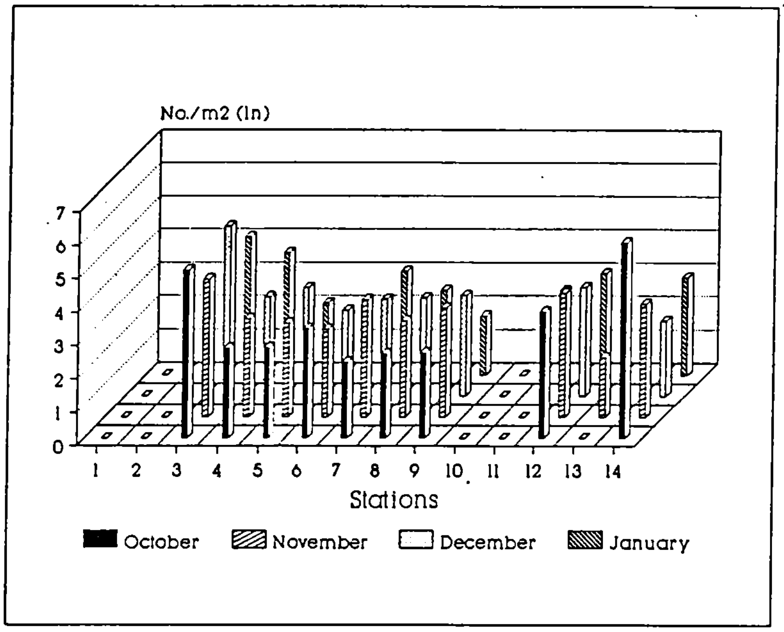


Fig. 3.17. Distribution of organic matter at staions 1 to 14





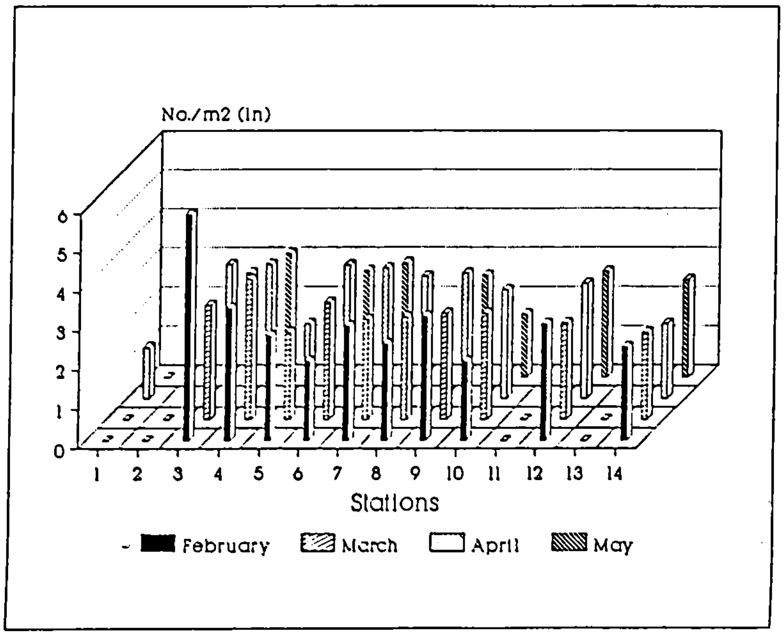
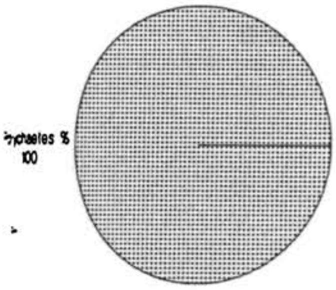


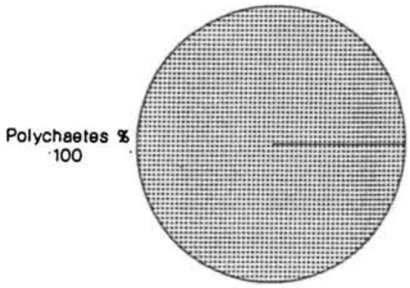
Fig. 3.18. Total benthic density (no./m^2) at different stations

Station 1

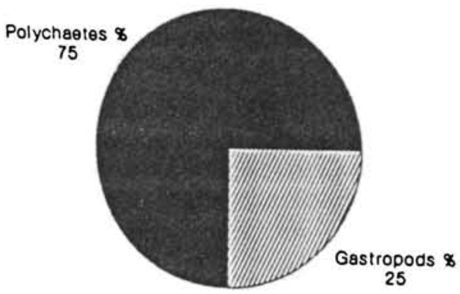
October



April



Station 2



July

Fig. 3.19. Percentage distribution of major groups of benthos at Stations 1& 2

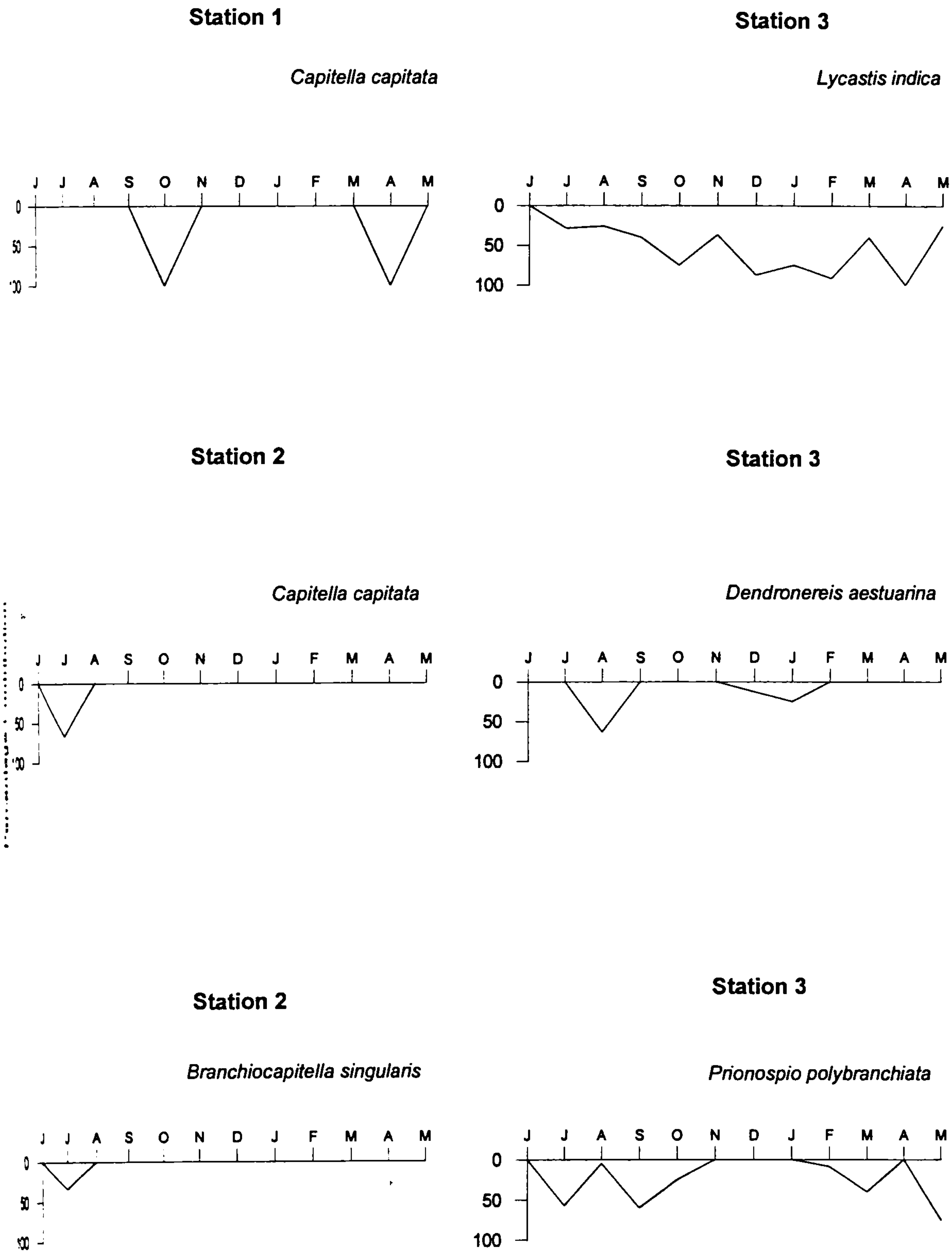


Fig. 3.20. **Percentage contribution of polychaete species at Stations 1,2 & 3**

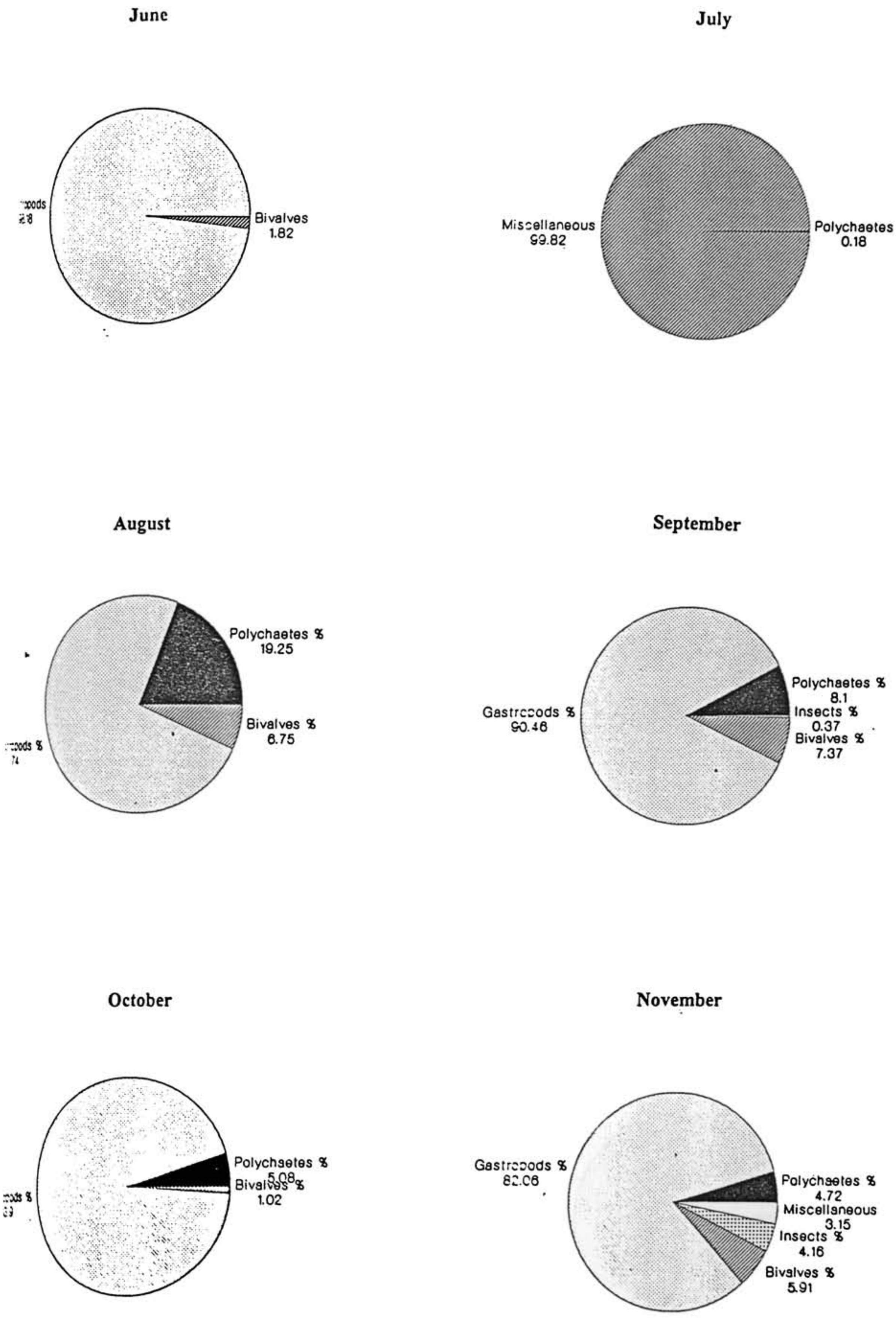


Fig. 3.21. Percentage distribution of major groups of benthos at Station 3

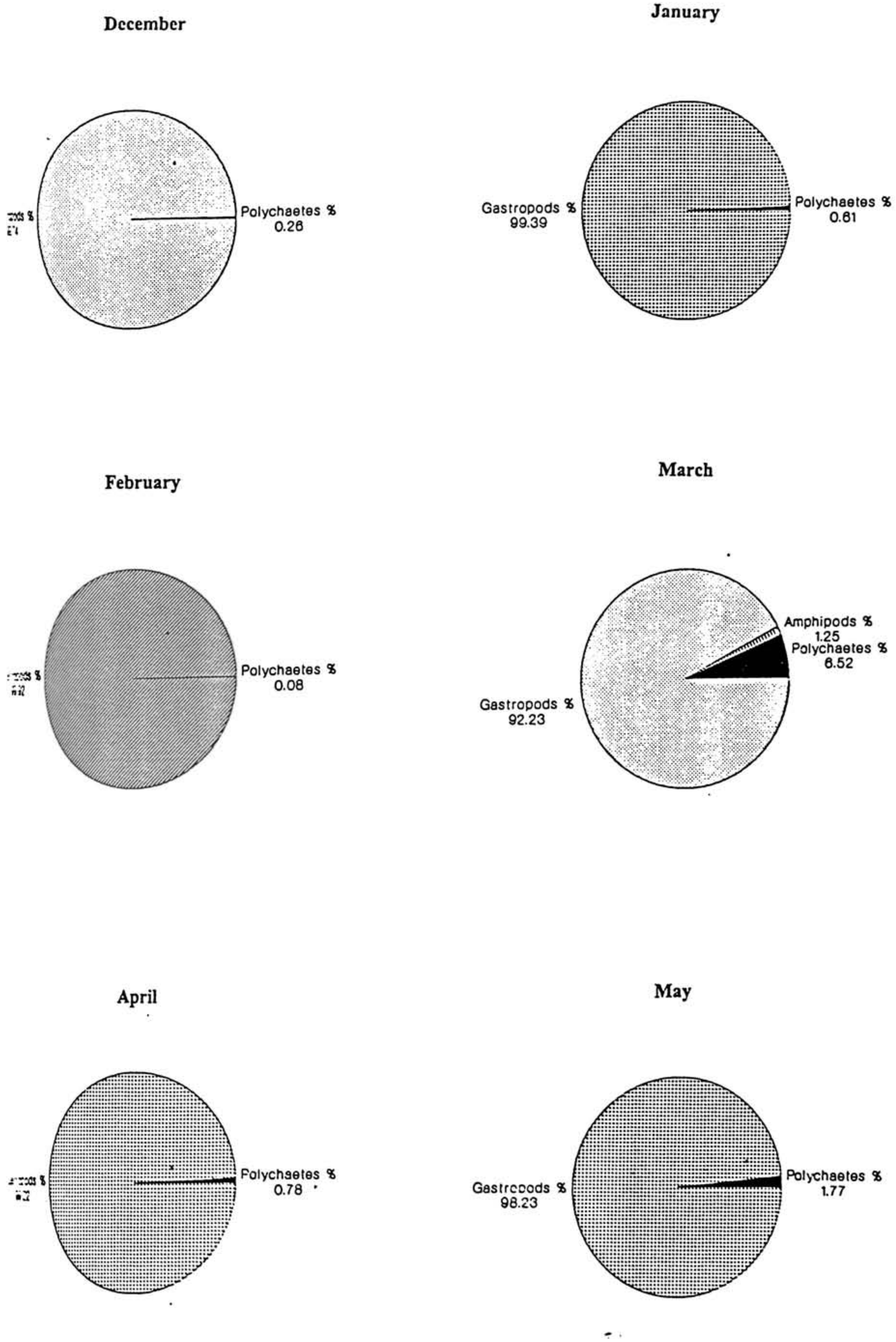


Fig.3.22. Percentage distribution of major groups of benthos at Station 3

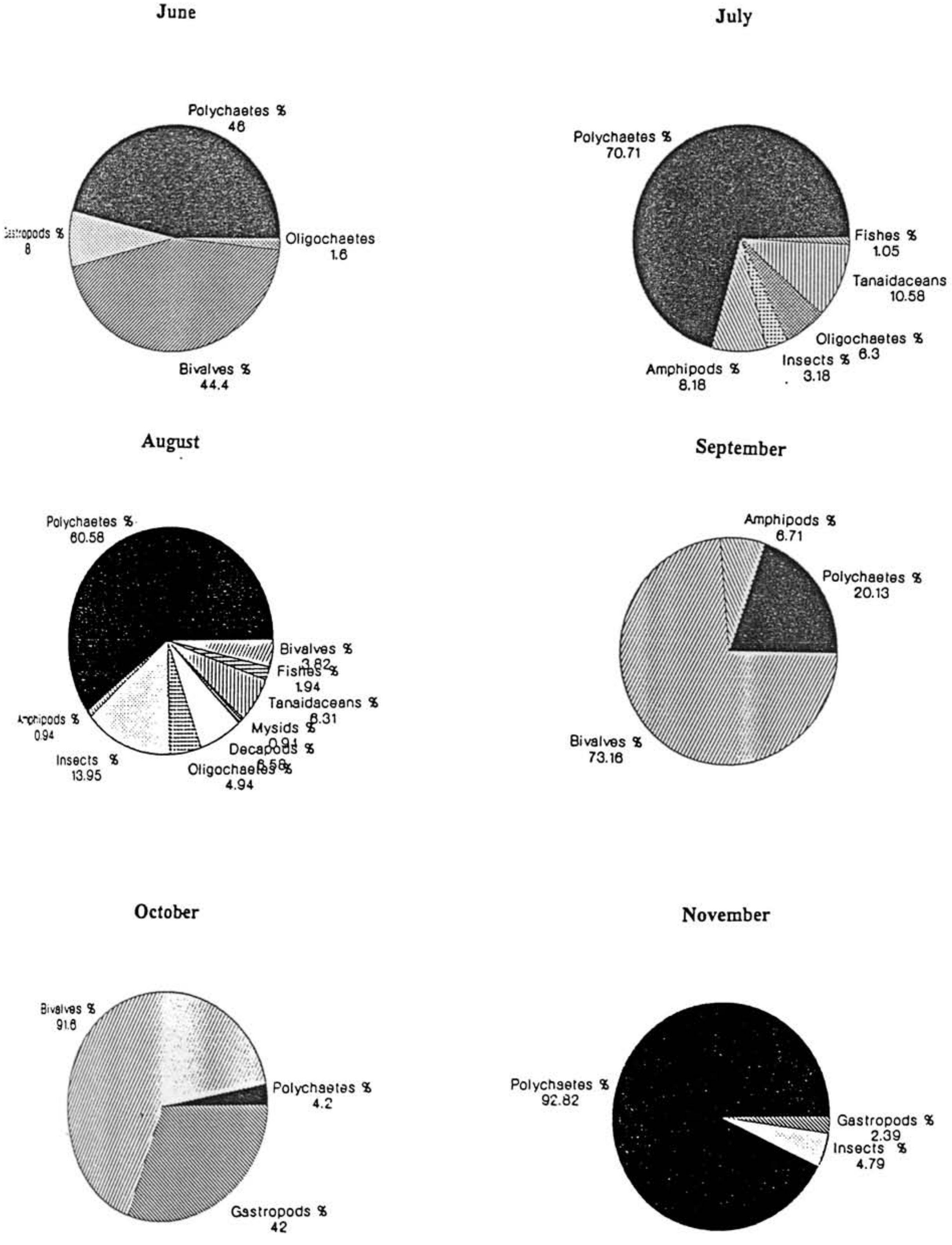


Fig. 3.23. Percentage distribution of major groups of benthos at Station 4

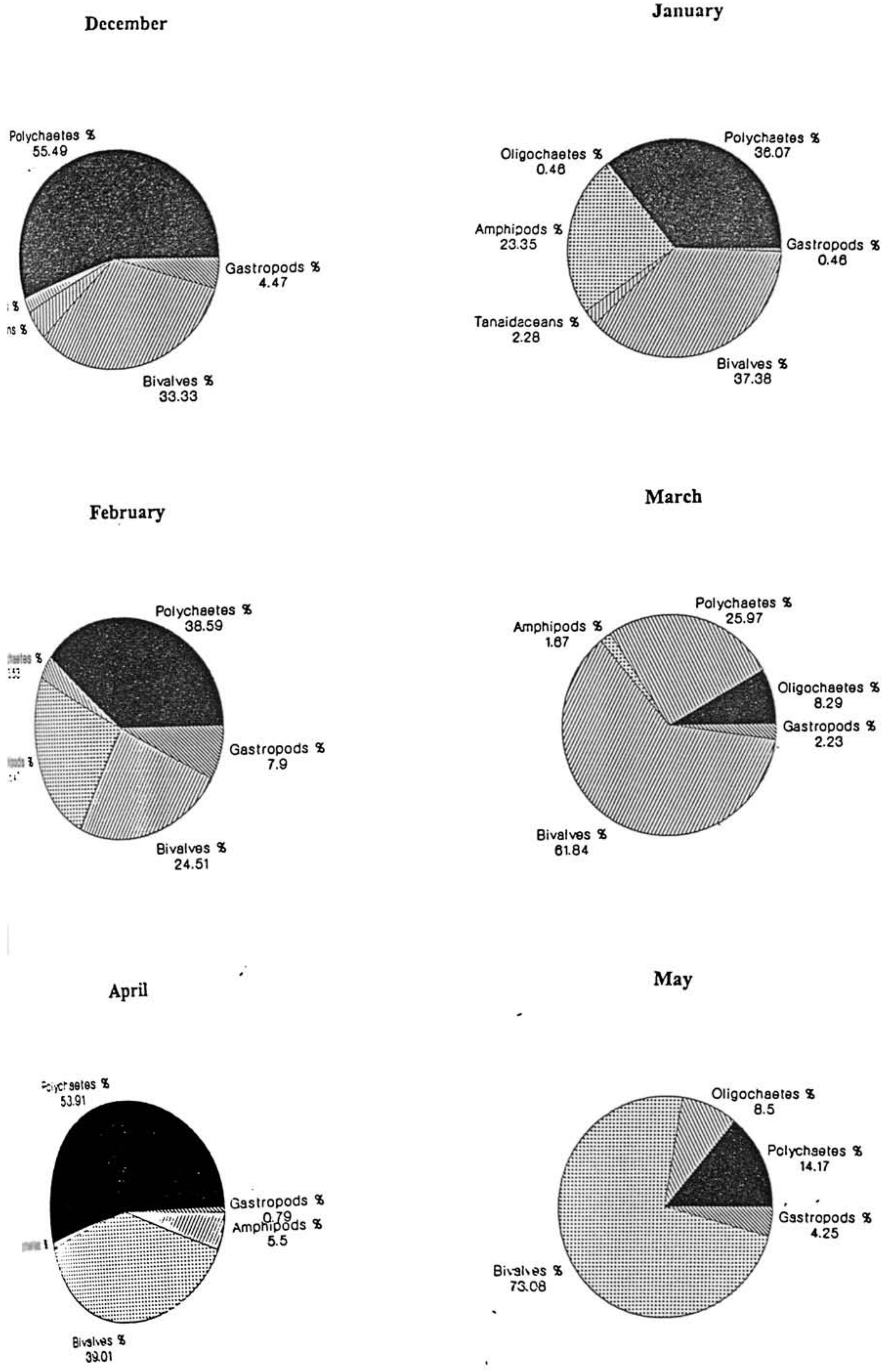
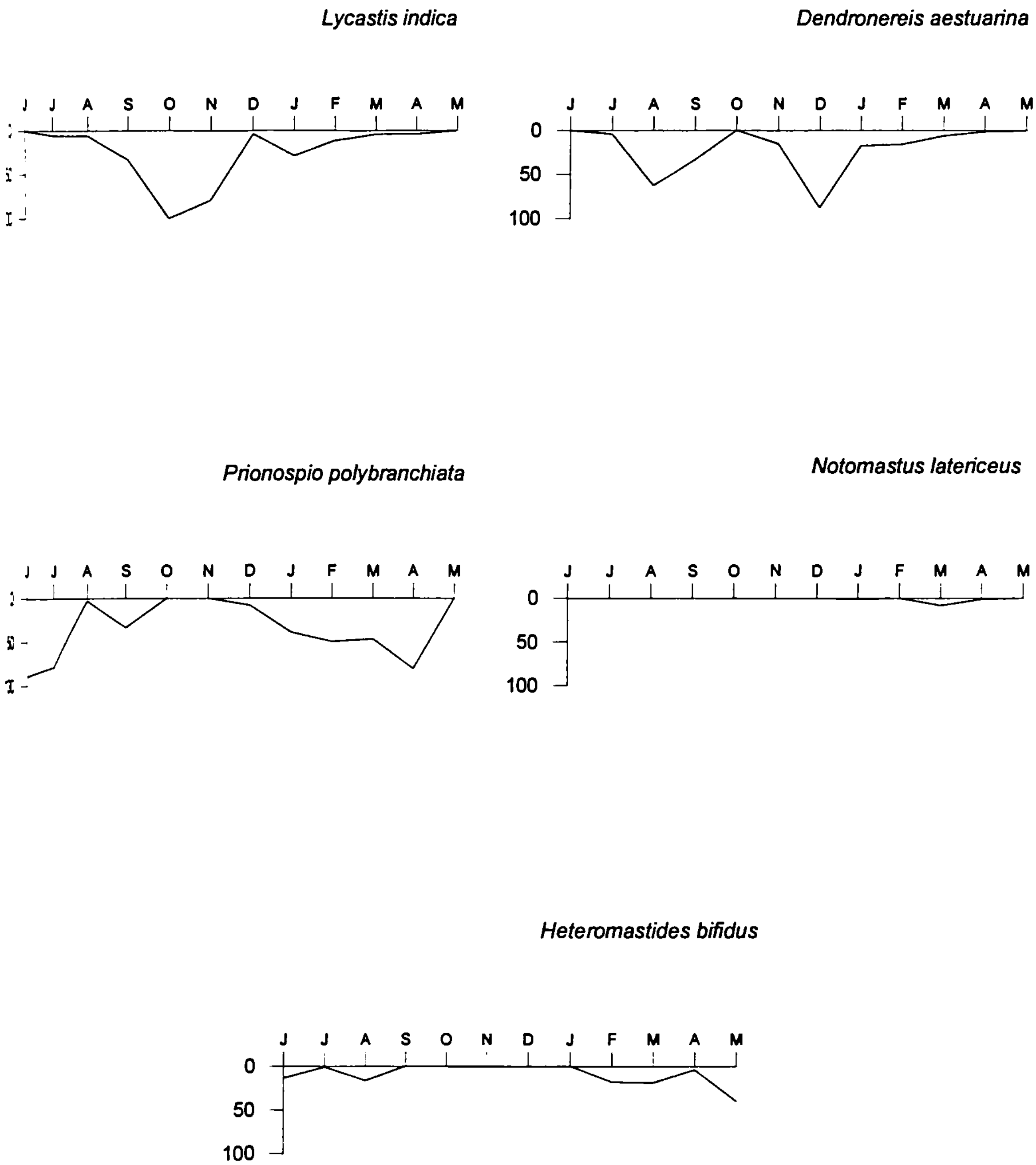


Fig. 3.24. Percentage distribution of major groups of benthos at Station 4



3.25. **Percentage contribution of common polychaete species at Station 4**

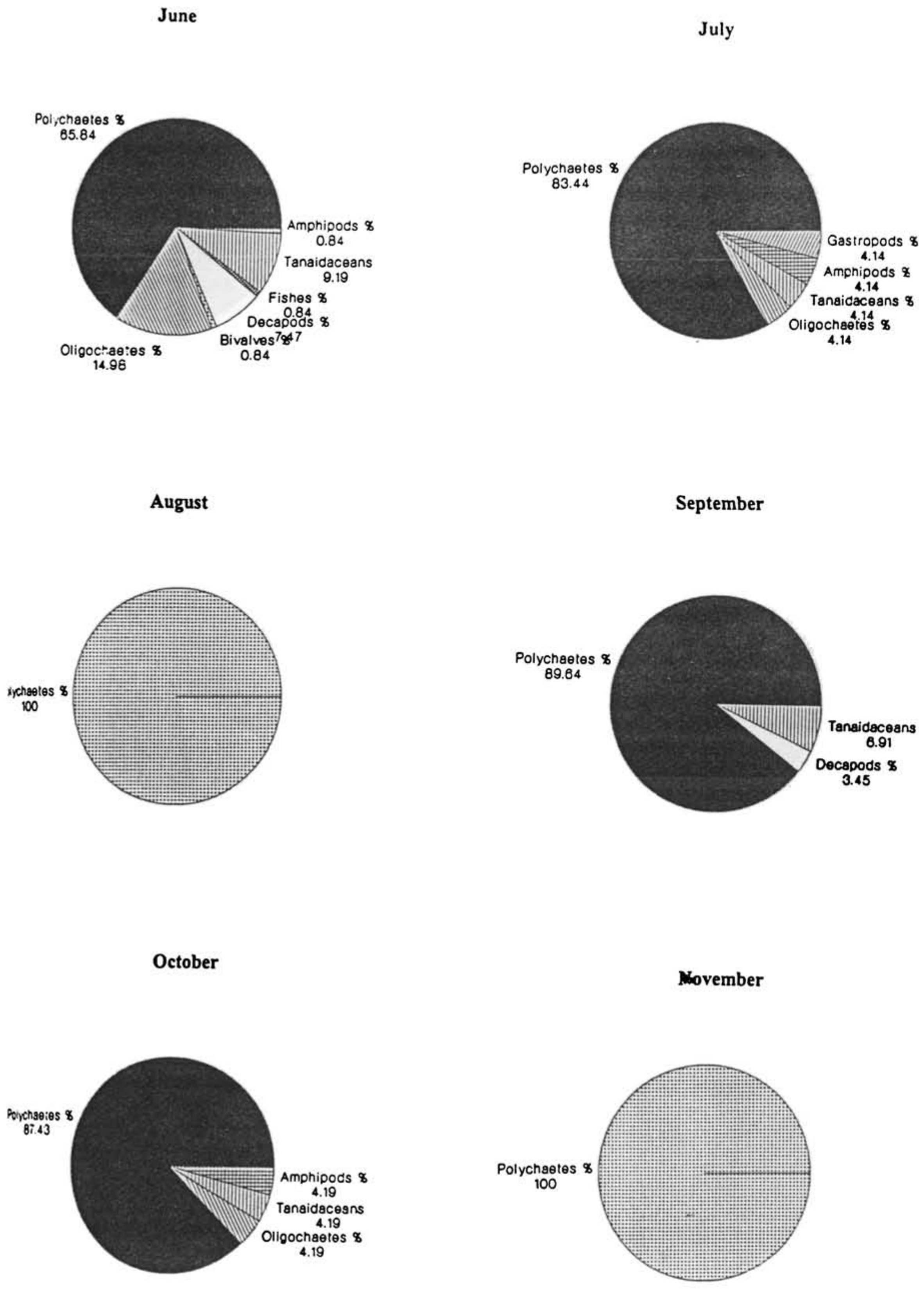


Fig.3.26. Percentage distribution of major groups of benthos at Station 5

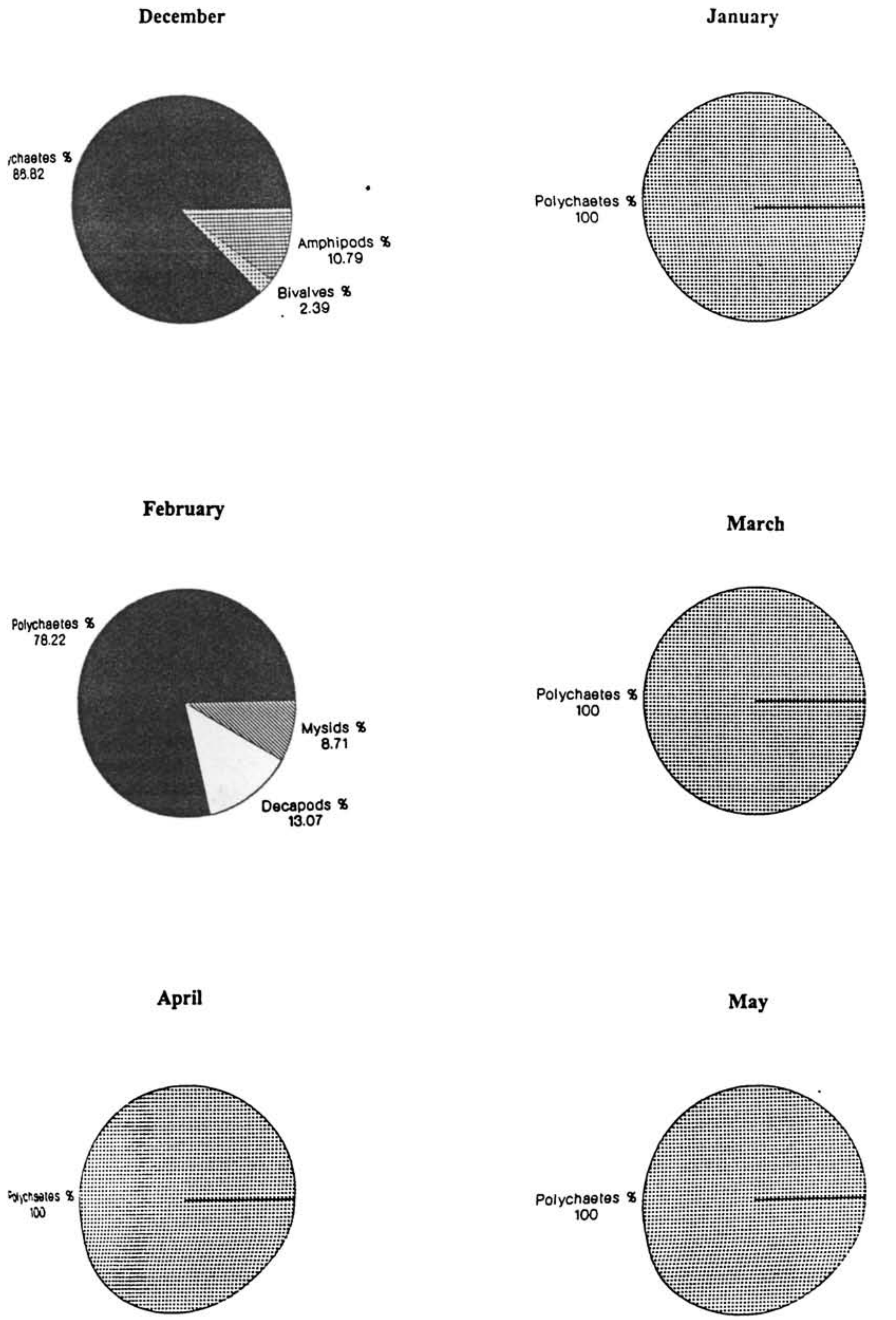


Fig.3.27. Percentage distribution of major groups of benthos at Station 5

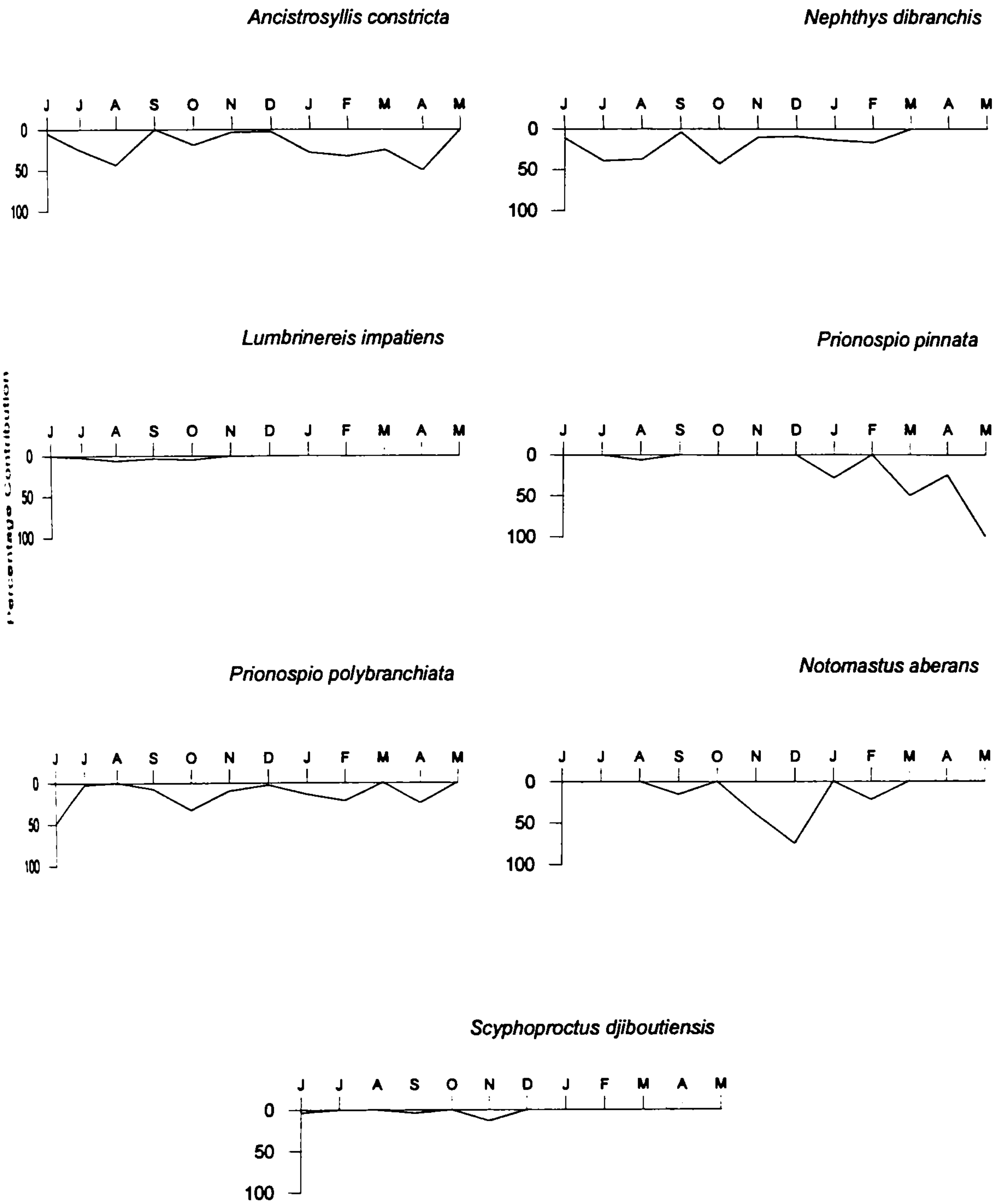


Fig. 3.28. Percentage contribution of common polychaete species at Station 5

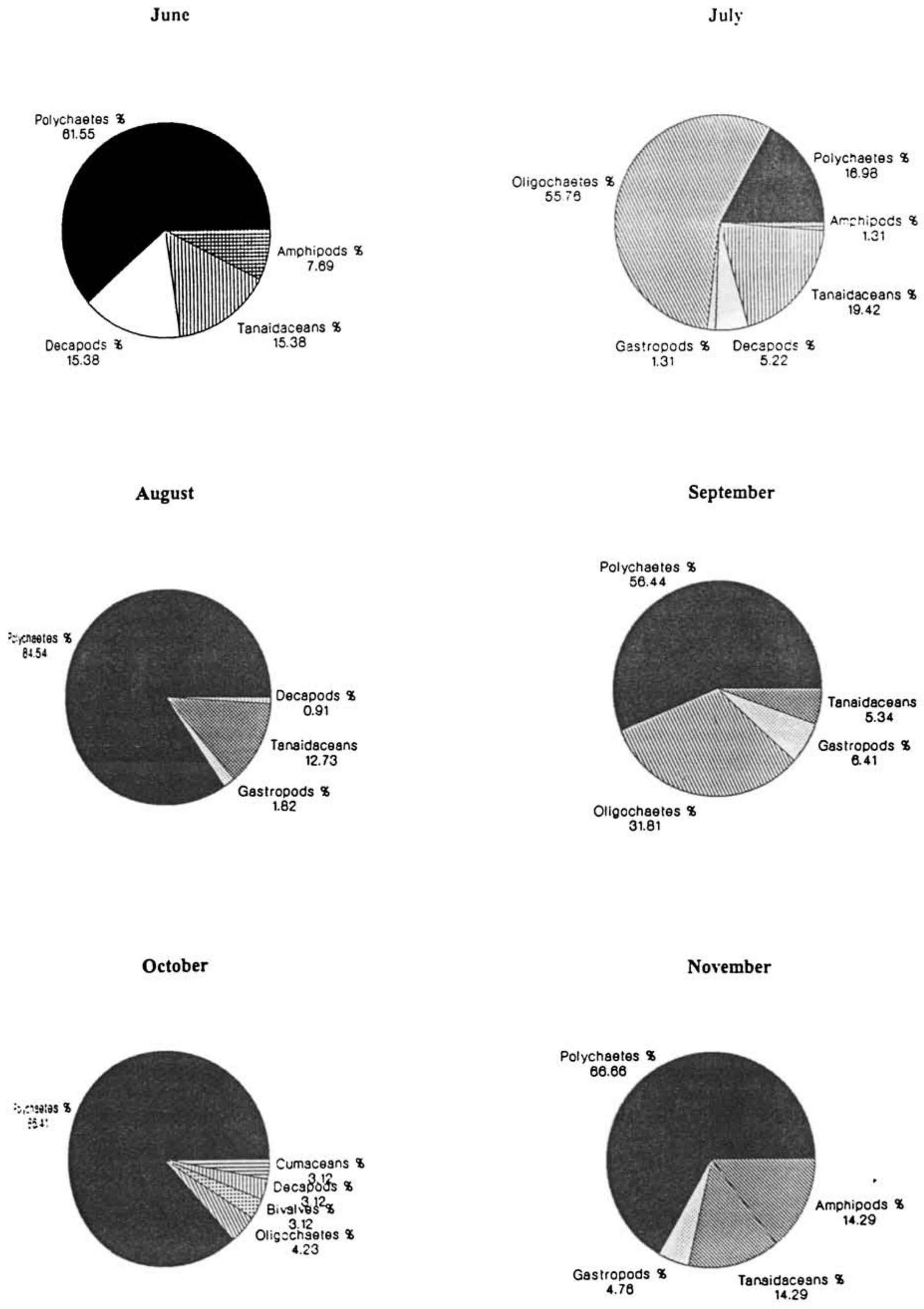


Fig.3.29. Percentage distribution of major groups of benthos at Station 6

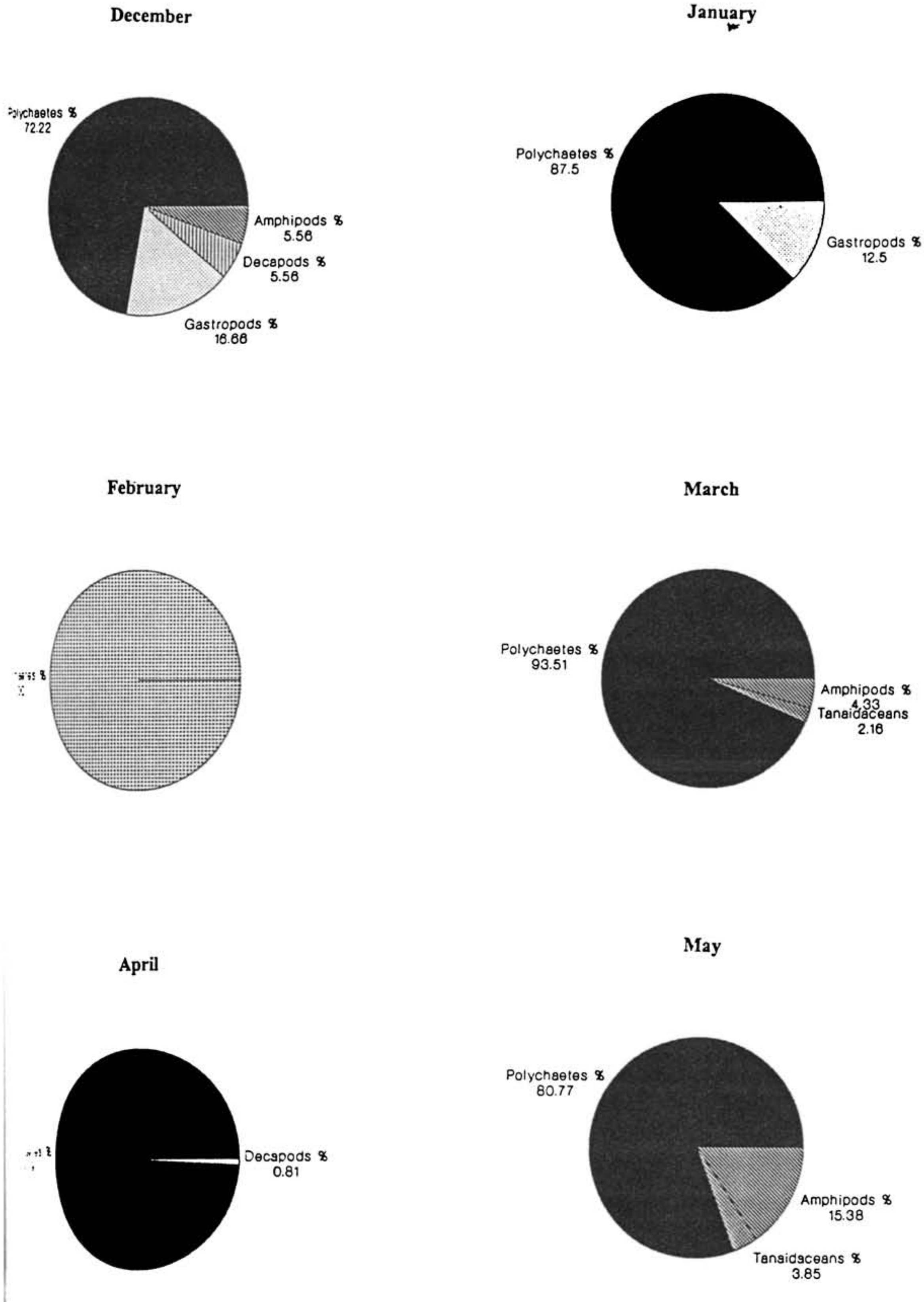


Fig.3.30. Percentage distribution of major groups of benthos at Station 6

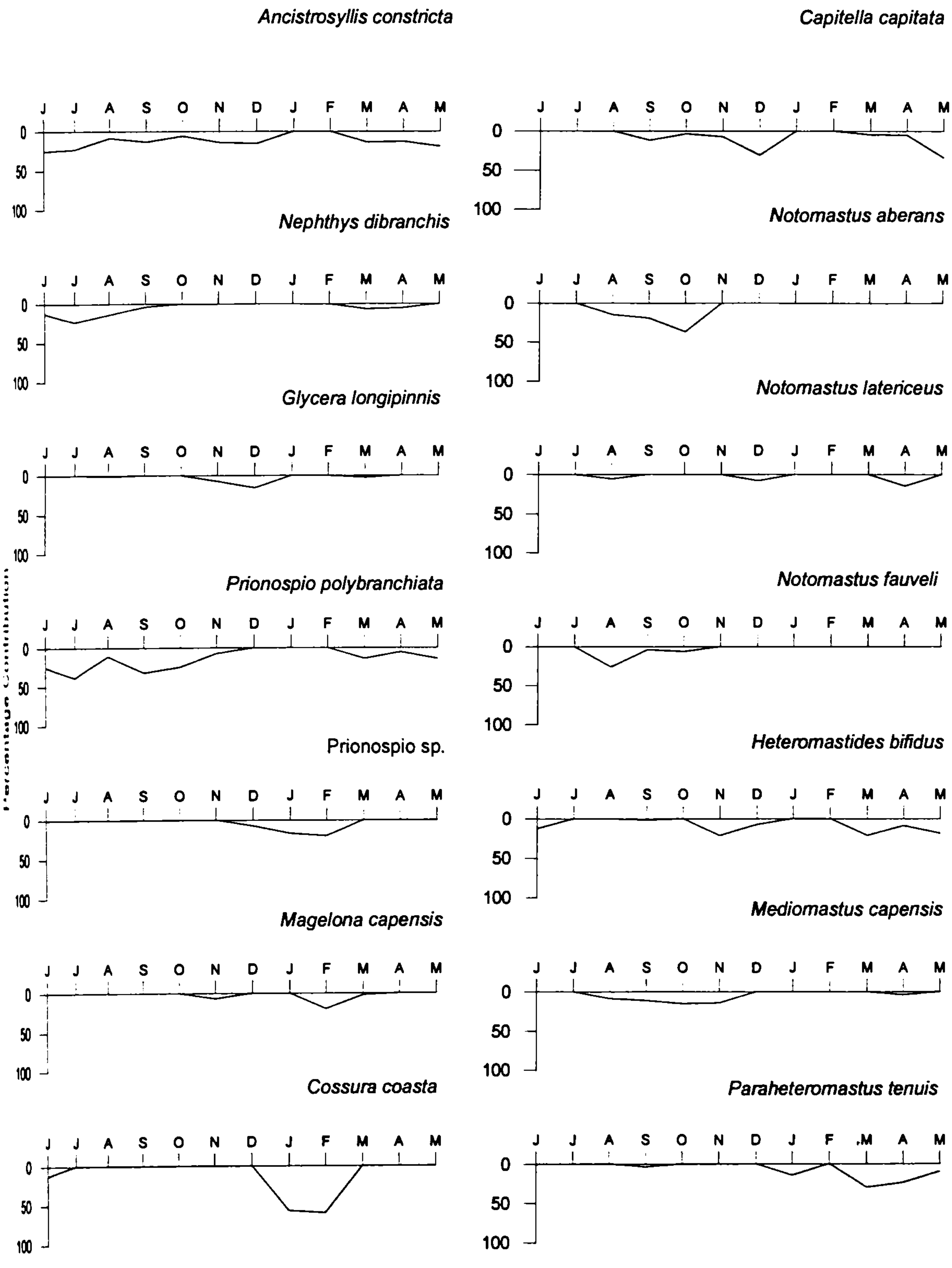


Fig. 3.31. **Percentage contribution of common polychaete species at Station 6**

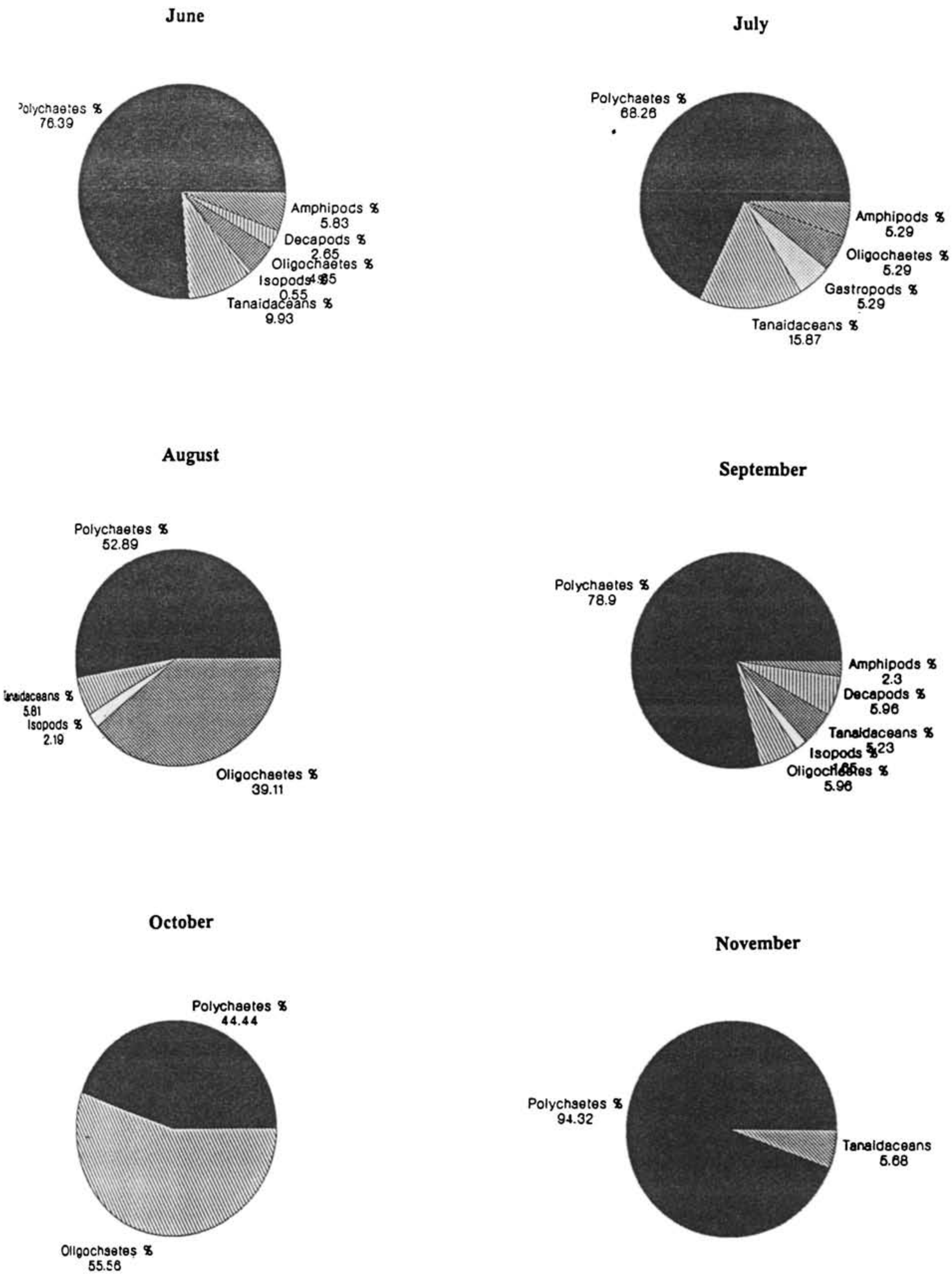


Fig.3.32. Percentage distribution of major groups of benthos at Station 7

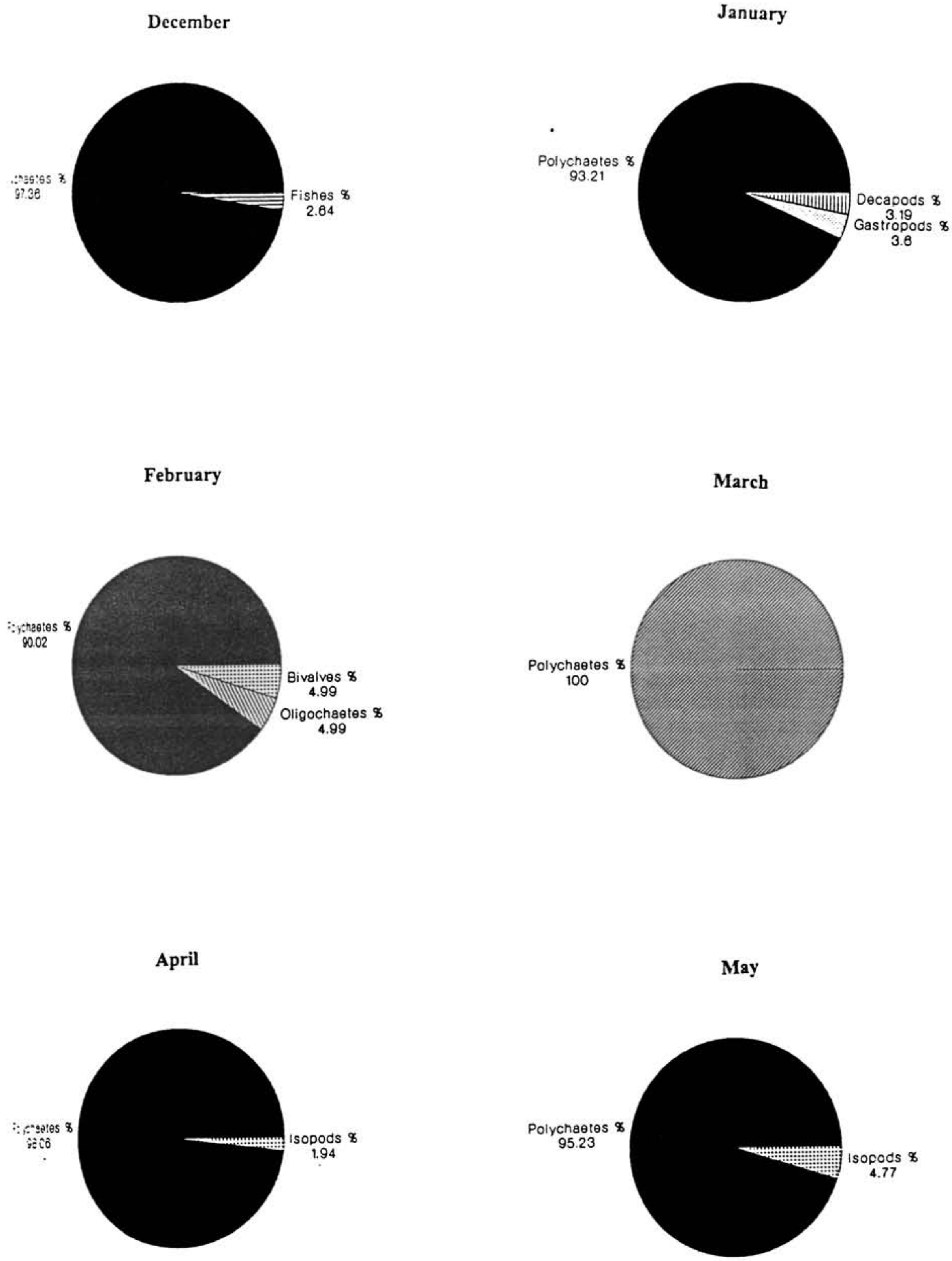


Fig.3.33. Percentage distribution of major groups of benthos at Station 7

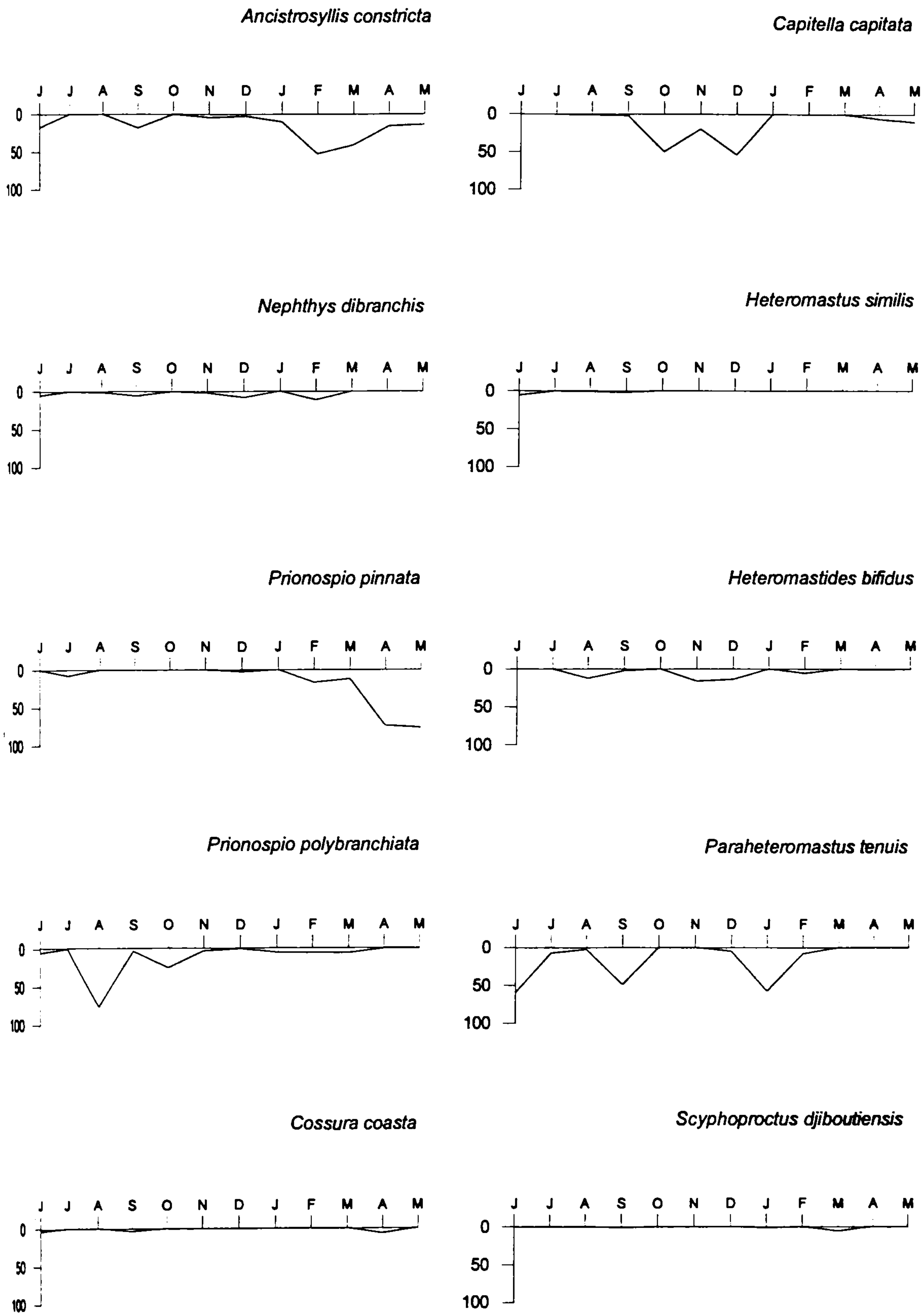


Fig. 3.34. **Percentage contribution of common polychaete species at Station 7**

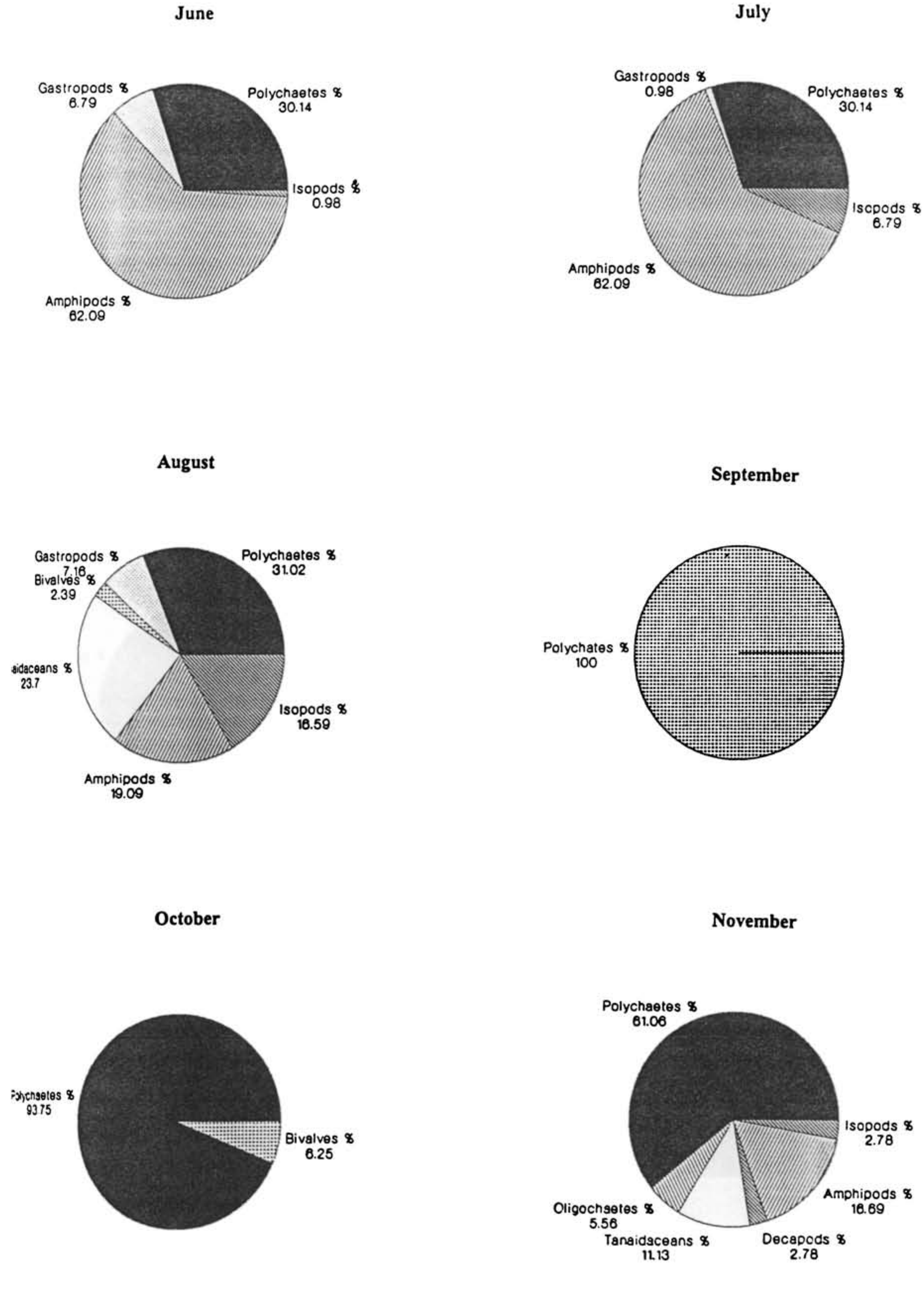


Fig. 3. 35. Percentage distribution of major groups of benthos at Station 8

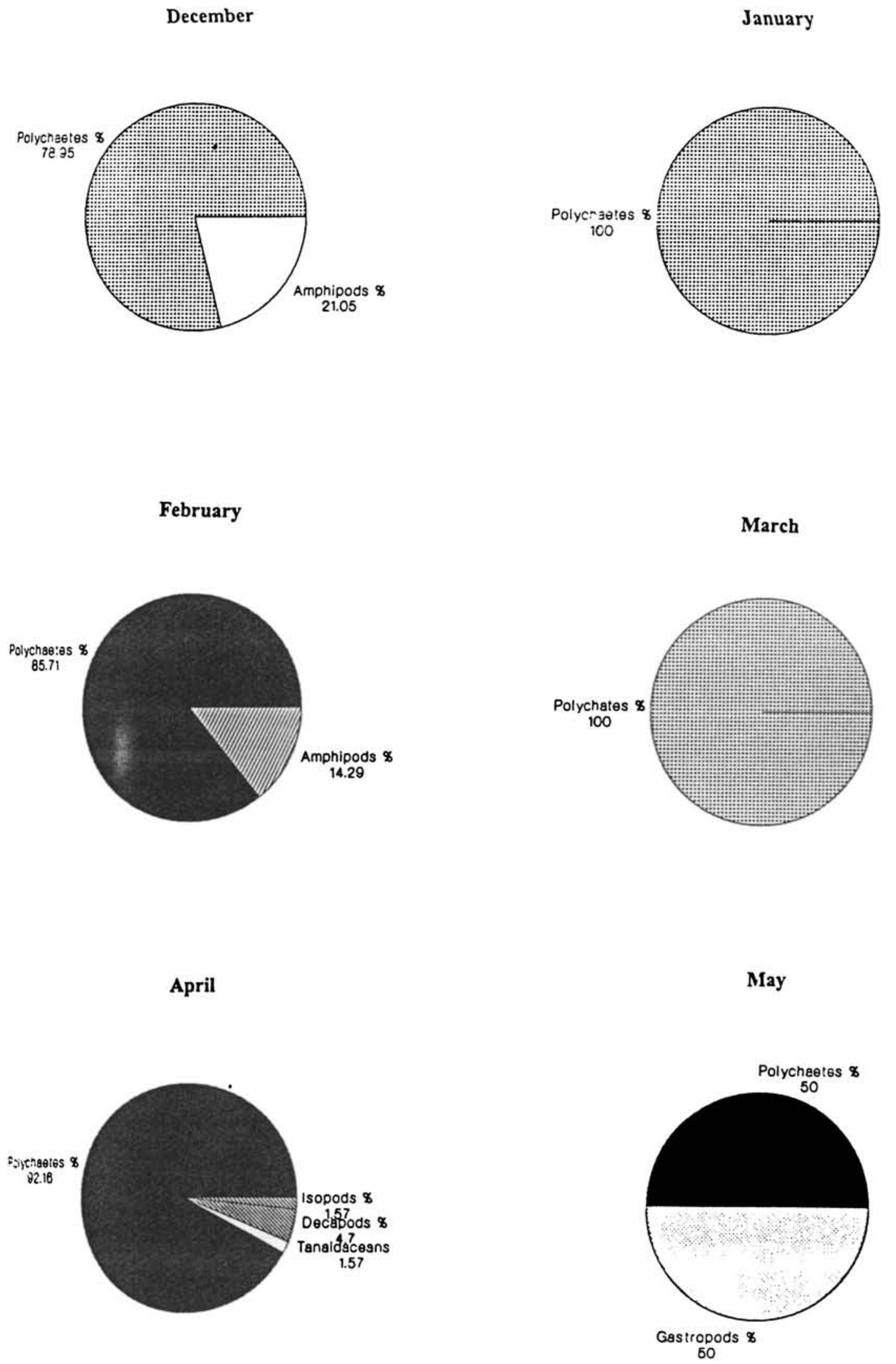


Fig. 3. 36. Percentage distribution of major groups of benthos at Station 8

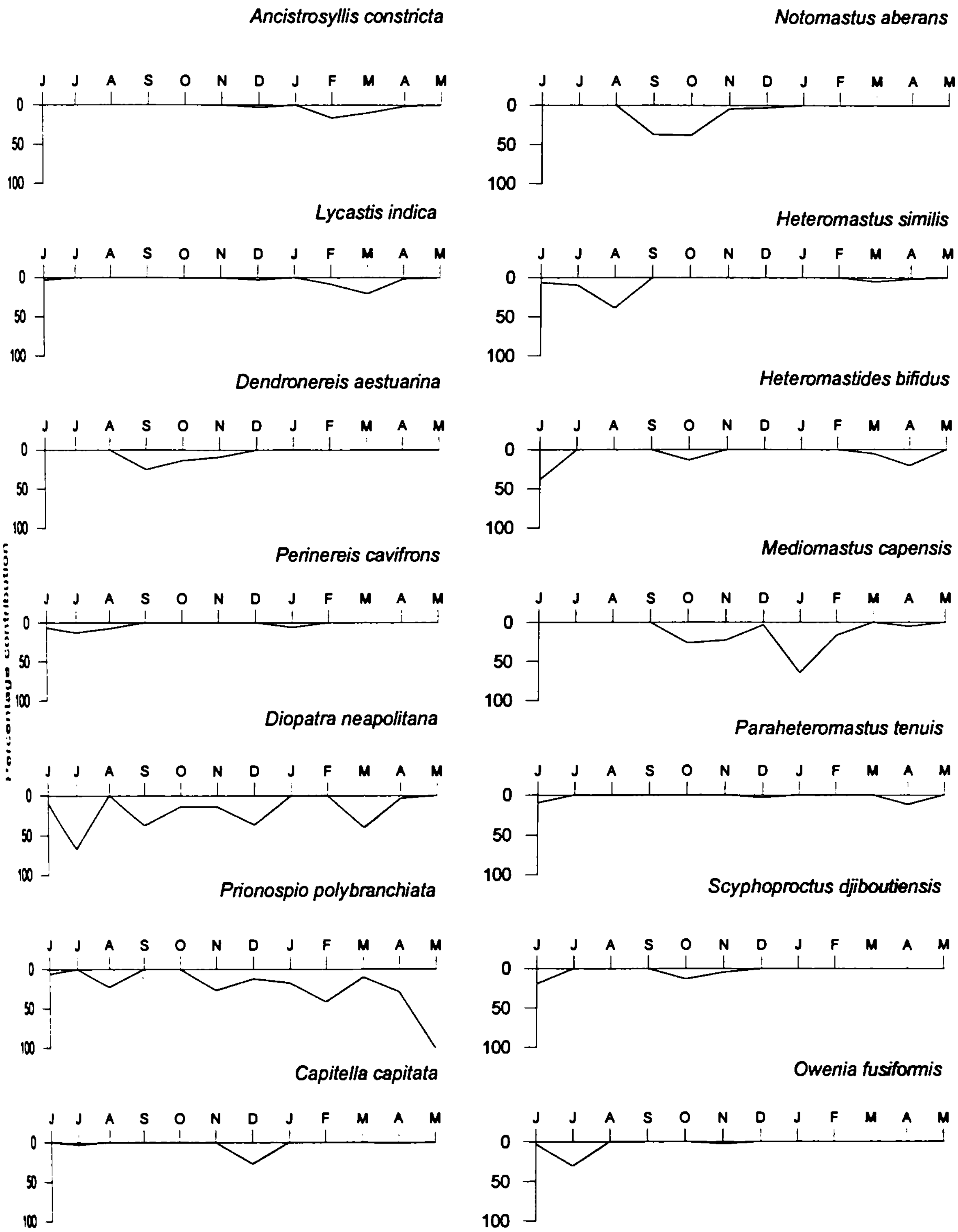


Fig. 3.37. **Percentage contribution of common polychaete species at Station 8**

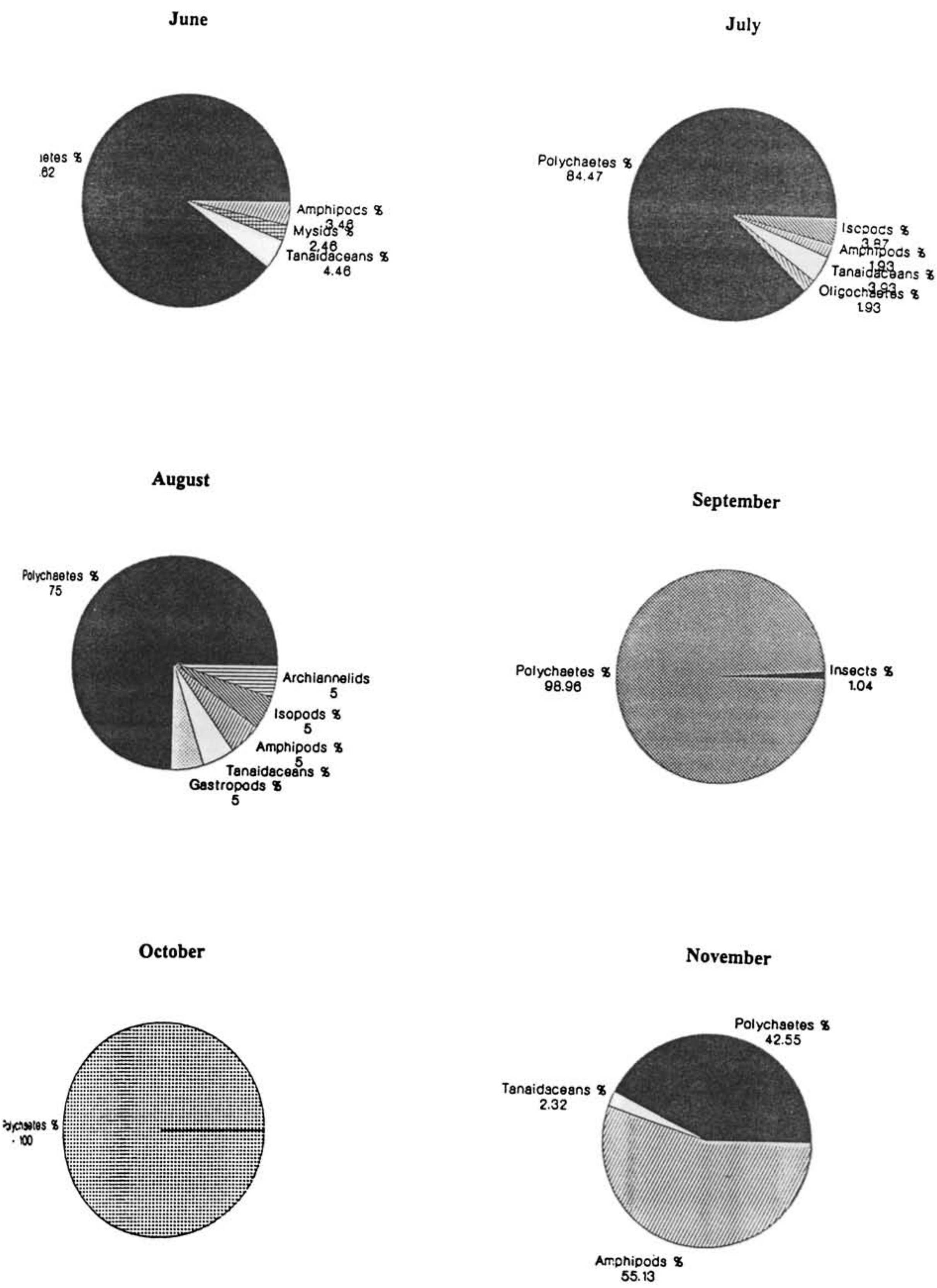


Fig.3. 38. Percentage distribution of major groups of benthos at Station 9

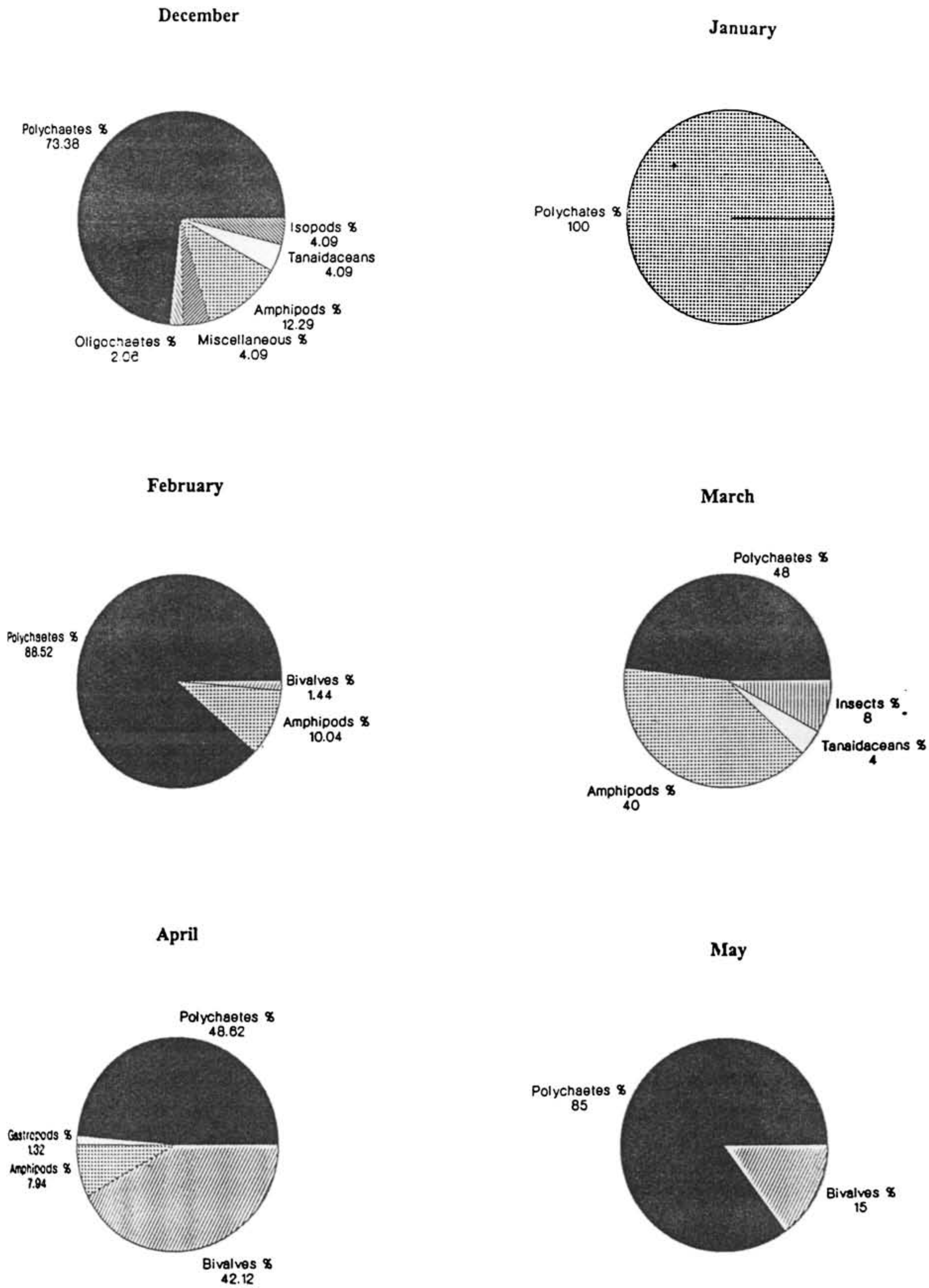


Fig. 3.39. Percentage distribution of major groups of benthos at Station 9

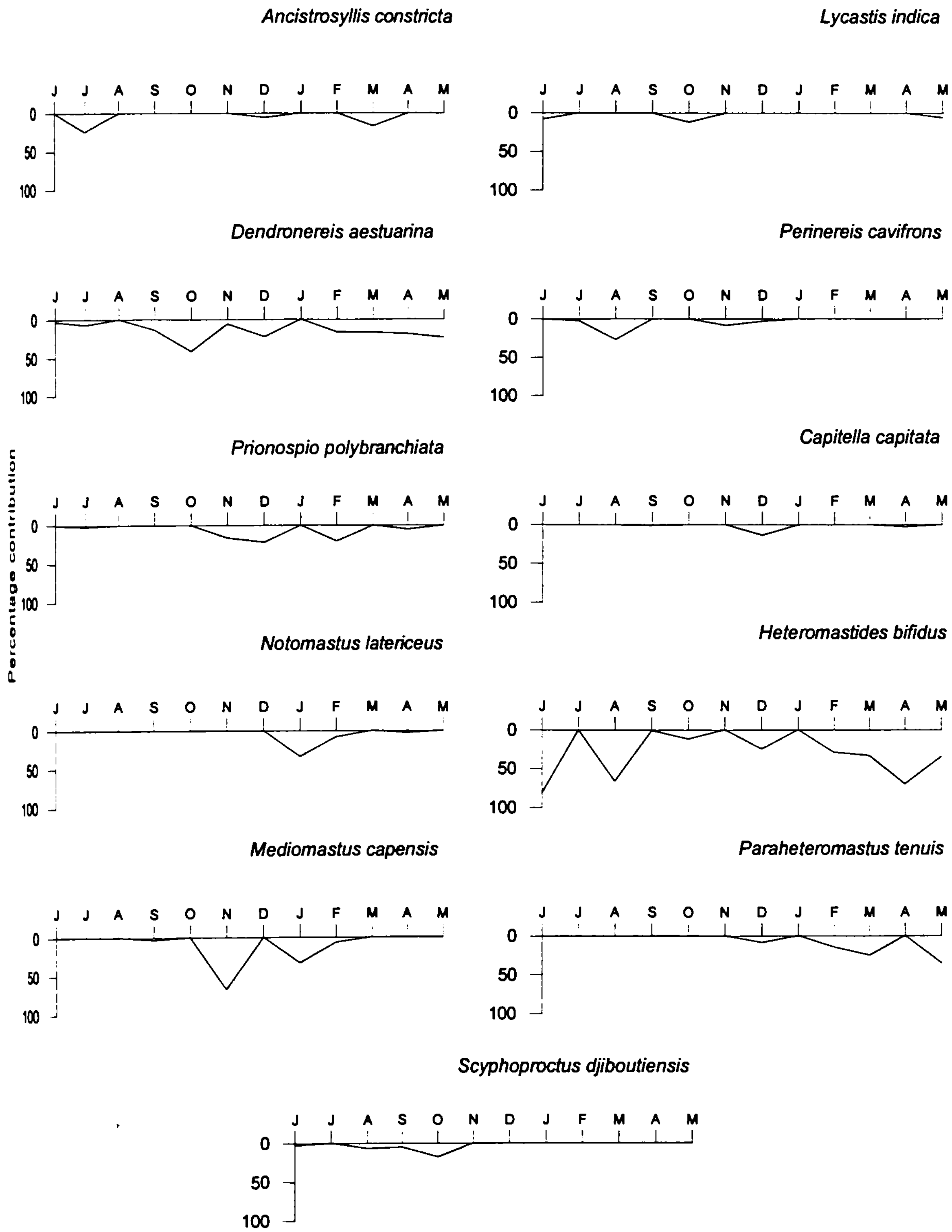


Fig. 3.40. **Percentage contribution of common polychaete species at station 9**

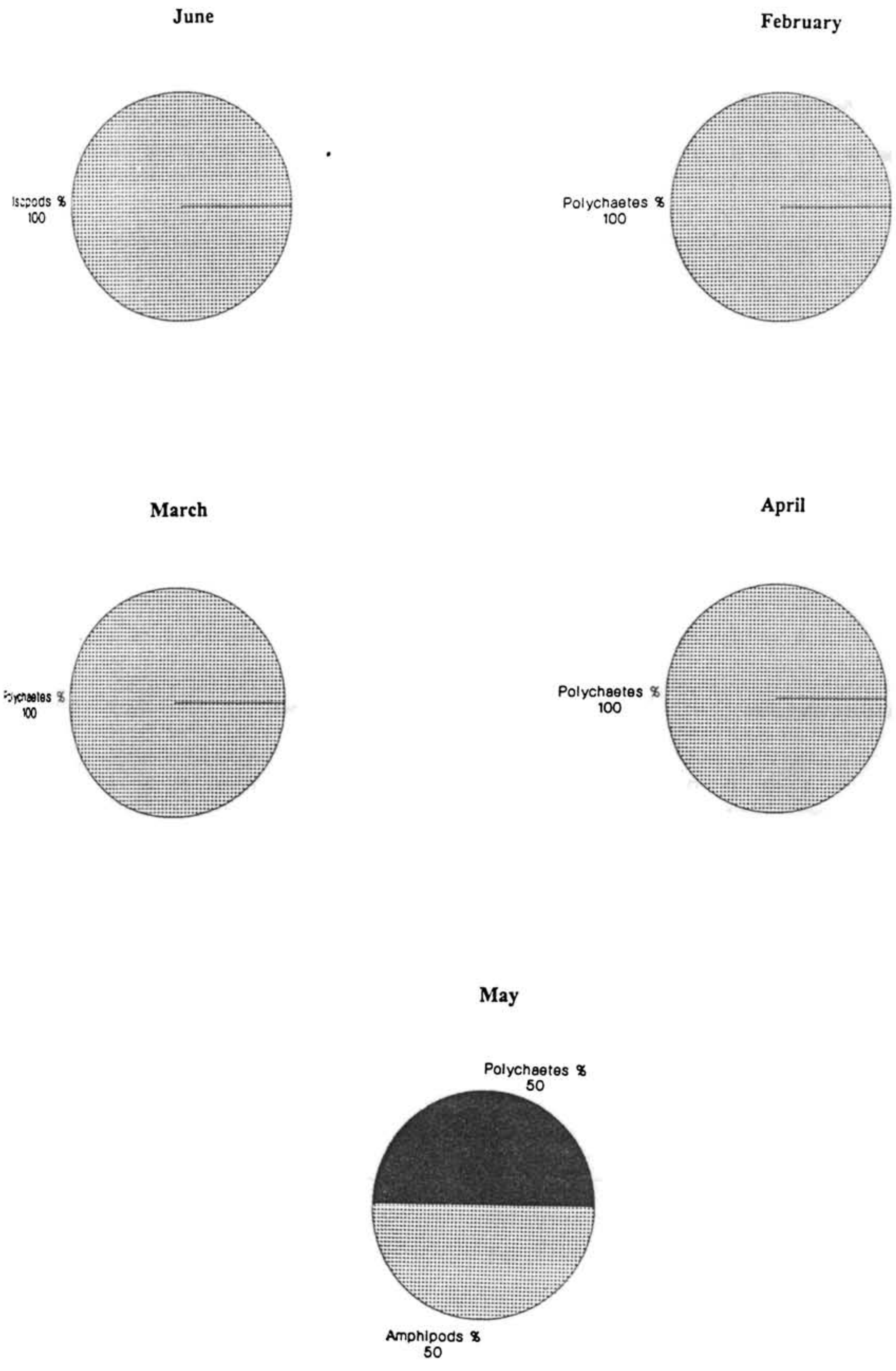


Fig.3.41. Percentage distribution of major groups of benthos at Station 10

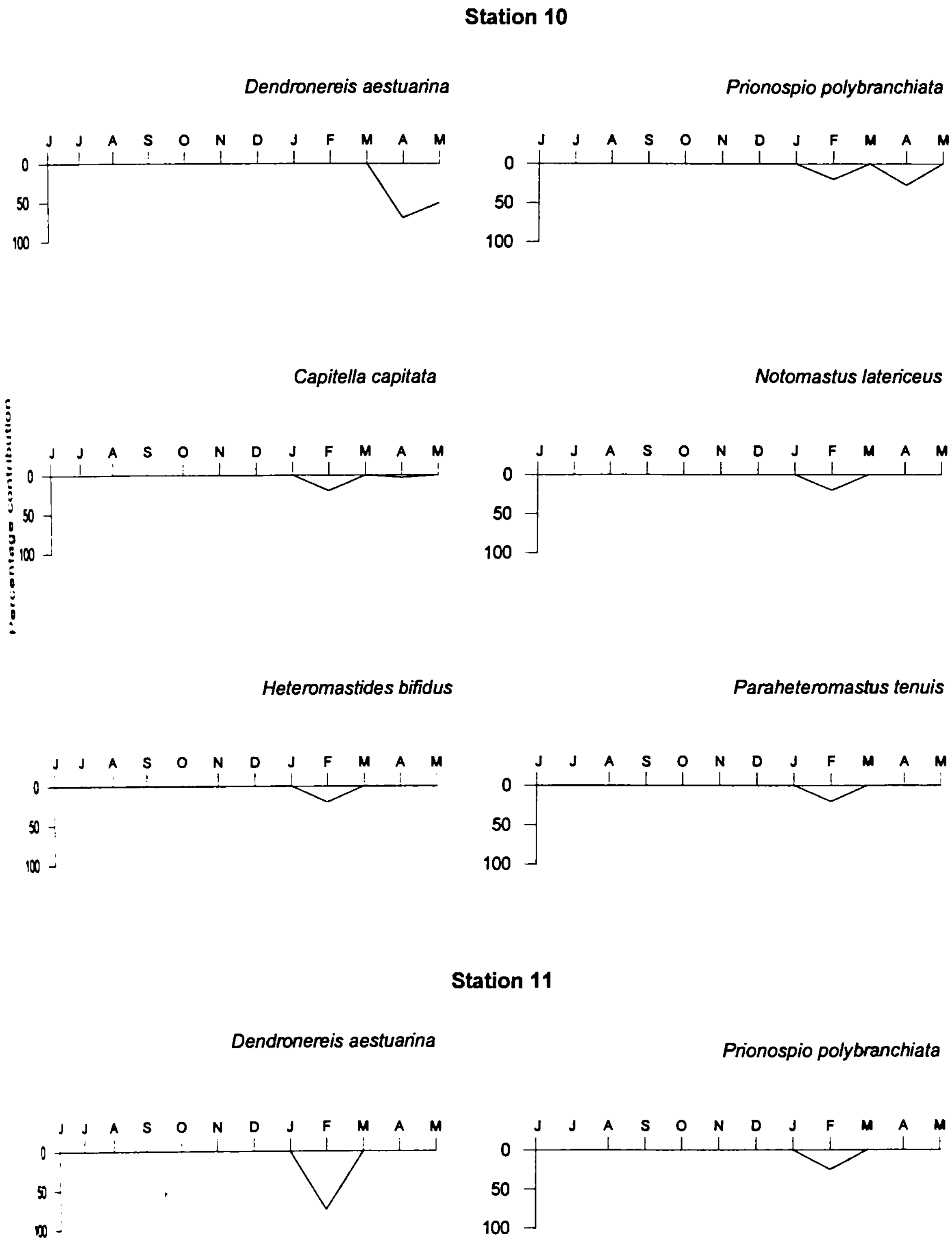


Fig. 3.42. Percentage contribution of polychaete species at stations 10 & 11

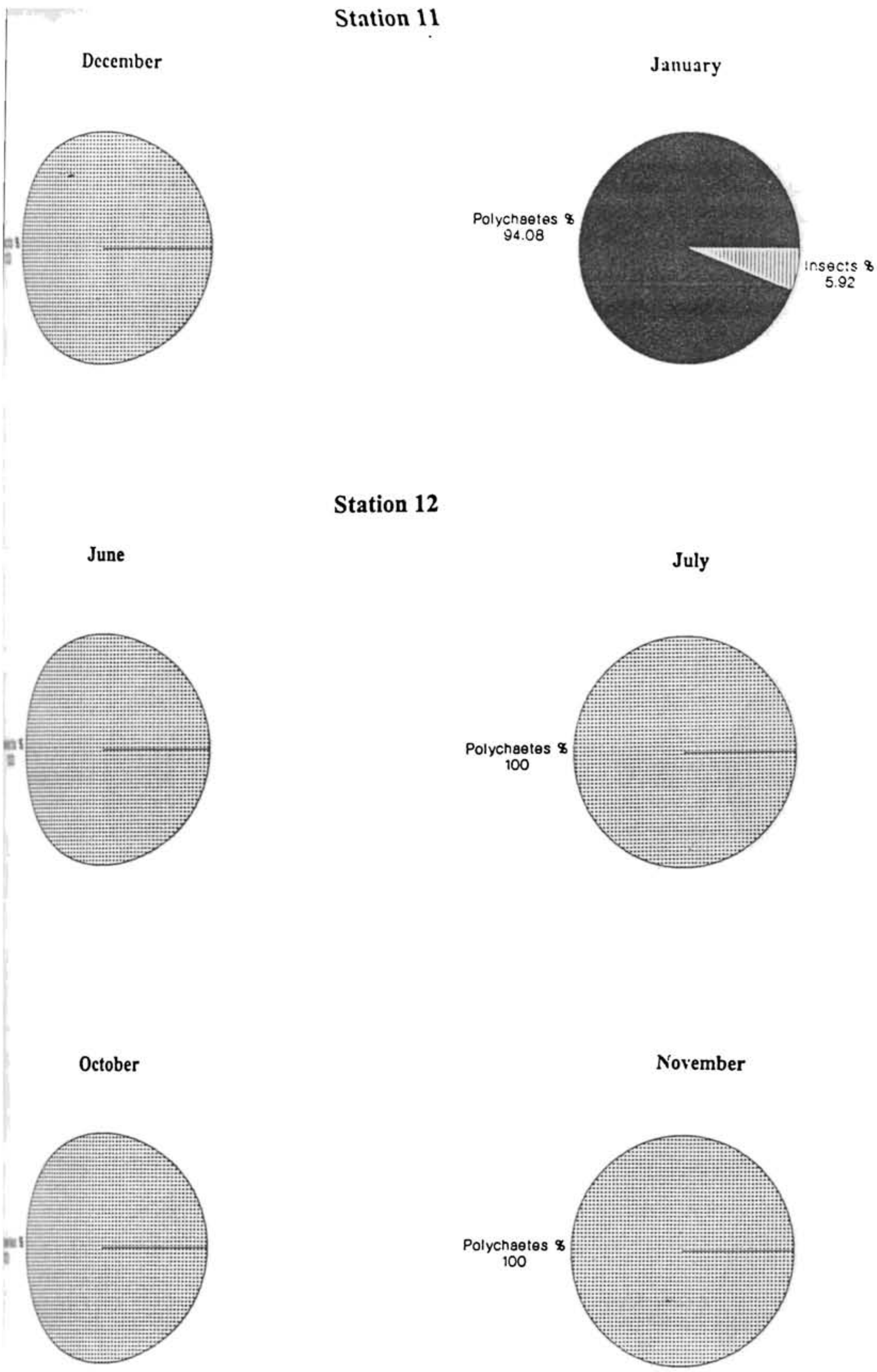


Fig.3.43. Percentage distribution of major groups of benthos at Station 11&12

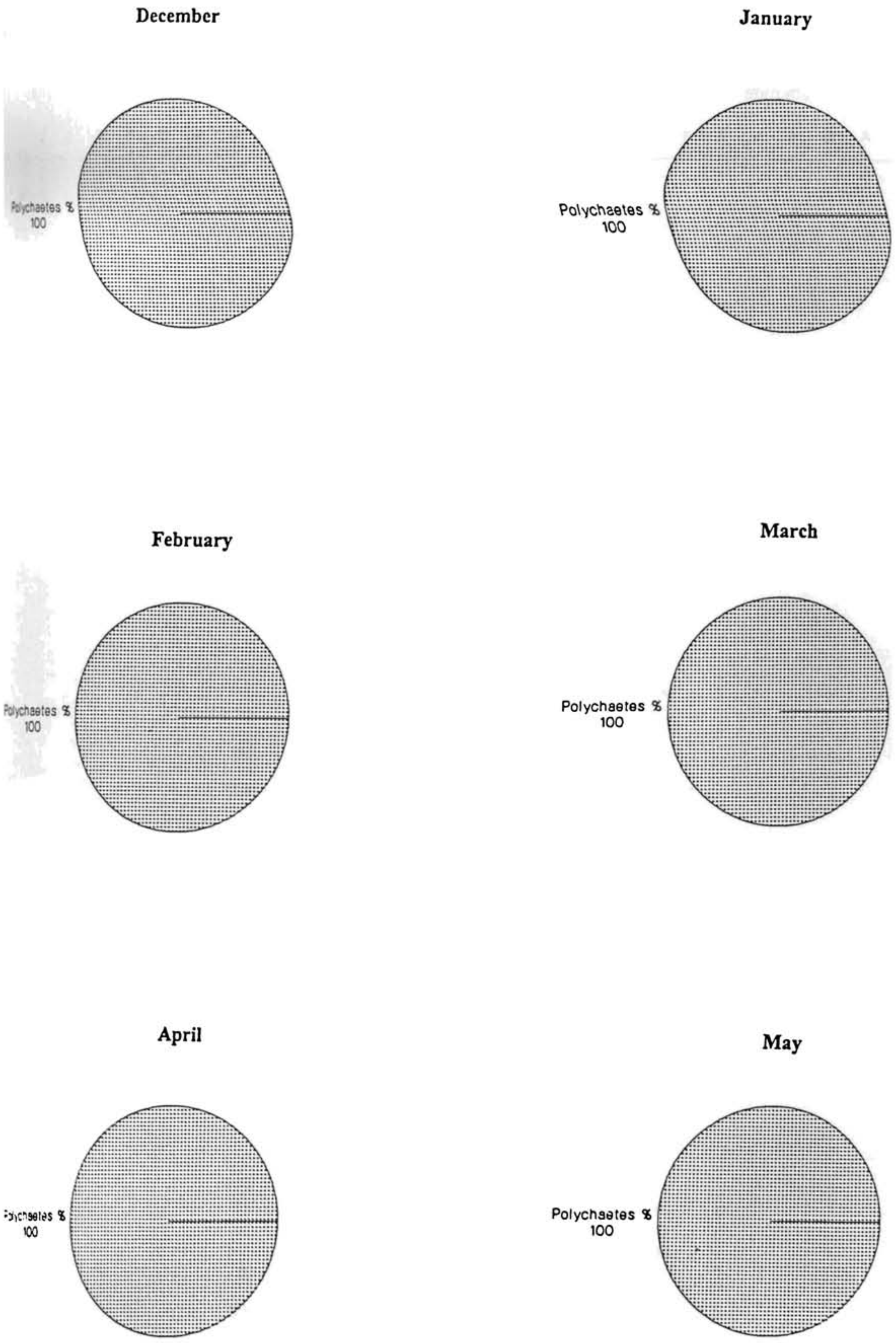


Fig. 3.44. Percentage distribution of major groups of benthos at Station 12

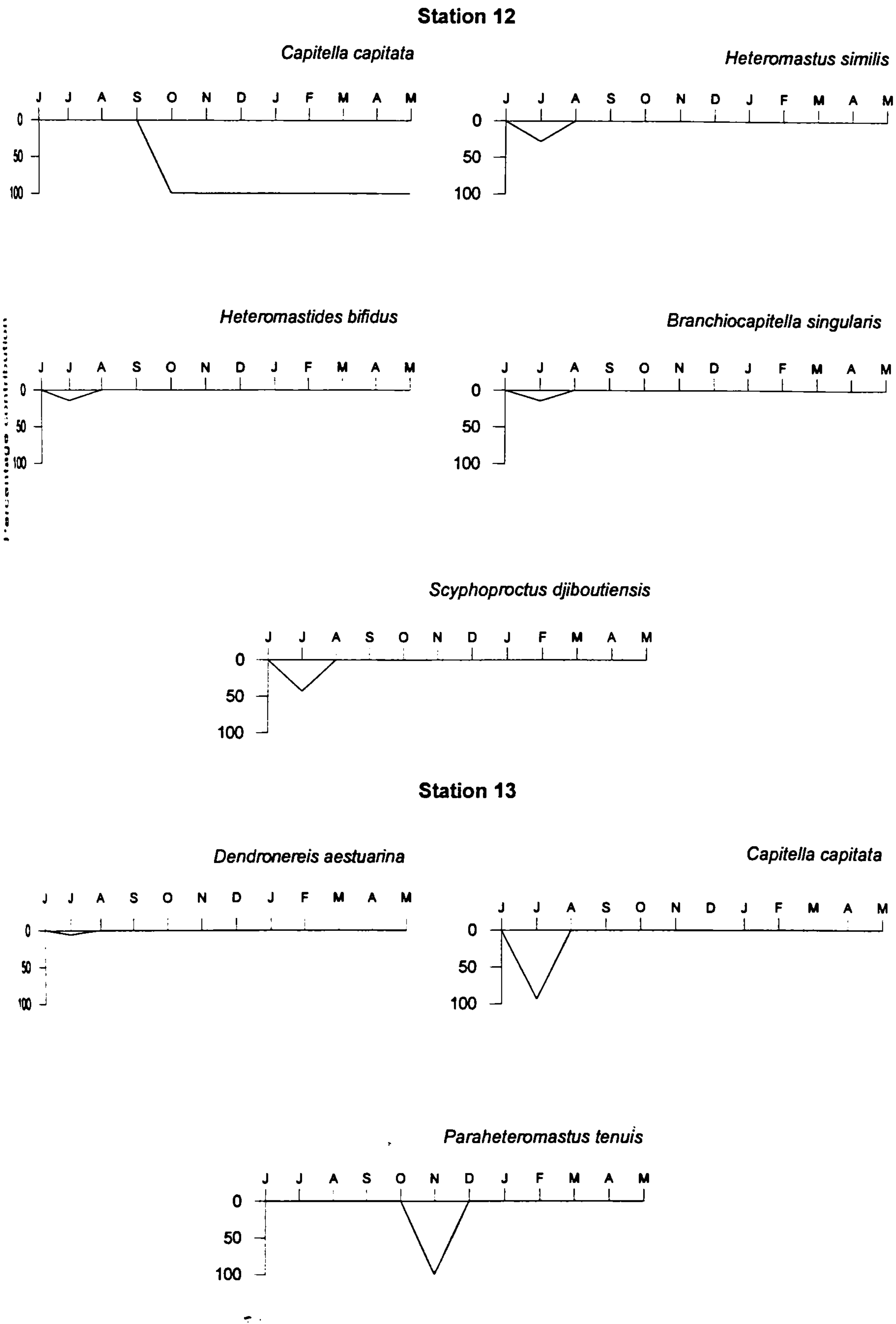


Fig. 3.45. **Percentage contribution of polychaete species at Stations 12 & 13**

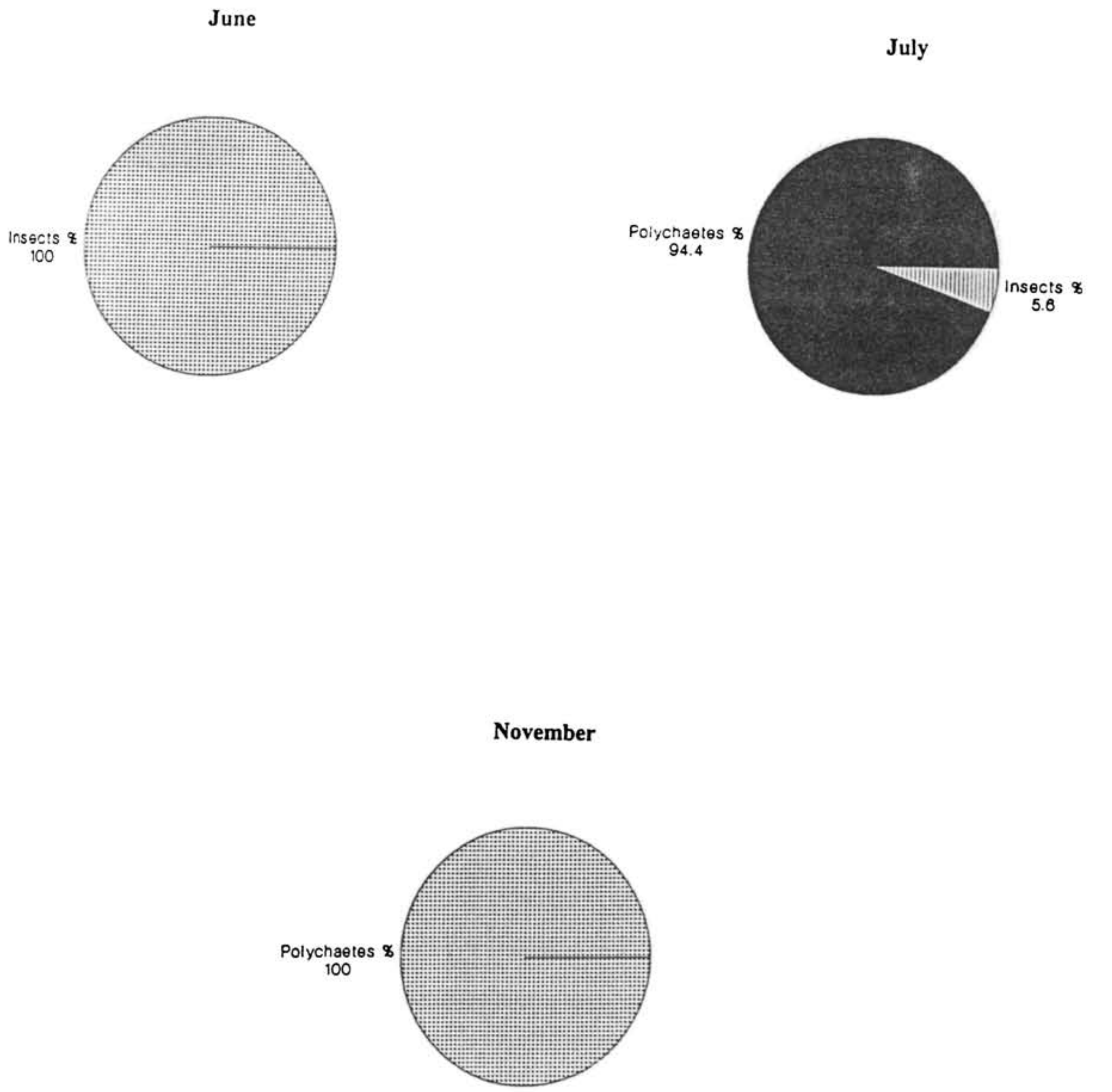


Fig.3.46. Percentage distribution of major groups of benthos at Station 13

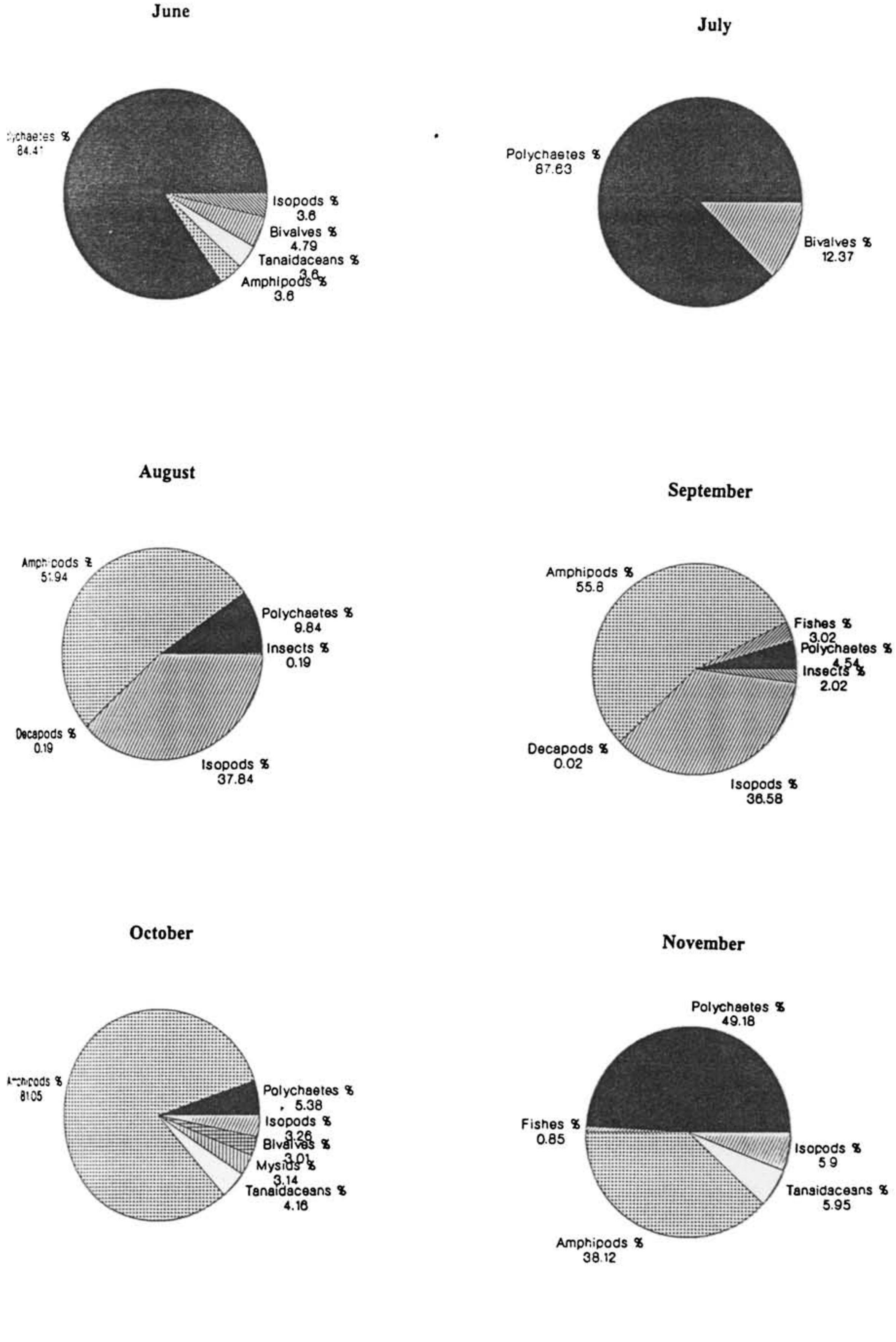


Fig. 3.47. Percentage distribution of major groups of benthos at Station 14

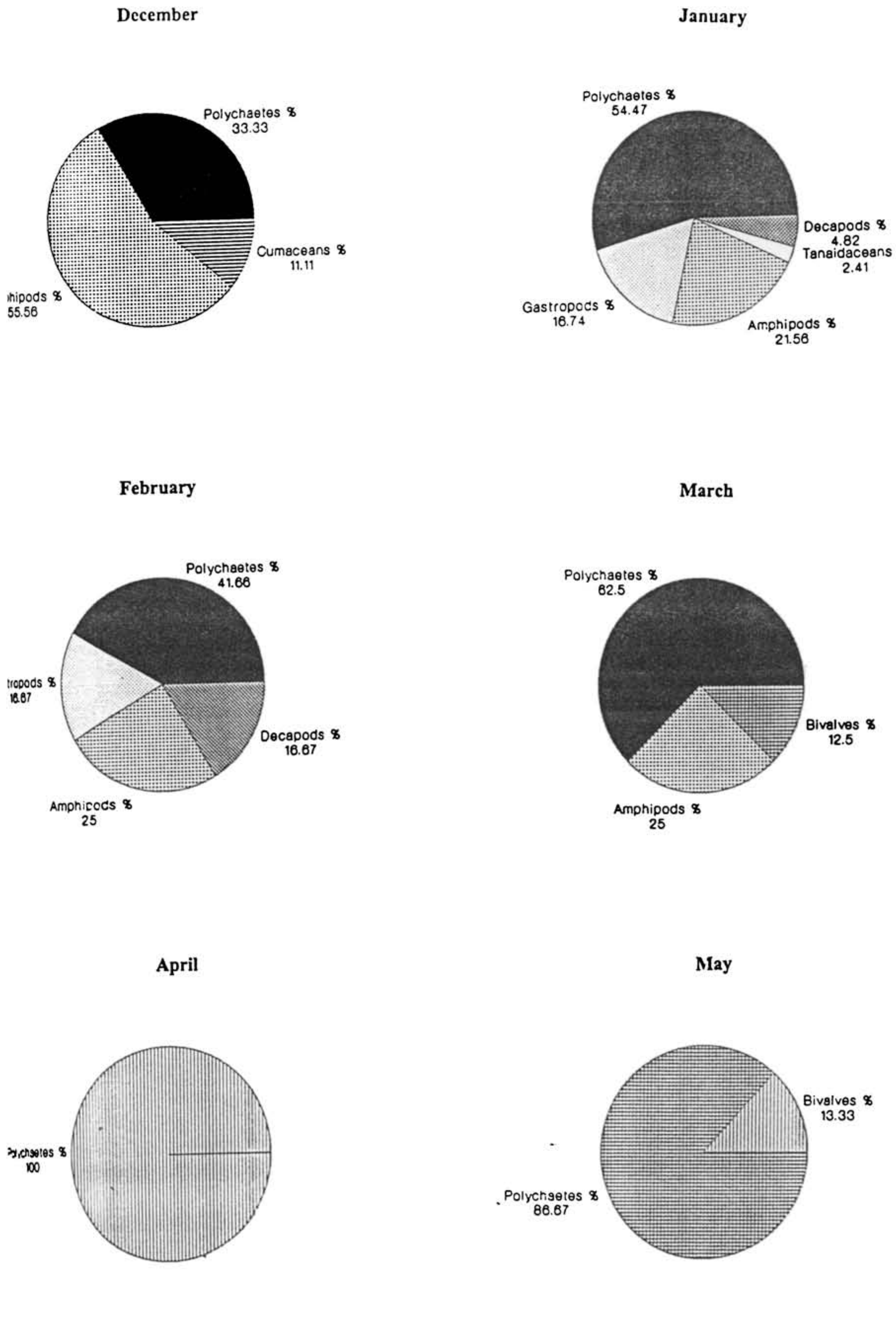


Fig.3.48. Percentage distribution of major groups of benthos at Station 14

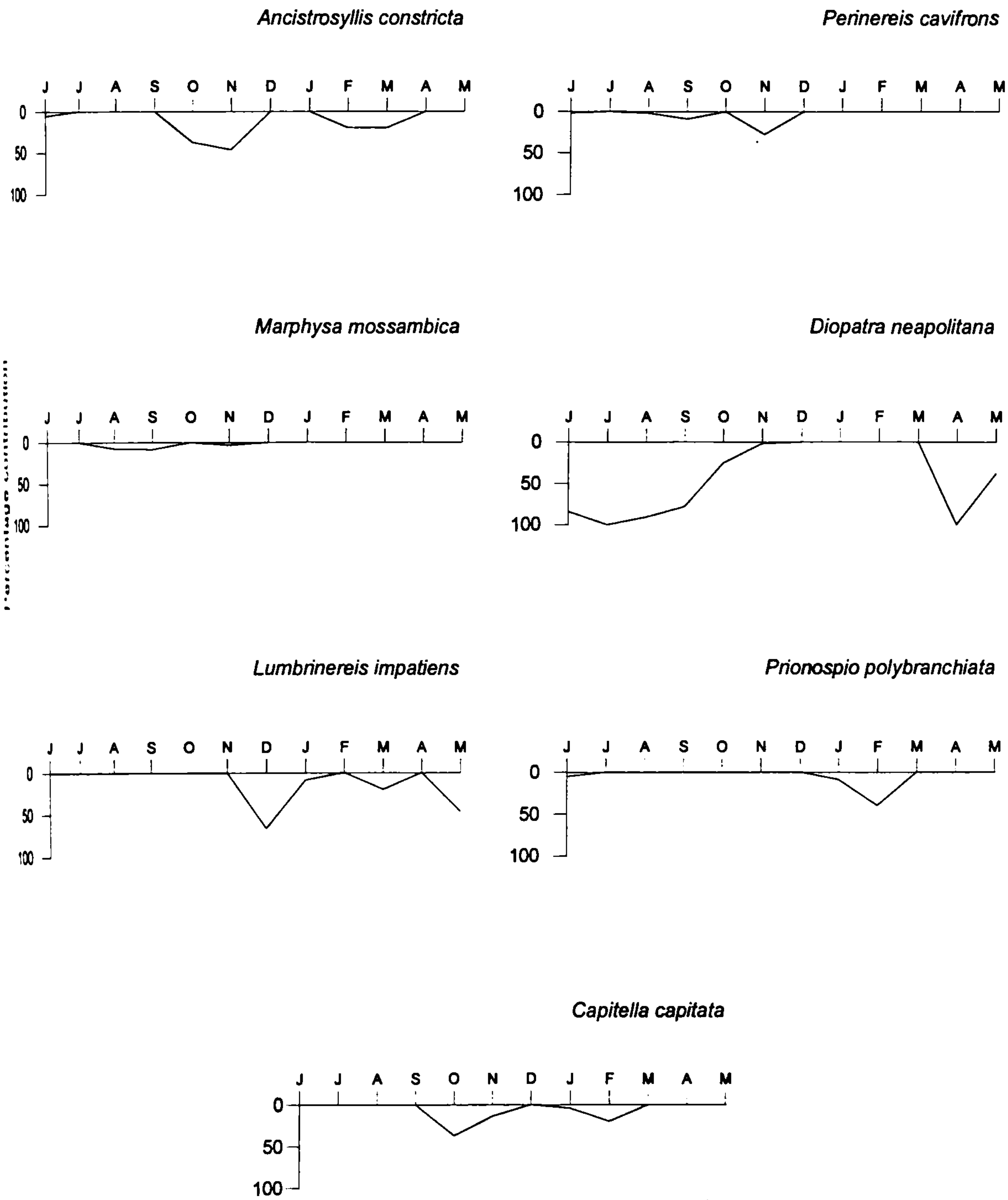


Fig. 3.49. Percentage contribution of common polychaete species at Station 14

Stn. 1

	J	J	A	S	O	N	D	J	F	M	A	M
J	–	●	●	●	●	●	●	●	●	●	●	●
J	100	–	●	●	●	●	●	●	●	●	●	●
A	100	100	–	●	●	●	●	●	●	●	●	●
S	100	100	100	–	●	●	●	●	●	●	●	●
O	100	100	100	100	–	●	●	●	●	●	⊕	●
N	100	100	100	100	100	–	●	●	●	●	●	●
D	100	100	100	100	100	100	–	●	●	●	●	●
J	100	100	100	100	100	100	100	–	●	●	●	●
F	100	100	100	100	100	100	100	100	–	●	●	●
M	100	100	100	100	100	100	100	100	100	–	●	●
A	100	100	100	100	33	100	100	100	100	100	–	●
M	100	100	100	100	100	100	100	100	100	100	100	–

Stn. 2

	J	J	A	S	O	N	D	J	F	M	A	M
J	–	●	●	●	●	●	●	●	●	●	●	●
J	100	–	●	●	●	●	●	●	●	●	●	●
A	100	100	–	●	●	●	●	●	●	●	●	●
S	100	100	100	–	●	●	●	●	●	●	●	●
O	100	100	100	100	–	●	●	●	●	●	●	●
N	100	100	100	100	100	–	●	●	●	●	●	●
D	100	100	100	100	100	100	–	●	●	●	●	●
J	100	100	100	100	100	100	100	–	●	●	●	●
F	100	100	100	100	100	100	100	100	–	●	●	●
M	100	100	100	100	100	100	100	100	100	–	●	●
A	100	100	100	100	100	100	100	100	100	100	–	●
M	100	100	100	100	100	100	100	100	100	100	100	–

30 - 40 ⊕ , 90 - 100 ●

Fig.3.50. Bray Curtis similarity coefficient (%) between months at stations 1 and 2.

Stn. 3

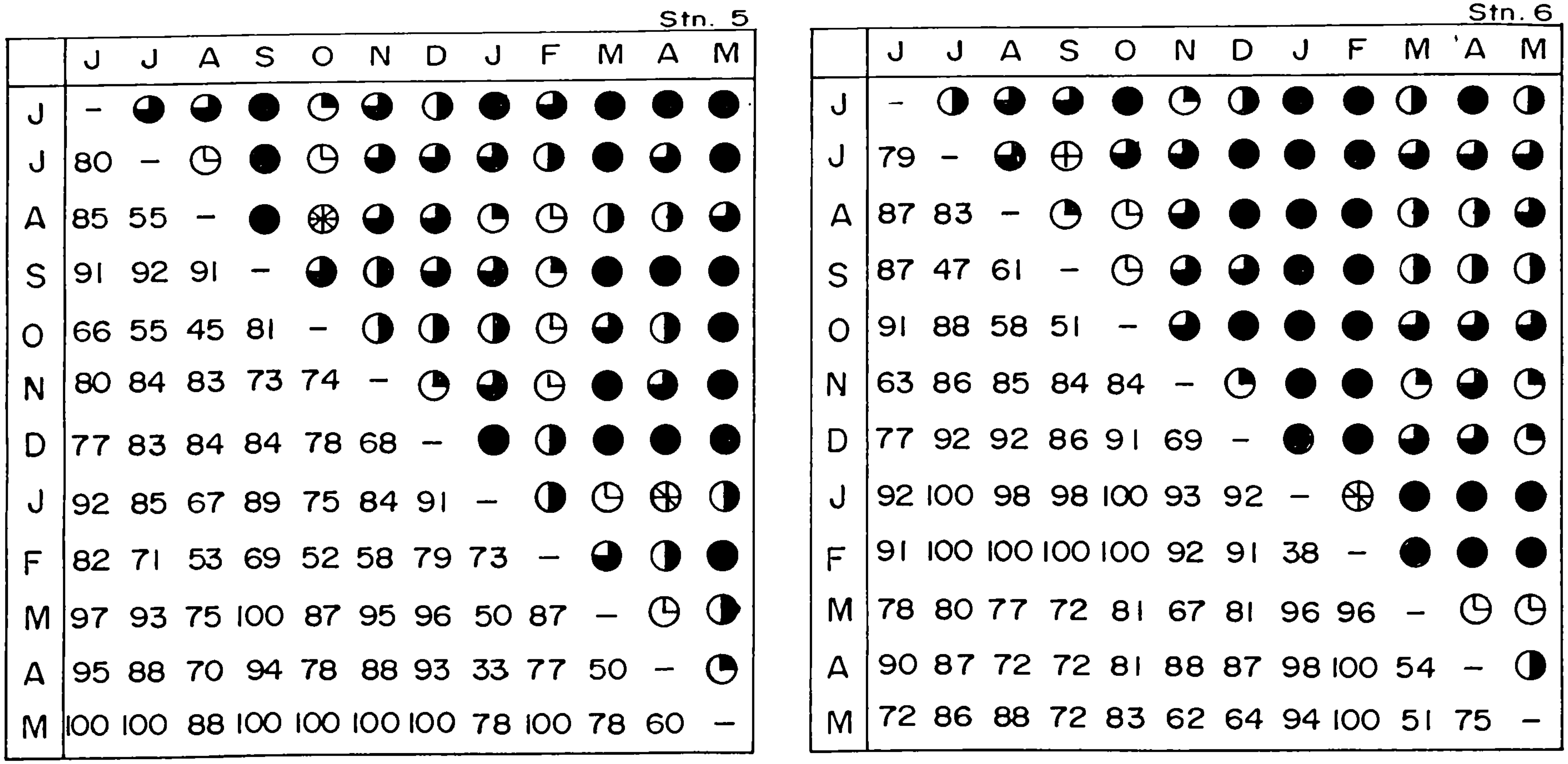
	J	J	A	S	O	N	D	J	F	M	A	M
J	-											
J	97											
A	83	78	–									
S	92	50	47	–								
O	98	13	82	58	–							
N	84	75	11	41	79	–						
D	98	22	84	64	9	83	–					
J	85	72	20	35	77	11	80	–				
F	100	77	97	91	71	96	66	96	–			
M	76	82	20	55	85	25	88	26	97	–		
A	41	94	65	83	95	67	96	68	99	51	–	
M	62	89	44	71	91	48	93	50	98	27	28	–

Stn. 4

	J	J	A	S	O	N	D	J	F	M	A	M
J	-											
J	66	–										
A	92	80	–									
S	69	93	93	–								
O	47	98	93	39	–							
N	98	89	84	89	94	–						
D	67	87	64	53	51	82	–					
J	62	70	83	88	81	78	73	–				
F	37	64	80	78	65	85	65	51	–			
M	52	95	87	86	77	95	80	55	51	–		
A	40	44	91	80	70	95	76	47	46	46	–	
M	46	92	93	74	52	98	72	66	60	50	47	–

0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100

Fig.3.51. Bray Curtis similarity coefficient (%) between months at stations 3 and 4.



30-40 ⊕, 40-50 ⊛, 50-60 ◷, 60-70 ◔, 70-80 ◑, 80-90 ◕, 90-100 ●

Fig.3.52. Bray Curtis similarity coefficient (%) between months at stations 5 and 6.

Stn. 7

	J	J	A	S	O	N	D	J	F	M	A	M
J	–	●	◕	⊕	●	◕	●	◔	◑	●	◕	●
J	95	–	●	◕	●	●	●	●	●	●	●	●
A	85	94	–	◕	●	◕	●	●	●	●	●	●
S	25	87	87	–	●	◕	◕	◷	◔	◕	◕	●
O	98	100	97	95	–	●	●	●	●	◕	●	●
N	87	97	85	86	96	–	◑	●	◕	◕	●	●
D	95	93	90	87	91	70	–	●	◑	◔	●	●
J	63	95	94	57	97	90	94	–	◑	◑	●	◕
F	73	93	92	68	92	85	77	79	–	◔	◔	◑
M	91	95	96	85	81	83	67	79	60	–	◑	◔
A	87	98	98	83	96	91	90	90	68	76	–	⊛
M	94	96	100	93	100	94	95	85	71	69	45	–

Stn. 8

	J	J	A	S	O	N	D	J	F	M	A	M
J	–	◕	◑	●	◕	◕	◑	●	◕	◑	◔	●
J	81	–	◑	●	●	●	◔	●	●	◕	●	●
A	77	75	–	●	●	◑	◕	◕	◕	●	●	●
S	91	95	100	–	◷	◑	◕	●	●	◑	●	●
O	83	97	100	50	–	◔	◕	◑	◕	◕	◕	●
N	87	90	79	73	62	–	◑	◑	◑	◕	◑	●
D	75	69	88	84	86	74	–	◕	◑	◔	◑	●
J	92	98	86	100	76	70	86	–	◔	◕	◕	◕
F	86	97	82	100	87	72	71	68	–	◑	◑	◕
M	79	85	90	79	83	82	61	89	71	–	◕	●
A	65	95	91	94	82	72	79	85	77	81		●
M	97	98	91	100	100	95	95	89	88	91	97	–

20-30 ⊕ , 40-50 ⊛ , 50-60 ◷ , 60-70 ◔ , 70-80 ◑ , 80-90 ◕ , 90-100 ●

Fig.3.53. Bray Curtis similarity coefficient (%) between months at stations 7 and 8.

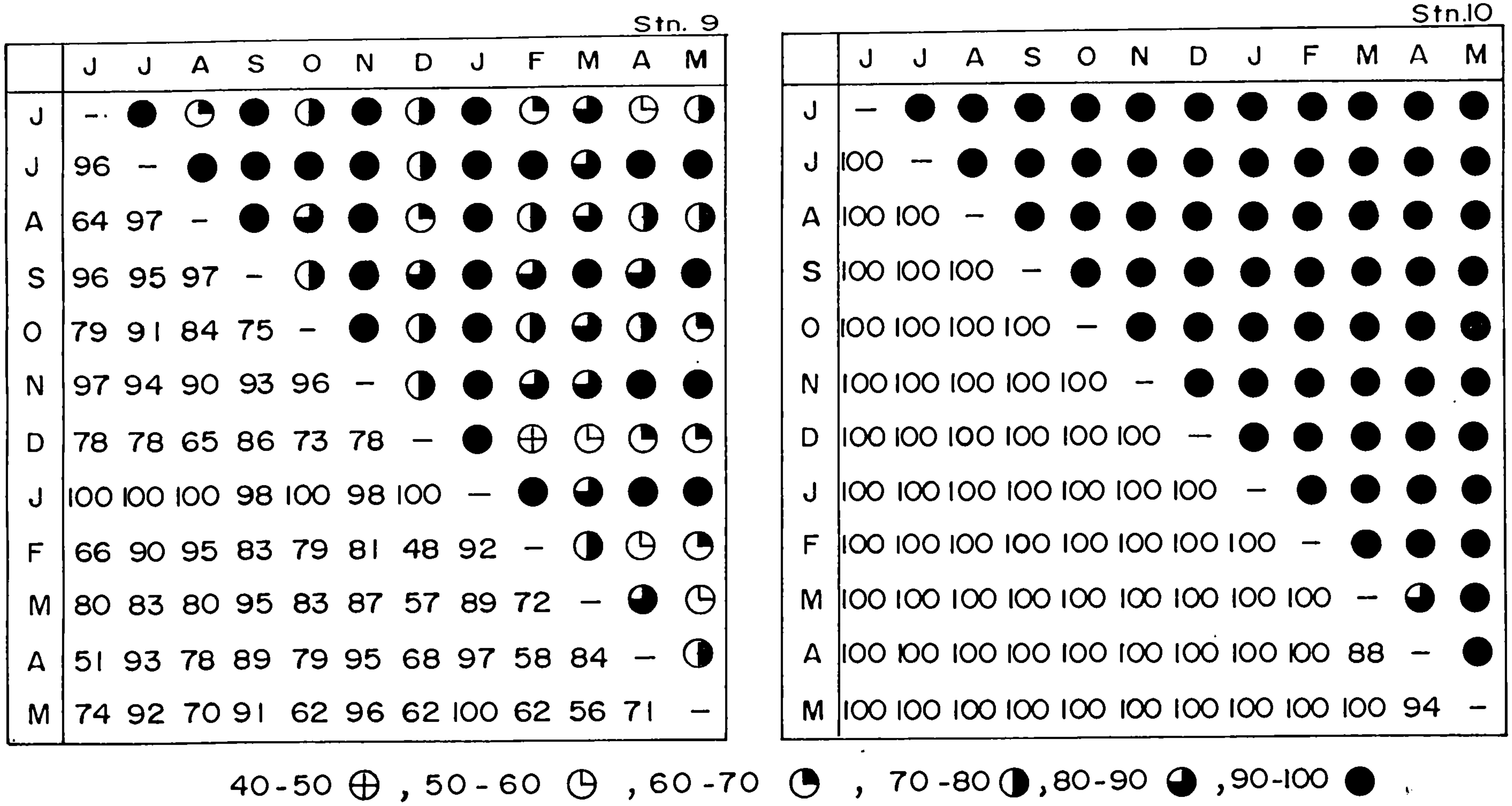
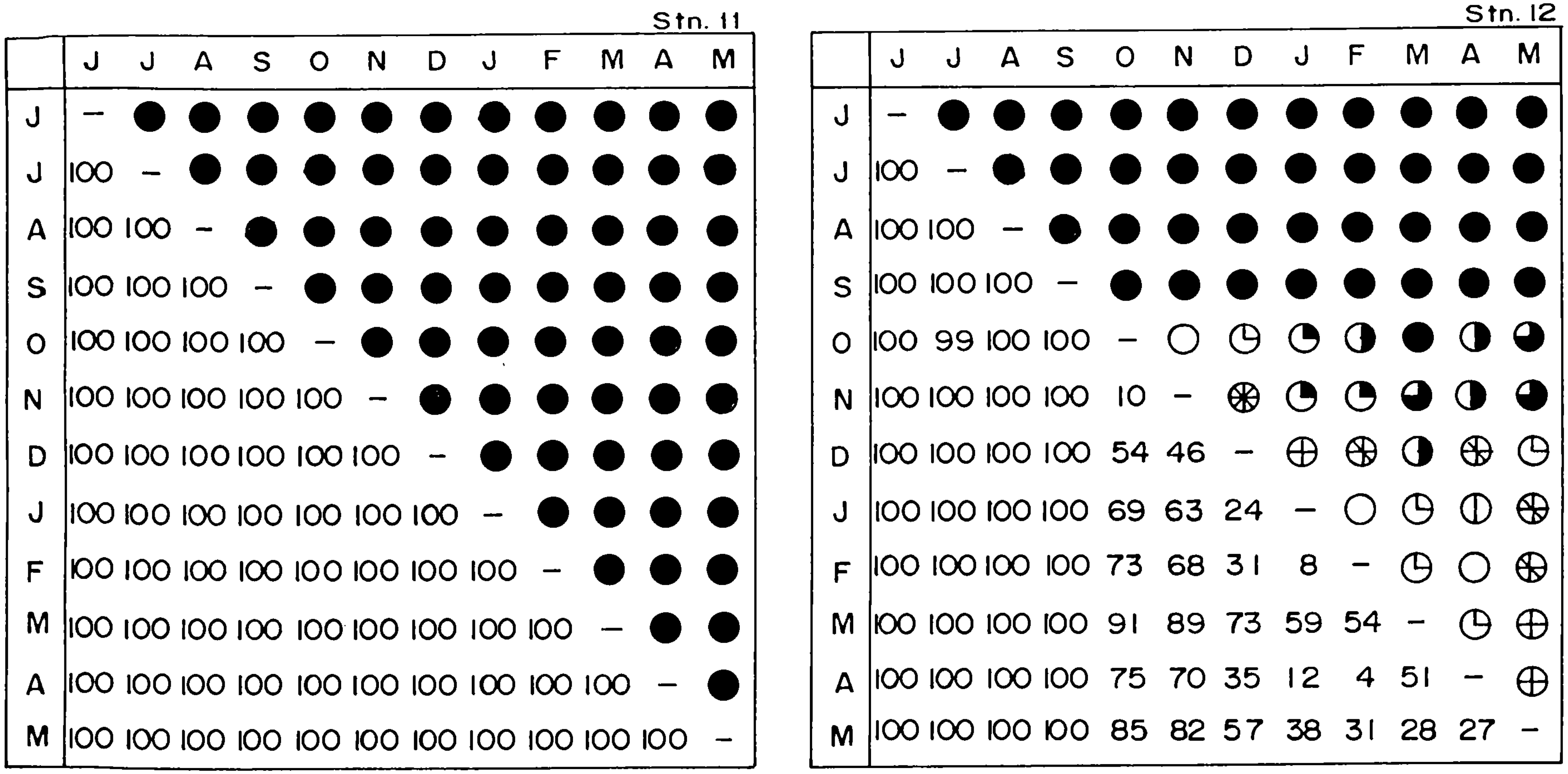


Fig.3.54. Bray Curtis similarity coefficient (%) between months at stations 9 and 10.



0-10 , 10-20 , 20-30 , 30-40 , 40-50 , 50-60 , 60-70 , 70-80 , 80-90 , 90-100

Fig. 3.55. Bray Curtis similarity coefficient (%) between months at stations 11 and 12.

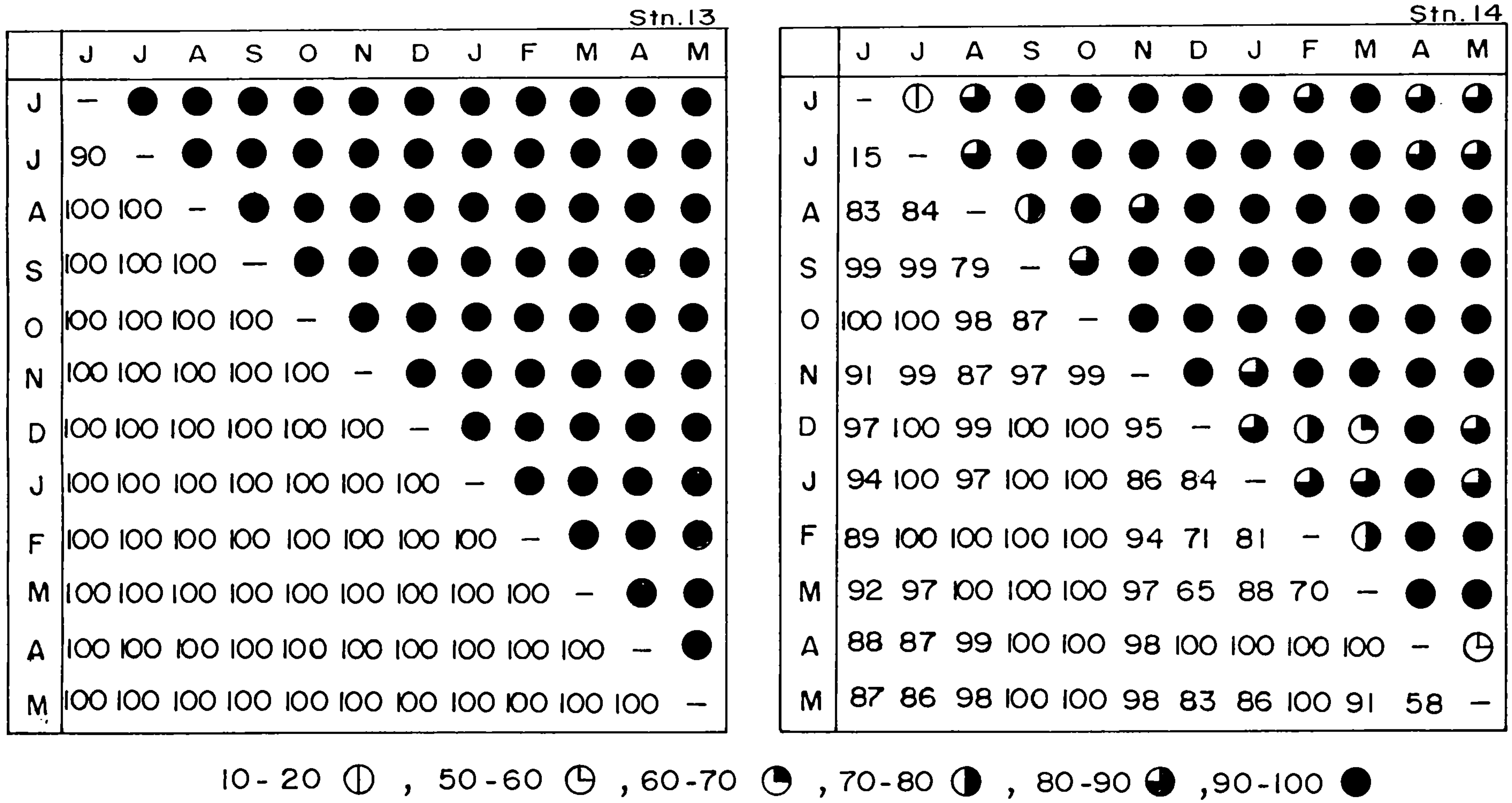


Fig. 3.56. Bray Curtis similarity coefficient (%) between months at stations 13 and 14.

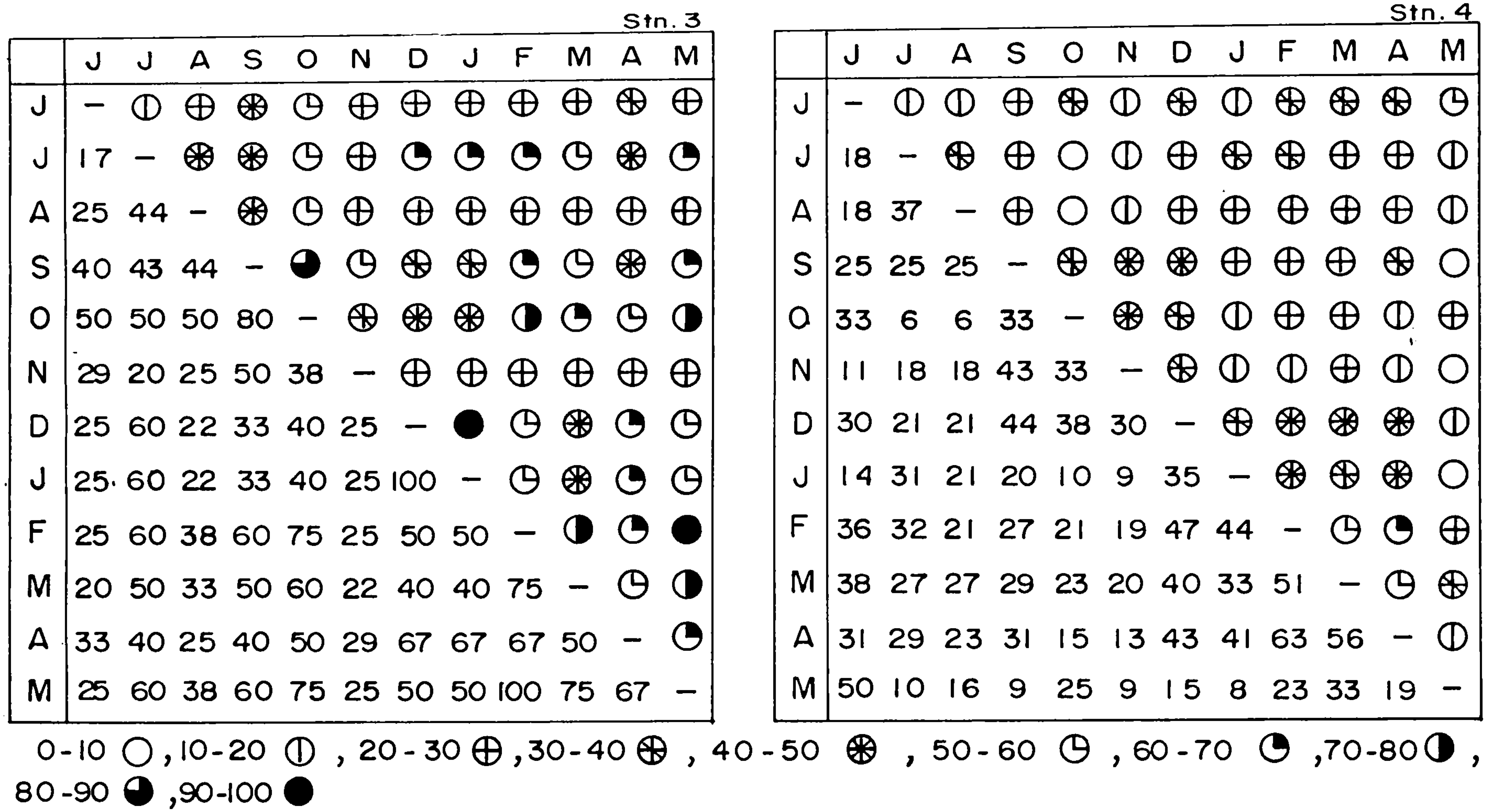


Fig.3.57. Community coefficient (%) between months at stations 3 and 4.

Stn. 5

	J	J	A	S	O	N	D	J	F	M	A	M
J	–	⊕	⦶	⊕	⊕	⊕	⊕	⊕	⊕	○	⦶	○
J	29	–	⊕	⦶	⊗	⊕	⊕	⊕	⦶	○	⦶	○
A	11	21	–	⦶	⊗	⦶	⊕	⊗	⊕	⊕	⊕	⊕
S	24	15	14	–	⊕	⊕	⊕	⊕	⊕	○	○	○
O	29	36	33	29	–	⊕	⊗	⊕	⊕	⦶	⊕	○
N	28	25	18	27	25	–	⊗	⊕	⊗	⦶	⊕	○
D	26	24	17	25	33	31	–	⊕	⊗	○	⊕	○
J	24	20	38	13	30	27	25	–	⊗	⊕	◔	⦶
F	22	19	20	29	27	37	33	30	–	⦶	⊕	○
M	6	7	29	0	10	10	8	25	10	–	⊛	⦶
A	13	5	33	8	25	22	20	50	25	40	–	⊗
M	0	0	20	0	0	0	0	17	0	25	33	–

Stn. 6

	J	J	A	S	O	N	D	J	F	M	A	M
J	–	⊛	⊕	⊕	⦶	⊗	⦶	○	○	⊕	⊕	⊕
J	27	–	⊕	⊕	⦶	⊕	⦶	○	○	⊕	⊕	⦶
A	29	29	–	⊗	⊕	⊗	⦶	○	○	⊕	⊕	⦶
S	26	26	32	–	⊗	⊕	⊕	○	○	⊗	⊗	⊛
O	15	15	22	39	–	⊕	○	○	○	⦶	⦶	⦶
N	32	25	30	29	24	–	⊕	○	○	⊛	⊕	⊗
D	16	16	17	20	10	25	–	○	○	⊕	⊕	⊕
J	7	0	5	6	0	6	7	–	⊗	○	○	○
F	8	0	0	0	0	6	8	33	–	○	○	○
M	28	21	27	39	14	44	21	6	7	–	⊗	⊛
A	26	26	26	37	19	23	26	6	0	32	–	⊗
M	27	19	14	40	18	38	27	8	0	43	31	–

0-10 ○ , 10-20 ⦶ , 20-30 ⊕ , 30-40 ⊗ , 40-50 ⊛ , 50-60 ◔

Fig. 3.58. Community coefficient (%) between months at stations 5 and 6.

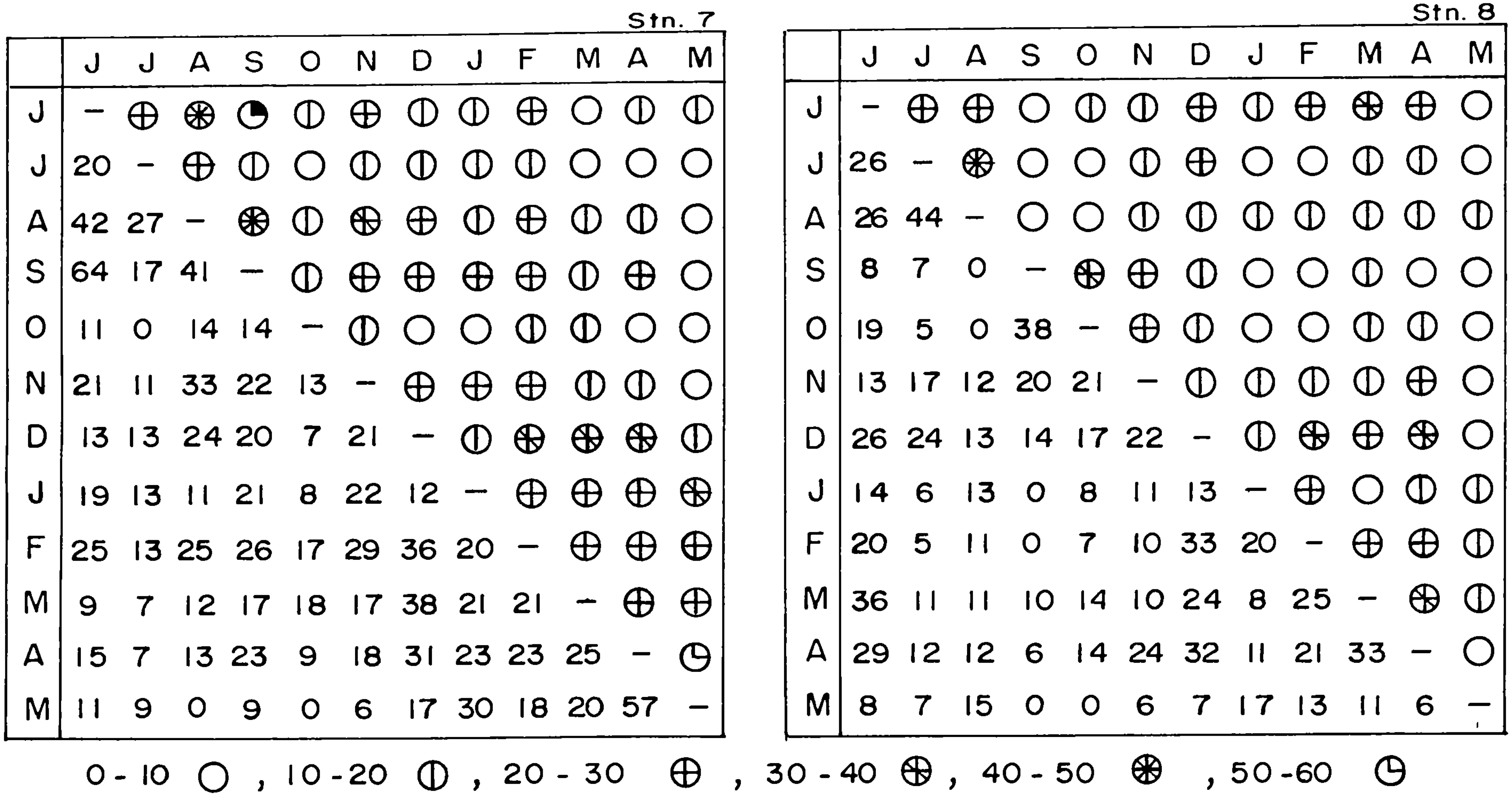


Fig.3.59. Community coefficient (%) between months at stations 7 and 8.

Stn. 9

	J	J	A	S	O	N	D	J	F	M	A	M
J	–	⦶	⦶	⦶	⊛	⦶	○	○	⦶	⊕	⊕	⊕
J	10	–	○	○	○	⦶	⊗	○	⦶	⊕	⦶	○
A	13	5	–	⦶	⦶	⊕	⊕	○	⦶	⦶	○	○
S	19	10	13	–	⊗	⊕	⦶	○	⦶	⦶	⊕	⦶
O	40	6	18	36	–	○	⦶	○	⦶	⦶	⦶	⊛
N	13	17	23	20	8	–	⊕	○	⊕	⦶	⦶	○
D	10	35	22	14	12	29	–	○	⊗	⊗	⊕	⦶
J	0	0	0	8	0	9	0	–	⦶	○	○	○
F	11	19	11	16	13	25	30	23	–	⊗	⊗	⊗
M	24	25	11	10	13	18	37	7	41	–	⦶	⊗
A	13	11	7	20	18	14	22	9	33	18	–	⊗
M	27	6	8	15	43	8	19	0	31	31	30	–

Stn.10

	J	J	A	S	O	N	D	J	F	M	A	M
J	–	⦶	⦶	⦶	⊛	⦶	⦶	○	○	○	○	○
J	10	–	○	⦶	○	⦶	⊗	○	⦶	⊕	⦶	○
A	13	5	–	⦶	⦶	⊕	⊕	○	⦶	⦶	○	○
S	19	10	13	–	⊗	⊕	⦶	○	⦶	⦶	⊕	⦶
O	40	6	18	36	–	○	⦶	○	⦶	⦶	⦶	⊛
N	13	17	23	20	8	–	⊕	○	⊕	⦶	⦶	○
D	10	35	22	14	12	29	–	○	⊗	⊗	⊕	⦶
J	0	0	0	8	0	9	0	–	⊕	○	○	○
F	0	19	11	16	13	25	30	23	–	○	⊗	○
M	0	25	11	10	13	18	37	7	0	–	○	○
A	0	11	7	20	18	14	22	9	33	0	–	⊕
M	0	6	8	15	43	8	19	0	0	0	25	–

0-10 ○ , 10-20 ⦶ , 20-30 ⊕ , 30-40 ⊗ , 40-50 ⊛

Fig.3.60. Community coefficient (%) between months at stations 9 and 10.

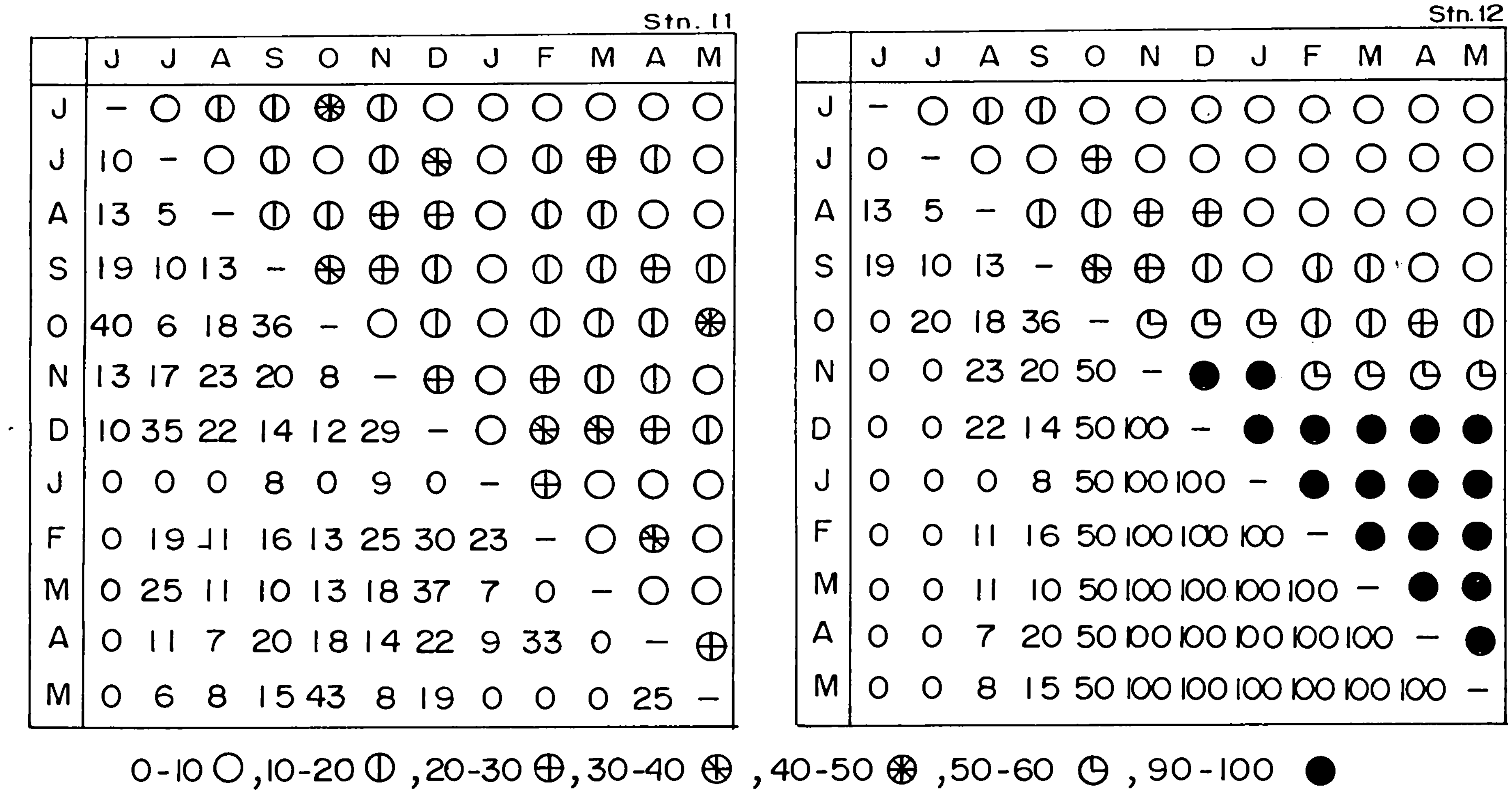


Fig.3.61. Community coefficient (%) between months at stations 11 and 12.

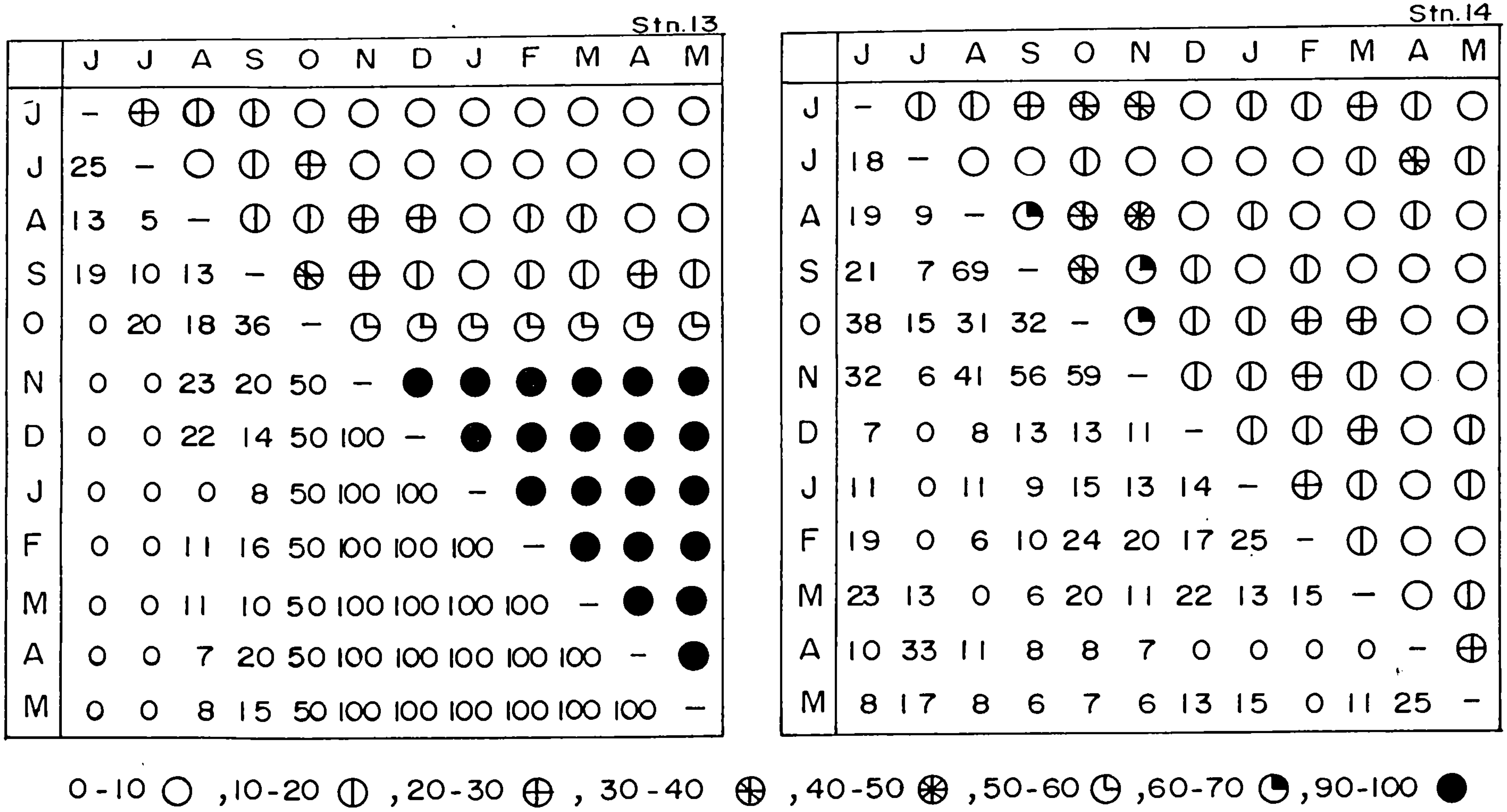


Fig.3.62. Community coefficient (%) between months at stations 13 and 14.

Table 3.1 **Attenuation Coefficient ('K' values) at stations 1 to 14**

ST. NO	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APL	MAY
1	2.0	1.5	1.0	1.2	5.0	3.0	1.5	3.0	1.5	1.5	3.0	1.0
2	3.0	1.5	1.5	2.0	5.0	3.0	1.5	3.0	3.0	2.0	3.0	2.0
3	1.5	3.0	1.67	1.2	3.0	1.0	1.2	3.0	1.5	2.0	2.5	3.0
4	1.5	3.0	3.0	3.0	3.0	1.2	1.5	1.88	1.5	3.0	1.0	1.0
5	1.5	3.0	3.0	2.0	5.0	3.0	7.5	5.0	3.0	1.5	2.0	3.0
6	6.0	6.0	1.5	2.0	1.88	2.0	1.5	1.0	1.76	1.5	1.5	3.0
7	1.5	15.0	3.0	2.0	1.88	1.88	1.2	1.5	2.0	2.0	2.0	3.0
8	1.5	3.0	1.5	2.0	5.0	1.5	1.0	3.0	2.0	1.5	2.0	1.2
9	5.0	3.0	1.5	1.5	3.0	1.5	2.0	1.5	1.5	1.5	2.0	1.2
10	3.0	5.0	1.0	1.5	2.0	1.5	1.5	1.5	2.0	3.0	1.0	1.0
11	3.0	5.0	1.2	1.2	3.0	0.60	1.5	1.0	1.0	0.60	1.0	0.75
12	1.5	5.0	1.5	0.75	3.75	1.2	1.2	1.0	1.0	1.5	1.5	0.75
13	1.2	5.0	1.0	0.86	5.0	0.75	1.0	1.0	1.2	1.5	1.0	0.86
14	0.86	10.0	1.2	2.0	1.5	1.5	3.0	3.0	1.5	1.5	1.2	1.0

Table 3.2 Variation in the energy content (J/g dry weight) at stations 1 to 14

STATIONS	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APL	MAY
1	848.02	873.72	475.63	2068.63	205.63	828.58	1380.67	2106.86	2248.56	1543.40	295.70	308.23
2	411.05	2286.79	462.46	1554.77	1246.32	1676.38	1053.43	1760.18	1272.02	894.46	244.30	783.86
3	449.93	25.70	411.05	1361.83	64.37	1676.38	333.94	1451.95	2261.09	34.99	38.66	205.63
4	488.16	976.32	539.57	231.34	424.22	314.71	1130.54	1451.95	205.63	1034.86	539.57	347.11
5	873.72	963.79	2209.68	411.05	603.94	828.58	1027.73	899.21	1349.14	860.98	822.31	1079.14
6	899.21	565.27	2209.68	1426.25	436.75	263.30	372.82	1104.84	822.31	12.96	488.16	411.05
7	655.34	1220.62	770.90	642.38	912.38	263.30	1143.50	1259.06	1015.20	822.31	783.86	873.72
8	748.44	128.52	1220.62	1040.90	796.61	957.10	308.23	1233.36	1259.06	69.98	141.48	77.11
9	1156.25	629.64	822.31	424.22	1169.21	959.69	38.66	100.01	1541.59	1069.85	1079.14	873.72
10	1451.95	12.96	12.96	12.96	12.96	1419.55	90.07	1233.36	1361.88	1588.25	1079.14	359.64
11	1416.31	38.66	12.96	12.96	77.11	57.67	218.59	1310.47	77.11	12.96	64.37	47.74
12	12.96	976.32	12.96	2068.63	1413.29	1522.37	1374.84	2106.86	12.96	1284.77	167.18	295.70
13	64.37	12.96	1053.43	12.96	102.82	250.56	64.37	1104.84	205.63	154.22	90.07	12.96
14	590.98	719.50	822.31	886.68	719.50	725.76	912.38	835.70	770.90	770.90	385.34	539.57

Table 3.3 Benthic density (No./m^2) at Stations 1 to 14

STATIONS	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APL	MAY	TOTAL
1	--	--	--	--	42	--	--	--	--	--	21	--	63
2	--	84	--	--	--	--	--	--	--	--	--	--	84
3	1151	82647	14189	28564	104605	13436	126584	13834	619280	8335	2688	4751	1020064
4	1313	1984	2234	313	500	877	939	4569	2379	3774	2671	1482	23035
5	2503	981	335	608	501	628	1752	147	482	168	84	21	8210
6	273	1607	2302	1965	1883	441	378	168	105	971	2606	546	13245
7	3812	397	2874	3217	189	3312	795	1316	841	356	2169	881	20159
8	1168	2150	880	168	336	755	874	355	294	418	1340	42	8780
9	855	1086	420	2025	356	1812	1025	63	1464	525	1586	420	11637
10	21	--	--	--	--	--	--	--	105	521	608	42	1297
11	--	--	--	--	--	--	21	355	--	--	--	--	376
12	63	147	--	--	6209	5129	1875	1146	980	292	896	520	17257
13	42	375	--	--	--	63	--	--	--	--	--	--	480
14	1315	1188	11231	88943	724543	2458	189	872	252	168	84	315	831558

Table 3.4 Benthic biomass (g/m^2) at Stations 1 to 14

STATIONS		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APL	MAY	TOTAL
1		--	--	--	--	0.19	--	--	--	--	--	0.10	--	0.29
2		--	0.34	--	--	--	--	--	--	--	--	--	--	0.34
3	*In. shells	2477.70	4710.36	8193.62	3698.32	96880.06	13057.07	276.88	1324.71	60519.53	649.58	212.80	279303.95	471304.58
	*Ex . shells			854.14	2504.39									462771.17
4	*In. shells	2397.27	11.73	76.63	1873.43	2819.64	5014.90	2875.28	9642.72	2935.15	4923.34	5043.44	7660.18	45273.71
	*Ex. Shells	422.17			240.14	218.97	893.50	339.87	1359.47	475.96	662.81	726.86	1215.02	6643.13
5		20.58	5.17	2.64	1.56	2.55	2.73	7.50	1.10	35.10	2.52	2.48	0.35	84.28
6		1.78	8.85	4.17	3.18	5.99	2.61	21.75	2.11	1.14	1.78	3.23	3.44	60.03
7		6.72	2.25	3.67	7.98	0.29	4.45	21.07	2.87	1.75	6.52	1.70	12.00	71.27
8		9.59	59.64	5.27	1.24	9.72	8.48	36.40	15.08	1.71	26.83	21.19	8.48	203.63
9		3.03	4.69	8.28	10.12	5.37	4.36	4.71	1.55	8.35	3.92	4.54	2.16	61.08
10		0.72	--	--	--	--	--	--	--	1.24	1.60	1.09	1.30	5.95
11		--	--	--	--	--	--	0.99	2.29	--	--	--	--	3.28
12		0.99	1.29	--	--	22.82	20.24	6.05	5.59	4.31	1.72	4.49	2.92	70.42
13		2.93	5.01	--	--	--	2.67	--	--	--	--	--	--	10.61
14	*In. shells	198.43	858.38	228.82	676.89	691.09	12.27	3.33	12.81	7.60	21.18	14.19	3.81	2728.80
	*Ex. Shells		459.24											2329.66

***In. Shells – Including shells** ***Ex. Shells – Excluding shells**

Table 3.5 Total No. of specimens, numerical abundance and percentage contribution of different groups of benthic fauna at stations 1 to 14.

St. No.	No. of specimens	Poly-chaetes	Oligo-chaetes	Archi-annelids	Amphi-pods	Tanaid-aceans	Isopods	Decapods	Mysids	Cumaceans	Gastro-pods	Bivalves	Insects	Fishes	Misc. groups
1	63	63 (100)	--	--	--	--	--	--	--	--	--	--	--	--	--
2	84	63 (75)	--	--	--	--	--	--	--	--	21 (25.00)	--	--	--	--
3	1020064	4719 (0.45)	--	--	21 (0.01)	--	--	--	--	--	1013093 (99.30)	2168 (0.21)	42 (0.02)	--	21 (0.01)
4	23035	10119 (43.93)	732 (3.18)	--	1988 (8.63)	564 (2.45)	--	147 (0.64)	21 (0.09)	--	566 (2.46)	8396 (36.45)	460 (1.99)	42 (0.18)	--
5	8210	6809 (82.94)	417 (5.08)	--	63 (0.77)	503 (6.13)	--	271 (3.30)	42 (0.51)	-	21 (0.25)	63 (0.77)	--	21 (0.25)	--
6	13245	10027 (75.70)	1563 (11.80)	--	252 (1.90)	857 (6.47)	--	210 (1.59)	--	21 (0.16)	294 (2.22)	21 (0.16)	--	--	--
7	20159	17296 (85.80)	1271 (6.30)	--	356 (1.77)	774 (3.84)	105 (0.52)	252 (1.25)	--	--	42 (0.21)	42 (0.21)	--	21 (0.10)	--
8	8780	5484 (62.46)	42 (0.48)	--	2084 (23.74)	605 (6.89)	334 (3.80)	84 (0.96)	--	--	105 (1.19)	42 (0.48)	--	--	--
9	11637	8668 (74.49)	42 (0.36)	21 (0.18)	1671 (14.36)	168 (1.44)	105 (0.90)	--	21 (0.18)	--	42 (0.36)	794 (6.83)	63 (0.54)	--	42 (0.36)
10	1297	734 (56.59)	--	--	21 (1.62)	--	21 (1.62)	--	--	--	--	521 (40.17)	--	--	--
11	376	334 (88.83)	--	--	--	--	--	--	--	--	--	--	42 (11.17)	--	--
12	17257	17194 (99.63)	--	--	--	--	--	--	--	--	--	--	63 (0.37)	--	--
13	480	417 (86.88)	--	--	--	--	--	--	--	--	--	--	63 (13.12)	--	--
14	831558	8921 (1.07)	--	--	770797 (92.69)	8584 (1.03)	41501 (4.99)	126 (0.02)	1042 (0.13)	21 (0.003)	188 (0.02)	294 (0.04)	42 (0.01)	42 (0.01)	--

(Values in the brackets indicates the %)

Table 3.6a **Average (X) and Coefficient of Variation (C.V.(%)) of total benthic density, water quality parameters and sediment characteristics at stations 1 to 7**

Parameters	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
Density (No./m^2)	5.25	238.05	7.00	331.66	85005.34	195.70	1919.58	64.75	684.17	104.18	766.33	103.87	1679.92	75.13
Temperature (°C)	29.83	4.47	29.97	4.97	29.72	4.55	30.01	4.95	29.58	4.96	29.42	5.27	29.61	5.88
Salinity (psu)	0.26	111.17	0.39	133.19	2.09	145.18	3.66	108.00	13.55	77.53	11.76	78.78	9.72	85.46
pH	7.59	7.26	7.50	6.66	6.97	4.48	7.04	6.30	7.49	5.69	7.56	6.09	7.50	6.24
DO (ml/l)	3.52	26.19	3.30	31.35	3.20	27.08	2.80	32.70	3.74	24.50	4.06	10.76	4.10	13.71
BOD (ml/l)	3.34	26.62	3.38	38.55	2.42	57.90	2.86	46.27	2.80	42.53	1.95	72.38	2.57	56.80
NO_2-N (µmol/l)	24.45	62.72	24.73	61.17	17.83	80.00	15.93	82.67	3.45	82.57	1.24	51.22	1.36	53.72
NO_3-N (µmol/l)	636.75	100.50	596.23	101.39	288.70	97.01	379.70	97.01	220.94	152.96	33.97	93.72	102.24	220.72
NH_4-N (µmol/l)	104.98	52.87	106.51	53.86	106.04	55.97	100.21	60.15	25.50	97.91	5.53	131.64	4.17	120.29
PO_4-P (µmol/l)	68.92	77.52	65.40	72.93	58.70	74.19	48.73	75.81	11.58	78.45	6.95	162.32	6.74	148.03
POC (ml/l)	4.11	86.16	3.34	73.13	3.61	91.42	3.21	69.04	3.88	82.64	2.36	78.74	2.78	86.58
Suspended load (mg/l)	148.91	95.53	220.00	109.77	163.75	86.57	170.47	76.90	388.69	163.81	203.58	87.06	205.77	73.57
Sand (%)	17.22	112.11	15.34	87.56	57.32	22.48	50.97	41.31	11.96	106.42	48.58	34.18	45.52	40.76
Silt (%)	21.44	49.41	31.32	58.61	2.02	200.27	6.18	156.28	24.64	71.73	13.62	86.74	10.92	120.71
Clay (%)	61.32	26.30	53.35	27.41	40.65	29.53	42.85	35.51	60.90	23.64	37.80	41.38	43.56	35.01
Organic matter (%)	5.08	65.44	5.26	51.89	3.21	107.51	2.67	65.84	4.60	43.13	3.48	76.66	3.99	30.98

Table 3.6b Average (X) and Coefficient of Variation (C.V.(%)) of total benthic density, water quality parameters and sediment characteristics at stations 8 to 14

Parameters	Station 8		Station 9		Station 10		Station 11		Station 12		Station 13		Station 14	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
Density (No./m^2)	731.67	78.88	969.75	62.99	108.08	191.51	31.33	312.00	1438.08	137.64	40.00	257.35	69296.50	287.22
Temperature (°C)	29.57	5.77	29.33	6.32	29.22	8.36	29.08	7.65	29.13	7.73	29.06	8.03	27.89	6.18
Salinity (psu)	10.27	92.01	3.46	134.20	1.92	209.42	0.16	187.00	0.37	253.02	0.02	210.52	22.29	53.78
pH	7.38	5.65	7.12	5.50	6.82	3.57	6.43	13.87	6.68	7.62	7.01	7.37	7.78	5.57
DO (m/l/)	3.80	17.96	4.24	19.22	3.96	26.30	4.92	14.96	4.53	18.05	5.03	12.69	3.95	15.59
BOD (ml/l)	2.25	60.51	1.39	70.86	0.94	88.40	1.13	92.85	1.58	91.79	0.96	85.33	1.91	65.73
NO_2-N (µmol/l)	1.59	114.85	1.15	79.82	1.09	91.19	0.55	79.99	0.62	78.15	0.39	96.04	0.78	69.95
NO_3-N (µmol/l)	126.76	155.40	258.46	197.77	281.62	193.76	154.41	202.05	91.18	153.82	51.23	138.08	53.23	169.99
NH_4-N (µmol/l)	7.85	120.74	9.99	111.17	15.79	103.42	21.19	83.26	30.01	106.70	1.15	156.68	2.55	239.74
PO_4-P (µmol/l)	5.13	101.49	4.28	120.51	4.28	122.52	10.27	77.88	11.72	72.12	2.85	191.85	4.37	197.84
POC (ml/l)	1.67	50.58	1.47	82.39	1.70	54.93	1.33	75.60	1.43	71.22	1.68	100.58	2.84	99.25
Suspended load (mg/l)	221.01	144.60	229.88	147.88	198.43	178.89	153.26	131.54	202.94	102.26	193.34	123.80	165.99	89.87
Sand (%)	43.17	39.02	58.29	29.68	60.57	35.80	75.82	14.84	59.80	31.98	76.30	15.60	37.19	32.82
Silt (%)	6.72	97.05	3.60	139.52	6.82	141.86	0.86	275.10	8.78	100.95	0.88	256.65	13.68	80.53
Clay (%)	50.11	32.97	38.35	41.74	32.71	42.63	23.32	47.79	31.43	54.25	22.82	53.26	49.13	31.47
Organic matter (%)	3.08	70.29	4.11	41.90	3.33	90.77	1.28	175.35	4.34	82.08	1.21	143.22	3.35	20.17

Table 3.7a Average (X no./m^2) and Coefficient of Variation (C.V.(%)) of species at stations 1 to 7

SPECIES	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
POLYCHAETES														
Aphrodita alta							3.50	331.66	5.25	331.66	22.50	331.66	3.50	223.61
Lepidonotus sp.														
Sthenelais boa														
Amphinome rostrata									3.50	331.66				
Ancistrosyllis constricta							1.75	331.66	71.42	90.19	95.92	91.92	199.25	100.09
Vanadis formosa							3.50	331.66						
Syllis spongicola											1.75	331.66		
Scoloplos madagascariensis					161.75	126.79							17.42	297.17
Lycastis indica					150.17	317.11	130.58	152.40	1.75	331.66				
Dendronereis aestuarina					6.17	202.41	172.00	145.45			3.50	223.61	5.25	238.04
Perinereidae							7.00	141.42						
Perinereis cavifrons									3.50	223.61	7.00	331.66		
Platynereis sp.									1.75	331.66	1.75	331.66	3.50	223.61
Nephthys dibranchis							5.25	238.05	97.33	105.97	50.42	155.61	46.92	129.26
Marphysa mossambica														
Diopatra neapolitana									15.67	331.66			1.75	331.66
Lumbrinereis simplex														
L. polydesma														
L. latreilli													12.25	283.92
L. impatiens							10.50	331.66	7.00	141.42	3.50	331.66	1.75	331.66
L. notocirrata											5.25	331.66		
Gonida emerita							1.75	331.66						
G. incerta														
Goniadopsis maskallensis											1.75	331.66		
Glycera longipinnis											8.75	153.62	15.67	331.66
G. alba							7.00	331.66						
G. benguellana														
Glycera. sp.														
Scolelepis indica											12.17	331.66		
Prionospio pinnata									15.75	155.16			204.58	217.42

Table 3.7a contd...

SPECIES	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
P. cirrifera							**8.75**	**331.66**						
P. cirrobranchiata											5.25	331.66		
P. polybranchiata					50.67	114.94	378.42	112.21	104.33	208.39	125.08	109.70	139.08	225.21
Prionospio. sp.									15.67	293.57	5.25	173.21	88.58	331.66
Disoma orissae					1.75	311.66	3.50	331.66						
Magelona capensis											5.25	173.21	32.92	331.66
Cossura coasta									1.75	331.66	14.00	196.85	10.50	223.61
Capitella capitata	5.26	238.05	3.50	331.66	3.50	331.66	1.75	331.66	3.50	331.66	50.77	107.45	114.50	165.58
Notomastus aberans									130.33	241.22	95.92	199.51	24.33	226.11
N. latericeus							10.50	223.61			41.75	250.42	7.00	254.95
N. fauveli									7.00	331.66	54.50	255.02	1.75	331.66
Heteromastus similis							1.75	331.66	5.25	238.05	5.25	238.05	22.58	233.12
H. filiformis									20.92	227.16				
Heteromastides bifidus					3.50	331.66	69.5	114.12	22.58	224.41	52.92	143.92	76.42	181.85
Mediomastus capensis							10.50	331.66	1.75	331.66	59.08	144.37	33.08	226.75
Leiochrides africanus											7.00	331.66		
Paraheteromastus tenuis					9.17	226.43	14.00	231.84	15.67	293.57	83.58	214.38	359.50	179.47
Branchiocapitella singularis			1.75	331.66										
Scyphoproctus djiboutiensis					12.83	240.69	2.42	331.66	14.00	196.85	12.25	226.33	7.00	187.08
Pulliella armata														
Branchiomaldane vincenti													1.75	331.66
Maldane sarsi														
Owenia fusiformis											1.75	331.66	8.75	267.58
Pista indica									1.75	331.66	1.75	331.66	1.75	331.66
Polycirrus coccineus														
OLIGOCHAETES														
Oligochaete sp.							61.00	144.81	34.75	2.96.06	130.25	220.70	105.92	290.64
ARCHIANNELIDS														
Polygordius sp.														

Table 3.7a contd...

SPECIES	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
AMPHIPODS														
Melita zeylanica							25.42	221.35			5.25	173.21		
Grandidierella bonneri							12.25	247.02	1.75	331.66			1.75	331.66
G. gilesi							62.75	236.14	1.75	331.66	10.50	223.61		
Quadrivisio bengalensis					6.83	253.53	49.58	195.32			5.25	238.05	17.42	, 200.48
Eriopisa chilkensis							15.67	293.57					3.50	223.61
Corophium triaenonyx									1.75	331.66			7.00	331.66
Caprillid sp.														
TANAIDACEANS														
Apseudes chilkensis							12.25	331.66	10.50	276.89	24.42	256.50	4000	167.11
A. gymnophobium							34.75	176.85	31.42	187.65	47.00	169.61	24.50	187.90
ISOPODS														
Cirrolinia fluviatilis													8.75	206.88
Anthuridae														
DECAPODS														
Penaeid prawn									1.75	331.66	12.25	130.15	10.50	173.21
Crab							12.25	331.66	20.83	247.74	7.67	260.23	7.00	141.42
Cumacea sp.											1.75	331.66		
Mysid sp.							1.75	331.66	3.50	331.66				
Acetes sp.											3.50	331.66		
GASTROPODS														
Gastropod sp.							28.00	123.74	1.75	331.66	5.25	238.05	3.50	223.61
Littorina littorea			1.75	331.66							7.00	187.08		
Solariella sp.							19.17	237.20						
Gastropod. sp. (long)					84041.92	198.25					8.75	267.58		
Dentalium sp.											3.50	331.66		

Table 3.7a contd…

SPECIES	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
BIVALVES														
Bivalve sp.							3.50	331.66	1.75	331.66	1.75	331.66		
Modiolus striatulus														
Cardium sp.														
Meritrix sp.							3.50	331.66						
Villorita cyprinoides					187.58	197.33	637.08	97.11	1.75	331.66				
Nucula sp.							15.67	255.67	1.75	331.66				
Pendora flexosa							39.92	331.66						
Paphia papilliens													3.50	331.66
INSECTS														
Asellus aquaticus														
Chironomids					10.83	226.38	38.33	238.26						
Insect larvae														
Hydroptila sp.														
FISHES														
Juvenile fish							1.75	331.66	1.75	33.66				
Gobidae							1.75	331.66					1.75	331.66
MISCELLANEOUS GROUPS														
Flat worm					9.50	2.71.91								

Table 3.7b Average (X no./m^2) and Coefficient of Variation (C.V. (%)) of species at stations 8 to 14

SPECIES	Station 8		Station 9		Station 10		Station 11		Station 12		Station 13		Station 14	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
POLYCHAETES														
Aphrodita alta	1.75	331.66												
Lepidonotus sp.													1.75	331.66
Sthenelais boa			1.75	331.66									7.00	223.61
Amphinome rostrata														
Ancistrosyllis constricta	10.50	152.75	26.08	241.98									142.42	218.60
Vanadis formosa														
Syllis spongicola														
Scoloplos madagascariensis														
Lycastis indica	14.00	165.83	10.50	191.49										
Dendronereis aestuarina	10.50	173.21	99.42	84.65	36.75	314.83	20.83	331.66			1.75	331.66	1.75	331.66
Perinereidae														
Perinereis cavifrons	14.00	176.78	15.75	173.21									34.75	261.44
Platynereis sp.	3.50	223.61	7.00	254.95									15.17	259.61
Nephthys dibranchis	3.50	223.61	29.50	331.66										
Marphysa mossambica													14.00	187.08
Diopatra neapolitana	93.92	134.51	1.75	331.66									361.17	117.98
Lumbrinereis simplex													13.92	331.66
L. polydesma													1.75	331.66
L. latreilli														
L. impatiens													19.25	186.09
L. notocirrata														
Gonida emerita														
G. incerta			3.50	331.66										
Goniadopsis maskallensis														
Glycera longipinnis	7.00	254.95											1.75	331.66
G. alba														
G. benguellana			1.75	331.66										
Glycera. sp.	1.75	331.66												
Scolelepis indica	1.79	331.66												
Prionospio pinnata													7.00	331.66

Table 3.7b contd...

SPECIES	Station 8		Station 9		Station 10		Station 11		Station 12		Station 13		Station 14	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
P. cirrifera														
P. cirrobranchiata	19.08	331.66												
P. polybranchiata	75.00	124.21	52.08	162.80	15.67	293.57	7.00	331.66					12.25	177.86
Prionospio. sp.	1.75	331.66	15.67	293.57										
Disoma orissae	1.75	331.66												
Magelona capensis														
Cossura coasta														
Capitella capitata	19.17	268.66	12.25	236.90	3.50	223.61			1417.08	139.94	27.75	331.66	104.25	274.70
Notomastus aberans	12.25	163.51	123.33	316.57										
N. latericeus	1.725	331.66	12.25	236.90	1.75	331.66								
N. fauveli	1.75	331.66	5.25	331.66										
Heteromastus similis	21.00	152.75	1.75	331.66					3.50	331.66				
H. filiformis	1.75	331.66												
Heteromastides bifidus	47.08	195.44	186.00	113.92	1.75	331.66			1.75	331.66			1.75	331.66
Mediomastus capensis	45.33	145.26	57.33	247.91										
Leiochrides africanus	19.25	220.26												
Paraheteromastus tenuis			36.67	163.30	1.75	331.66					5.25	331.66		
Branchiocapitella singularis									1.75	331.66				
Scyphoproctus djiboutiensis	15.67	224.80	17.50	182.21					8.75	228.91				
Pulliella armata			3.50	223.61										
Branchiomaldane vincenti														
Maldane sarsi			1.75	331.66										
Owenia fusiformis	10.50	223.61												
Pista indica	1.75	331.66											1.75	331.66
Polycirrus coccineus													1.75	331.66
OLIGOCHAETES														
Oligochaete sp.	3.50	331.66	3.50	223.61										
ARCHIANNELIDS														
Polygordius sp.			1.75	331.66										

Table 3.7b contd...

SPECIES	Station 8		Station 9		Station 10		Station 11		Station 12		Station 13		Station 14	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
AMPHIPODS														
Melita zeylanica	1.75	331.66	7.00	223.61										
Grandidierella bonneri	7.00	254.95	15.95	225.26	1.75	331.66							129.50	312.62
G. gilesi	1.75	331.66	7.00	187.08									3123.17	259.91
Quadrivisio bengalensis	10.50	152.75	80.67	262.12									4928.83	314.25
Eriopisa chilkensis	27.92	156.93	10.50	173.21									1665.75	309.71
Corophium triaenonyx	121.25	268.55											54385.83	306.63
Caprillid sp.	3.50	223.61												
TANAIDACEANS														
Apseudes chilkensis	26.00	308.11	5.25	73.21									7.00	254.95
A. gymnophobium	24.42	223.35	8.75	182.21									708.33	324.59
ISOPODS														
Cirrolinia fluviatilis	24.33	223.61	1.75	331.66									3458.42	279.07
Anthuridae	3.50	223.61	7.00	223.61	1.75	331.66								
DECAPODS														
Penaeid prawn	5.25	331.66											3.90	331.66
Crab	1.75	331.66											7.00	187.08
Cumacea sp.													1.75	331.66
Mysid sp.			1.75	331.66									86.82	331.66
Acetes sp.														
GASTROPODS														
Gastropod sp.	8.75	206.88	1.75	331.66									13.92	298.16
Littorina littorea			1.75	331.66										
Solariella sp.														
Gastropod. sp. (long)														
Dentalium sp.													1.75	331.66

Table 3.7b contd…

SPECIES	Station 8		Station 9		Station 10		Station 11		Station 12		Station 13		Station 14	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
BIVALVES														
Bivalve sp.														
Modiolus striatulus	1.75	331.66												
Cardium sp.													17.50	182.21
Meritrix sp													3.50	331.66
Villorita cyprinoids			7.00	331.66										
Nucula sp.														
Pendora flexosa			59.17	269.55	43.42	331.66								
Paphia papilliens	1.75	331.66											3.50	331.66
INSECTS														
Asellus aquaticus											1.75	331.66		
Chironomids			5.25	238.05					5.25	331.66	3.50	223.61		
Insect larvae							175	331.66					3.50	223.61
Hydroptila sp.							1.75	331.66						
FISHES														
Juvenile fish													3.50	233.61
Gobidae														
MISCELLANEOUS GROUPS														
Flat worm			3.50	331.66										

Table 3.8a **Average (X) and Coefficient of Variation (C.V. (%)) for each month at stations 3 to 7 based on species distribution**

Months	Station 3		Station 4		Station 5		Station 6		Station 7	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
June	82.21	353.53	32.63	638364	67.65	219.19	6.20	198.66	95.30	337.56
July	6026.86	352.00	50.65	366.15	26.51	268.23	36.52	381.54	9.93	366.45
August	890.00	301.20	54.80	273.51	9.05	342.03	52.32	199.06	70.80	351.83
September	2040.29	354.60	7.83	459.69	16.43	219.84	44.66	250.57	80.43	288.98
October	7471.79	360.17	12.50	571.87	13.54	293.42	42.80	282.69	4.73	321.84
November	959.71	323.16	21.93	466.21	16.97	272.56	10.02	170.03	82.80	252.26
December	9041.71	359.53	23.48	363.33	47.35	397.01	8.59	203.97	19.88	338.47
January	988.14	358.20	114.23	214.30	4.54	243.67	3.82	357.07	32.90	359.95
February	44234.29	360.25	59.48	206.80	12.49	235.78	2.39	428.49	22.08	300.68
March	592.36	351.74	94.35	368.42	4.54	342.33	22.07	248.64	12.05	268.81
April	192.00	357.53	66.78	358.98	2.27	358.82	59.23	214.30	53.18	466.01
May	339.36	999.00	37.05	999.00	0.57	999.00	12.41	999.00	19.93	999.00

Table 3.8b Average (X) and Coefficient of Variation (C.V. (%)) for each month at stations 8 to 14 based on species distribution

Months	Station 8		Station 9		Station 10		Station 11		Station 12		Station 13		Station 14	
	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)	X	C.V.(%)
June	26.55	235.47	20.85	476.75	2.33	282.84	0.00	999.00	10.50	223.61	8.40	122.47	35.54	455.06
July	48.86	382.72	26.49	257.67	0.00	999.00	0.00	999.00	24.50	91.47	75.00	172.46	32.11	526.74
August	20.00	211.53	10.24	339.19	0.00	999.00	0.00	999.00	0.00	999.00	0.00	999.00	303.54	365.45
September	3.82	375.83	49.39	447.52	0.00	999.00	0.00	999.00	0.00	999.00	0.00	999.00	2403.86	358.20
October	7.64	235.19	8.68	309.92	0.00	999.00	0.00	999.00	1034.83	221.80	0.00	999.00	19582.24	502.17
November	17.16	177.02	41.17	370.55	0.00	999.00	0.00	999.00	854.83	223.61	12.60	200.00	66.43	187.93
December	19.86	260.79	25.00	191.80	0.00	999.00	5.25	173.21	312.50	223.61	0.00	999.00	5.11	277.11
January	8.07	437.68	2.56	323.73	0.00	999.00	88.75	110.53	191.00	223.61	0.00	999.00	23.57	211.56
February	6.68	282.48	35.20	230.41	11.67	89.44	0.00	999.00	163.33	223.61	0.00	999.00	6.81	190.39
March	9.50	300.81	15.37	188.56	57.89	282.84	0.00	999.00	48.67	223.61	0.00	999.00	4.54	243.67
April	30.45	240.70	35.61	343.43	67.56	199.61	0.00	999.00	149.33	223.61	0.00	999.00	2.27	600.00
May	0.95	999.00	10.24	999.00	4.67	999.00	0.00	999.00	86.67	999.00	0.00	999.00	8.51	999.00

Table 3.9 Correlation coefficient (r) of total benthic density with water quality parameters and sediment characteristics

Parameters	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Stn. 13	Stn. 14
Temperature (°C)	-0.04	-0.40	0.02	0.24	-0.32	0.26	-0.43	-0.38	0.12	0.68	0.04	-0.14	-0.58	0.05
Salinity (psu)	0.11	-0.19	-0.05	0.76	-0.57	0.04	-0.24	-0.34	-0.15	0.92	0.82	-0.07	-0.18	0.01
pH	-0.14	-0.29	-0.10	0.33	-0.46	0.35	0.06	-0.47	-0.27	0.26	-0.12	-0.26	0.14	0.20
DO (ml/l)	-0.01	0.08	-0.07	0.01	0.10	0.05	0.29	-0.21	-0.16	-0.86	-0.48	-0.12	0.06	0.04
BOD (ml/l)	0.22	0.15	0.32	0.15	0.17	0.37	-0.08	0.05	-0.36	0.01	-0.25	-0.26	-0.06	-0.31
NO_2-N (µmol/l)	-0.26	-0.39	0.25	0.49	0.62	-0.23	0.39	0.24	0.12	0.71	-0.10	0.35	-0.03	-0.15
NO_3-N (µmol/l)	0.08	-0.17	0.07	0.24	0.17	0.06	-0.22	0.51	-0.18	0.44	-0.15	-0.27	0.85	-0.15
NH_4-N (µmol/l)	0.06	-0.45	0.26	0.37	-0.10	0.02	-0.37	-0.15	0.01	0.35	-0.33	0.22	-0.24	-0.09
PO_4-P (µmol/l)	-0.19	-0.25	0.05	0.71	-0.03	-0.04	-0.14	-0.27	-0.26	-0.04	-0.13	-0.06	-0.12	-0.04
POC (ml/l)	-0.05	-0.18	-0.20	-0.09	-0.28	0.24	-0.37	0.15	0.11	-0.14	0.07	-0.31	0.64	-0.10
Suspended load (mg/l)	0.21	-0.05	-0.35	-0.38	0.85	-0.15	0.29	0.12	-0.03	-0.24	-0.21	-0.30	-0.07	0.21
Sand (%)	0.40	-0.28	0.05	0.09	0.38	-0.45	0.32	0.25	0.24	-0.21	-0.04	-0.38	0.15	-0.51
Silt (%)	-0.56	-0.13	0.80	0.06	-0.16	0.20	-0.17	0.33	-0.21	0.28	-0.12	-0.17	-0.03	-0.41
Clay (%)	-0.11	0.42	-0.33	-0.16	0.02	0.33	-0.24	-0.39	-0.19	0.13	0.06	0.51	-0.14	0.69
Organic matter (%)	-0.50	0.59	0.56	0.40	-0.11	-0.47	-0.72	-0.36	-0.12	0.46	0.63	0.34	-0.22	0.04

Table 3.10a **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance (Pielou's) index (*D*) and Eveness (Heip's) index (*E*) for benthic community structure at stations 2 & 3**

MONTHS	STATION - 2					STATION - 3				
	M	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
JUN						0.75	0.03	0.31	0.85	0.14
JUL	2.39	0.62	1.50	--	--	1.87	0.04	0.17	5.48	0.04
AUG						0.94	0.28	0.90	0.86	0.21
SEPT						2.07	0.03	0.14	0.80	0.03
OCT						1.38	0.01	0.12	3.52	0.04
NOV						3.35	0.18	0.58	0.17	0.13
DEC						9.03	0.05	0.02	0.35	0.01
JAN						1.11	0.01	0.06	0.08	0.03
FEB						0.80	0.01	0.09	1.14	0.04
MAR						1.76	0.04	0.19	0.40	0.07
APL						0.67	0.02	0.07	0.89	0.07
MAY						1.25	0.04	0.14	0.06	0.08

Table 3.10b **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance (Pielou's) index (*D*) and Eveness (Heip's) index (*E*) for benthic community structure at stations 4 & 5**

MONTHS	STATION - 4					STATION - 5				
	M	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
JUN	2.95	0.63	1.69	0.98	1.15	9.48	0.84	3.21	0.84	1.71
JUL	9.75	0.64	2.45	1.17	0.76	8.47	0.78	2.66	0.83	1.21
AUG	9.65	0.79	2.86	0.69	1.18	3.65	0.66	1.80	0.95	1.27
SEPT	3.69	0.44	1.38	0.56	0.74	8.27	0.84	3.05	0.70	2.01
OCT	1.71	0.16	0.50	0.52	0.32	5.12	0.74	2.25	0.78	1.41
NOV	3.13	0.43	1.28	0.79	0.65	5.76	0.78	2.51	0.56	1.61
DEC	5.42	0.64	1.93	1.33	0.84	5.68	0.55	1.80	0.78	0.63
JAN	1.13	0.86	3.25	0.91	1.39	5.17	0.81	2.50	0.82	2.24
FEB	8.87	0.87	3.28	0.73	1.99	5.19	0.82	2.63	0.56	2.15
MAR	7.72	0.64	2.25	0.63	0.71	3.10	0.65	1.75	0.54	1.58
APL	7.39	0.65	2.02	0.73	0.59	2.39	0.62	1.50	0.47	1.74
MAY	4.36	0.51	1.64	0.55	0.68	--	--	--	--	--

le 3.10c **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance (Pielou's) index (*D*) and Eveness (Heip's) index (*E*) for benthic community structure at stations 6 & 7**

MONTHS	STATION – 6					STATION – 7				
	M	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
JUN	8.51	0.89	3.24	1.01	2.72	9.64	0.69	3.23	1.00	0.77
JUL	7.18	0.65	2.20	1.07	0.80	6.20	0.738	2.77	0.85	1.08
AUG	10.27	0.89	3.46	0.95	2.06	6.67	0.67	2.99	1.19	0.66
SEPT	8.39	0.84	3.07	0.85	1.71	12.47	0.77	4.28	0.82	1.00
OCT	7.73	0.80	2.76	1.13	1.34	4.05	0.71	3.50	1.12	1.71
NOV	11.32	0.91	3.65	1.01	2.90	7.85	0.82	5.43	0.94	1.34
DEC	8.93	0.88	3.28	0.68	2.56	7.15	0.69	3.21	0.84	1.08
JAN	4.14	0.69	2.00	0.62	1.60	5.91	0.65	2.86	1.01	0.91
FEB	2.28	0.56	1.37	0.92	1.47	6.25	0.75	3.98	1.02	1.49
MAR	8.48	0.84	2.99	1.02	1.71	6.01	0.79	4.85	0.80	1.71
APL	8.09	0.87	3.26	0.85	2.09	4.15	0.43	1.76	0.52	0.45
MAY	5.89	0.83	2.76	0.42	2.12	2.38	0.33	1.50	0.37	0.51

le 3.10d **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance (Pielou's) index (*D*) and Eveness (Heip's) index (*E*) for benthic community structure at stations 8 & 9**

MONTHS	STATION – 8					STATION – 9				
	M	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
JUN	7.51	0.85	3.05	1.08	2.02	6.28	0.42	1.50	1.00	0.44
JUL	8.29	0.64	2.19	1.07	0.66	9.10	0.81	2.92	0.78	1.46
AUG	9.38	0.88	3.28	0.72	2.13	6.14	0.69	2.26	0.56	1.22
SEPT	2.07	0.65	1.56	0.95	1.88	6.27	0.49	1.62	0.73	0.45
OCT	6.38	0.85	2.88	1.19	2.39	3.61	0.74	2.14	0.65	1.88
NOV	11.20	0.95	3.63	0.96	2.63	4.99	0.64	1.90	1.17	0.81
DEC	9.39	0.82	2.93	0.53	1.48	9.94	0.89	3.42	0.66	2.23
JAN	3.61	0.54	1.57	0.84	0.96	3.42	0.72	1.92	1.04	1.95
FEB	5.60	0.80	2.55	0.83	1.97	8.02	0.85	3.02	1.15	1.77
MAR	6.15	0.77	2.53	1.04	1.65	9.05	0.89	3.36	0.70	2.54
APL	11.04	0.85	3.16	0.51	1.51	5.09	0.69	2.04	0.73	0.96
MAY	1.42	0.49	1.00	0.33	1.72	3.51	0.75	2.13	0.52	1.86

3.10e **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance (Pielou's) index (*D*) and Eveness (Heip's) index (*E*) for benthic community structure at stations 11 & 14**

MONTHS	STATION – 11					STATION – 14				
	M	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
JUN						6.64	0.41	1.50	1.02	0.39
JUL						1.50	0.22	0.65	1.10	0.45
AUG						4.55	0.61	1.65	1.15	0.52
SEPT						5.58	0.64	1.72	0.65	0.39
OCT						4.32	0.29	0.97	2.22	0.15
NOV						9.51	0.88	0.33	1.46	1.93
DEC	--	0.65	2.00	0.01	2.24	4.05	0.76	2.20	2.01	2.00
JAN	1.81	0.44	1.09	0	0.99	7.83	0.85	3.02	2.05	1.95
FEB						7.67	0.87	3.09	1.66	2.61
MAR						5.17	0.81	2.50	0.62	2.24
APL						--	0.33	0.93	1.22	2.12
MAY						2.76	0.69	1.83	0.43	1.75

Table 3.11 **Stationwise average (X) and Coefficient of Variation (C.V. (%)) for species richness, concentration, diversity, dominance and evenness indices at stations 1 to 14**

STATIONS		*M*	*SI*	*H*	*D*	*E*
3	X	1.65	0.06	0.20	1.23	0.07
	σ	1.00	0.08	0.26	1.56	0.06
	C.V.(%)	60.25	142.76	127.03	127.01	86.72
4	X	6.33	0.60	2.04	0.83	0.91
	σ	3.05	0.19	0.80	0.33	0.42
	C.V.(%)	48.23	31.73	38.95	38.95	46.21
5	X	5.19	0.67	2.14	0.67	1.46
	σ	2.59	0.22	0.82	0.26	0.61
	C.V.(%)	49.97	33.10	38.48	38.48	41.72
6	X	7.60	0.80	2.84	0.88	1.92
	σ	2.39	0.11	0.64	0.20	0.58
	C.V.(%)	31.46	13.45	22.63	22.63	30.31
7	X	6.56	0.66	2.20	0.87	1.058
	σ	2.53	0.14	0.57	0.23	0.41
	C.V.(%)	38.62	20.76	25.81	25.81	39.05
8	X	6.84	0.75	2.53	0.83	1.75
	σ	3.12	0.13	0.770	0.25	0.53
	C.V.(%)	45.68	17.61	30.30	30.30	30.53
9	X	6.29	0.71	2.35	0.81	1.47
	σ	2.20	0.14	0.63	0.22	0.67
	C.V.(%)	35.01	19.53	26.80	26.80	45.24
11	X	0.15	0.09	0.26	0.026	1.22
	σ	0.50	0.21	0.61	0.01	0.68
	C.V.(%)	331.63	228.19	234.95	234.62	55.93
14	X	4.97	0.61	1.95	1.30	1.37
	σ	2.62	0.24	0.85	0.57	0.87
	C.V.(%)	52.76	39.05	43.83	43.82	63.09

Table 3.12 Niche breadth for benthic species at stations 1 to 14

SPECIES	1	2	3	4	5	6	7	8	9	11	14
POLYCHAETES											
Aphrodita alta				2.74	2.18	1.30	4.45	4.34			
Lepidonotus sp.											4.34
Sthenelais boa									4.34		3.33
Amphinome rostrata					2.74						
Ancistrosyllis constricta				4.34	8.05	8.04	6.98	4.96	2.55		2.53
Vanadis formosa				2.74							
Syllis spongicola						4.34					
Scoloplos madagascariensis							1.83				
Lycastis indica			6.32	5.11	4.34			4.84	3.80		
Dendronereis aestuarina			1.24	5.20		4.45	3.54	4.12	8.09	1.32	4.34
Perinereidae			3.54	5.71							
Perinereis cavifrons					4.45	1.89		4.21	4.14		2.30
Platynereis sp.					4.34	4.34	4.45	4.45	2.96		2.31
Nephthys dibranchis				3.54	6.85	4.64	5.35	4.45	1.23		
Marphysa mossambica											3.67
Diopatra neapolitana					1.41		4.34	5.67	4.34		5.62
Lumbrinereis simplex											1.46
L. polydesma											4.34
L. latreilli							2.15				
L. impatiens				1.60	5.71	2.74	4.34				3.84
L. notocirrata						2.17					
Gonida emerita				4.34							
G. incerta									2.74		
Goniadopsis maskallensis						4.34					
Glycera longipinnis						5.16	1.41	2.96			4.34
G. alba				1.89							
G. benguellana									4.34		
Glycera. sp.								4.34			
Scolelepis indica						1.52		4.34			
Prionospio pinnata					4.95		2.74				1.89

Table 3.12 contd…

SPECIES	1	2	3	4	5	6	7	8	9	11	14
P. cirrifera				1.72							
P. cirrobranchiata						2.17		1.34			
P. polybranchiata			6.16	6.08	3.71	6.68	3.20	6.55	4.05	1.8891	3.91
Prionospio. sp.					1.91	5.02	1.09	4.35	1.91		
Disoma orissae			4.34	2.74				4.34			
Magelona capensis						5.02	1.21				
Cossura coasta					4.34	3.45	3.32				
Capitella capitata	3.54	1.41	2.74	4.34	2.74	6.35	4.25	2.28	2.10		1.84
Notomastus aberans					2.39	2.82	2.42	4.58	1.26		
N. latericeus				3.32		2.21	2.96	4.34	2.10		
N. fauveli					1.89	2.15	4.34	4.34	2.18		
Heteromastus similis				4.34	3.54	3.54	2.67	4.77	4.34		
H. filiformis					2.47			4.34			
Heteromastides bifidus			2.74	6.03	2.46	5.01	3.88	3.08	6.34		4.34
Mediomastus capensis				1.60	4.34	4.59	2.31	4.99	2.39		
Leiochrides africanus						1.89					
Paraheteromastus tenuis			2.17	2.64	1.91	2.84	3.35	2.92	3.99		
Branchiocapitella singularis		1.91									
Scyphoproctus djiboutiensis			1.72	4.34	3.45	2.78	4.35	2.10	3.89		
Pulliella armata									4.45		
Branchiomaldane vincenti							4.34				
Maldane sarsi											
Owenia fusiformis						4.34	2.25	3.32			
Pista indica					4.34	4.34	4.34	4.34			4.34
Polycirrus coccineus											4.34
OLIGOCHAETES											
Oligochaete sp.				5.24	1.71	2.28	1.69	2.74			
ARCHIANNELIDS											
Polygordius sp.									4.34		

Table 3.12 contd...

SPECIES	1	2	3	4	5	6	7	8	9	11	14
AMPHIPODS											
Melita zeylanica				2.89				4.34	3.33		
Grandidierella bonneri				2.57	4.34	5.02	4.34	2.96	2.99		1.30
G. gilesi				2.66	4.34			4.34	4.35		1.88
Quadrivisio bengalensis			4.34	3.13		3.32	3.62	4.96	2.22		1.25
Eriopisa chilkensis				1.91		3.5402	4.45	4.20	4.57		1.32
Corophium triaenonyx					4.34		1.89	1.91			1.33
Caprillid sp.								4.45			
TANAIDACEANS											
Apseudes chilkensis				1.52	2.34	2.50	4.01	1.57	5.02		2.94
A. gymnophobium				3.74	3.45	4.54	3.97	2.74	4.14		1.13
ISOPODS											
Cirrolinia fluviatilis							3.76	2.44	4.34		1.71
Anthuridae								4.45	3.33		
DECAPODS											
Penaeid prawn					4.34	5.77	4.57	2.17			2.74
Crab				1.52	2.53	4.34	4.57	4.34			4.35
Cumacea sp.						2.74					4.34
Mysid sp.				4.34	2.74				4.34		1.09
Acetes sp.						4.34					
GASTROPODS											
Gastropod sp.				6.00	4.34	3.54	4.45	3.77	4.34		2.02
Littorina littorea		1.16				4.35			4.34		
Solariella sp.				2.93							
Gastropod. sp. (long)			3.83			2.59					
Dentalium sp.						2.74					4.34

Table 3.12 contd…

SPECIES	1	2	3	4	5	6	7	8	9	11	14
BIVALVES											
Bivalve sp.				2.74	4.34	4.34					
Modiolus striatulus								4.34			
Cardium sp.											3.89
Meritrix sp.				2.74							2.74
Villorita cyprinoides			2.64	7.33	4.34				1.89		
Nucula sp.				2.56	4.34						
Pendora flexosa				1.18					2.06		
Paphia papilliens							2.74	4.34			2.74
INSECTS											
Asellus aquaticus											
Chironomids			4.45	2.64					3.54		
Insect larvae										4.34	4.45
Hydroptila sp.										4.34	
FISHES											
Juvenile fish				4.34	4.34						4.45
Gobidae				4.34			4.34				
MISCELLANEOUS GROUPS											
Flat worm			4.34						2.74		

Table 3.13 **Q-Mode factor analysis for grouping in the months at stations 1 to 14**

STATIONS	FACTOR	MONTHS*	RANGE OF FACTOR LOADING	EIGEN VALUE	CLOSENESS RATIO	VARIANCE VALUE	VARIANCE %
3	1	1, 2, 4, 5, 7, 8, 9, 10, 11, 12	-0.73 to -0.74	11.98	99.85	6.409	53.41
	2	3, 6	-0.73 to -0.75	0.15	97.98	5.59	46.70
5	1	8, 10, 12	0.62 to 0.99	5.13	42.77	2.45	20.38
	4	6, 7	0.93 to 0.95	2.40	62.75	2.08	17.30
	3	2, 3, 4	-0.75 to -0.97	1.69	76.79	2.920	24.34
	4	1	-0.96	1.00	85.12	1.54	12.87
	5	4	-0.97	0.73	91.22	1.00	8.32
	6	9	0.61 to 0.76	0.50	95.34	1.39	11.59
6	1	7, 12	-0.71 to -0.96	3.99	33.20	1.59	13.28
	2	8, 9	0.97 to 0.97	1.74	63.85	1.82	15.19
	3	2, 4	0.88 to 0.99	1.94	49.36	1.89	15.74
	4	5	0.91	1.22	74.02	1.18	9.85
	5	10, 11	-0.89 to -0.93	0.96	82.04	2.01	16.71
7	1	1, 4, 8	-0.96 to -0.98	3.70	30.77	2.96	24.65
	2	11, 12	-0.98 to -0.98	2.44	51.11	2.16	18.03
	3	6	-0.96	1.80	66.06	1.01	8.46
	4	3	0.99	1.05	74.08	1.01	8.39
8	1	12	-0.94			1.12	9.30
	2	2, 7	-0.73 to -0.96			1.56	12.9601
	3	5, 8	-0.75 to -0.93			1.71	14.27
	4	1	0.96	1.04	70.81	1.09	9.05
	5	3	-0.98	0.30	78.30	1.04	8.70
9	1	1, 3	0.88 to 0.92	4.92	41.02	2.17	18.10
	2	8	-0.98	1.51	53.58	1.15	9.57
	3	4, 5	-0.69 to -0.96	1.43	65.48	1.41	11.77
	4	2	0.99	1.01	73.98	1.02	8.50
12	1	3, 4, 5, 6, 7, 8, 9, 10	1.00 to 1.00	8.00	80.00	8.00	80.00
	2	2	1.00	1.00	90.00	1.00	10.00
	3	1	1.00	1.00	100.00	1.00	1.00
14	1	1, 2,11	-0.99 to -0.99	3.55	29.58	3.22	26.87
	2	3, 4, 5	0.76 to 0.99	2.91	53.85	2.62	21.86
	3	10	-0.95	2.18	71.99	1.03	8.62
	4	9	0.95	0.88	79.30	1.01	8.41
	5	8	-0.98	0.75	85.84	1.01	8.41

*Months – **June to May are given in the order 1 – 12**

CHAPTER 4

MANGROVE ECOSYSTEM OF PUDUVYPIN

4.1 INTRODUCTION

Mangroves are relatively sheltered areas along tropical estuaries, coastal lagoons and backwaters where the regular ebb and flood tides lead to mixing of fresh water from rain and land drainage with marine, coastal and estuarine waters. Mangrove swamps are heavily vegetated intertidal wetlands. When the area is submerged, which is only for short durations, they are very shallow with a maximum water depth in the swamps rarely exceeding 2m. It is not an oasis which is neither land nor sea, but is an important buffer deriving its wealth from both the land and sea and thus it enriches the coastal waters and provides an important forestry and fishery resource. Mangrove formation is a typical tropical phenomenon, which is of great ecological, economic and social significance. They are also called as tidal forests or coastal wetlands. The most important components of this ecosystem are water, soil and the biota, which belong to different families of plant and animal kingdom. These formations along the estuaries, backwaters or the deltas of major estuaries function as important links between the land and the sea (Untawale, 1987). Mangrove ecosystem as a whole is of considerable importance as coastal stabilizers, shelterbelt areas, nursery grounds, for aquaculture, for tannin, timber, charcoal and several other by-products. Mangroves are an assemblages of different plants belonging to different families of angiosperms, with certain specialized characters like special root systems, pneumatophores, prop roots, knee roots etc., viviparous germination and salt glands. These plants along with associated floral and faunal species occupy the intertidal mud flats along the estuaries and deltas. From time immemorial mangrove resources were utilized by mankind without upsetting ecological balance. In recent years stress on mangrove ecosystem is increasingly felt due to land reclamation and indiscriminate exploitation.

The mangrove ecosystem is self sufficient in production and utilization of food material. This is mainly detritus based system unlike the coastal system which is basically plankton based. The protein rich detritus is mostly consumed by the detritivorous organisms from the riverine or nearshore areas, which come to mangrove swamps for feeding, breeding and utilization as nurseries (Odum & Heald, 1975). In the high-energy food webs of coastal ecosystem detritus appears to be one of the primary sources of carbon and nitrogen (Odum, 1971; Benner *et al.*, 1986). They are characterized by their ability to flourish in this specialized environment. Some of the important factors responsible for their growth and distribution are the substratum, temperature, soil, salinity and nutrients. Mangroves cannot tolerate exposure to temperatures less than 20°C for a long period. Therefore their formation are found only in the tropical and some subtropical coasts of the world. Further mangrove trees as well as their seeds and propagules favour soft muddy substratum for their growth. The benthic components also show different range of salinity tolerance (Sunilkumar, 1993).

1) Species able to tolerate small variations in salinity (more than $24\%_0$).
2) Moderately tolerant forms (species withstood a salinity as low as $20\%_0$)
3) Healthy tolerant euryhaline forms (salinity from 0.2 to $29.76\%_0$).

The dense root system of mangrove trees also helps to reduce the wave action and hold the sediments. A thick belt of mangrove forest not only minimizes the coastal erosion but also traps valuable sediments, protects the hinder land under cultivation, dwellings and other developments from cyclones, storms or high tidal bores (Saenger *et. al.*, 1983). Since these detritus rich mangrove areas are used by valued table fishes, prawns, crabs and oysters for their reproduction or growth, such swamps are considered of great economic importance for capture as well as captive fisheries. The use of mangrove forests as sites of human settlements and reclamation for other conversion purposes has been a persistent danger to the existence of the said forest of late along the Indian coast. With the rapid development of industries and increase in population stress, the mangroves have become a major victim of exploitation.

There is adequate evidence in tropical mangrove ecosystem to show a direct correlation between the productivity of mangrove forest and fishery potential (Macnae, 1974). The importance of mangrove areas as nurseries for juvenile marine fisheries has been reported by various authors (Day *et al.*, 1981; Odum *et al.*, 1982; Thayer *et al.*, 1987; Robertson and Duke, 1987 & Blaber *et al.*, 1989).

Mangroves are salt tolerant forest ecosystem of tropical and subtropical intertidal regions of the world, where conditions are sheltered and suitable. The mangroves may form extensive and productive forests, which are the reservoirs of a large number of species of plants and animals. Planktonic and benthic animal communities play a vital role in the secondary and tertiary productivity in the mangrove ecosystems.

Several reports are available from the different mangrove ecosystems of west and east coasts of India. Untawale and Parulekar (1976) have studied the ecology of mangroves in the estuaries of Goa, but productivity values are not available for that region. The mangroves of Kutch are of open scrubby type with low wooded *Avicennia marina* and *Rhizophora mucronata.* The degree of sedimentation in the inshore waters of the Gulf seems to be most deleterious factor affecting the marine fauna (Pillai *et al.*, 1979). Effects of petroleum products on mangrove seedlings were studied by Jagtap and Untawale (1980). Silas and Alagarswami (1983) have suggested that the mangrove areas in the upper reaches of the creeks of the Andaman-Nicobar islands can be utilized for developing aquaculture farms without disturbing the mangroves on the sea front, which protect the coastal zone against sea erosion. The mangrove ecosystem of the Andaman-Nicobar areas has a very high production rate exceeding 2 $gC/m^2/day$ and attaining upto 3.6 $gC/m^2/day$ (Gopinathan and Rajagoplan, 1983). Jagtap (1985) have worked on the ecological studies in relation to the mangrove environment along the Goa coast. Data on primary, secondary and benthic production rates for the Mandovi – Zuari estuarine complex have been summarized by Qasim and Wafar (1990).

For Pichavaram mangroves on the east coast at Porto Novo Krishnamurthy and Sundararaj (1973) have given an average primary production rate of 7.56 $gC/m^2/day$ and a net production of 6.29 $gC/m^2/day$. The Pitcharavaram mangroves with a net work of creeks and canals, dominated by *Rhizophora* sp. and *Avicennia* sp. provide shelters and food for juveniles of mullets, prawns and edible oysters.

Choudhury and Chakrabarti (1974) studied the wildlife biology of Sundarbans, West Bengal. Choudhary (1978) carried out the study on the mangrove environment of Sundarbans, West Bengal. Ganapathy (1982) conducted studies on brackish water prawns and fish farming in Tamilnadu. Manikandavelu and Ramdhas (1994) carried out the work on bioproduction dynamics of Tuticorin mangrove ecosystem. Mangroves of Godavari delta are denser and dominated by *Avicennia* sp., *Exoecaria agallocha* and *Rhizophora* sp. and the larvae of economically important species of prawns *Penaeus monodon, P. indicus* and *Metapenaeus monoceros* which, migrate to the Godavari mangrove environment from the adjacent coastal waters (Chandra Mohan *et al.,* 1997).

The construction of barrages and bunds for irrigation has brought about imbalance in the mangrove ecosystems of Kerala. This environment is locally called as "Kandalkadu". The common source of pollution such as oil spillage, sewage, effluents from industries and agriculture practices using heavy doses of fertilizers and pesticides have been a threat to the mangrove ecosystem in Kerala. According to an estimate there were 70,000 hectares of mangrove marshes in Kerala, a few centuries ago (Blasco, 1975.) Vannucci (1984) stated that the whole backwaters of Kerala were once a mangrove swamps. In the south Vembanad region, the swampy areas (Kari lands) with black peaty soil having high proportion of carbanaceous wood, represent areas, which were dense mangrove in the past. These areas come to a total of 61 km^2. Similarly in the middle and northern sector of the backwaters about 60 km^2 of paddy-cum-shrimp culture fields, were also converted from mangrove marshes (Gopalan *et al.*, 1983). Even now the remnants of the mangrove vegetation can be seen in almost all such fields. The existing mangrove swamps of Kerala supports the growth and production of estuarine fishes and prawns. For mangroves of Cochin Backwater the value reported for primary production is 160-1485 $mgC/m^2/day$ (Rajagopalan, 1985). In this estuarine system, the mangrove areas of Vypin and Perumbalam form good nursery grounds for *Penaeus indicus, Metapenaeus dobsoni* and *M.monoceros* (Rajagopalan *et al.*, 1986). Mangroves of Puduvypin are denser and dominated by *Avicennia officianalis, Exoecaria agallocha, Rhizophora mucronata, R. apiculata, Acanthens ilicifolius* and *Brugueira* sp. and the larvae of economically important species of prawns *Penaeus monodon, P. indicus,* *Metapenaeus monoceros* and *M. dobsoni*, the crab *Scylla serrata* and fishes like *Mugil cephalus, Liza* sp., *Chanos chanos, Lates calcarifer, Eleutheronema tetradactylum, Elops saurus, Megalops cyprinoides and the larvae of scialids, perches and clupeids* which, migrate to the Puduvypin mangrove environment from the adjacent coastal waters (Purushan, personal communication). The fish seed recruitment details and the related aspects of this tidal ecosystem have been already been described (Purushan, 1989).

Investigations on the fauna of the mangrove swamps in Cochin estuary was initiated by Kurian (1984). Studies on the benthic fauna of the mangrove swamps of Cochin area was conducted by Sunilkumar (1993). Impact of environmental parameters on polychaetous annelids in the mangrove area was investigated by Sunilkumar and Antony (1994). The comparative study on the community structure and distributional ecology of benthos in the mangrove swamps of Cochin estuary was made by Sunil Kumar (1995). A new record of five species of polychaetes from the mangrove ecosystem of Cochin backwaters was reported by Sunilkumar (1999).

4.2 LOCATION OF THE SAMPLING STATIONS (Fig.3.1, Plates 4.1–4.111 & Table 4.1)

According to available historical evidence (Menon, 1924), the Vypin (9°58' to 10°12' N and 76°10' to 76°12' E) located in the central Kerala was formed in 1341AD as a result of a huge deluge. The northern arm of Vembanad lake extending between Cochin and Kodungallur separates it from the mainland. Cochin barmouth in the south, Arabian sea in the west and Munambam harbour in the north are its boundaries. Puduvypin is a naturally accreted wetland at the southwestern tip of Vypin island, which has taken shape in recent years. Being located only northwestern bank of Cochin barmouth facing Arabian sea most of the accreted area is subjected to inundation by semidiurnal type of rhythm in Cochin barmouth. The tidal inundation also brings into the area a large number of fish and shrimp seed of commercially important species, which are disseminated far and wide depending on the tidal amplitude. The almost 400 hectares area accreted so far is exclusively marshy with lot of mangrove vegetation.

MANGROVE ENVIRONMENT OF PUDUVYPIN

Stn. P1

Stn P2

PLATE 4.1

Stn. P3

Stn. P4

PALTE 4.11

Stn. P5

Stn. P6

The environment is a shallow salt marsh with a depth of about 1 to 1.5m, a width ranging from 40 to 50m and about a kilometer along the north south axis. Collections were made for water quality studies, sediment samples and benthos from 6 stations in the Puduvypin mangrove swamp. The stations are 50 to 60 m apart.

4.3 RESULTS

4.3.1 Water quality (Figs. 4.1 - 4.3)

Temperature (°C)

Spatial variation in temperature was very low and the values fluctuated between 30.4 and 33.0 during pre-monsoon months, 26.5 and 30.0 during monsoon months and 29.0 and 33.0 during post-monsoon months. The seasonal averages for the 6 stations showed that the pre-monsoon values were high compared to monsoon and post-monsoon values. The pre-monsoon, monsoon and post-monsoon averages for the 6 stations ranged from 30.75 to 31.75, 28.80 to 29.18 and 29.5 to 30.63 respectively. The annual range in temperature for the entire study area was between 26.5 and 33.0, where the minimum temperature was observed at stations P2, P3 and P6 in June and the maximum at station P1 in February and stations P4, P5 and P6 in October.

Salinity (psu)

In the study area fresh water condition (1.45 to 2.74) prevailed during June at all the stations, which slowly increased from July to November. From December onwards the salinity values fluctuated between 22.03 and 28.33 and reached maximum of 30.7 at stn. P4 during February. The spatial variation in salinity was not pronounced since the stations are very close. During monsoon months the values fluctuated between 1.45 (June) and 10.28 (August) both at station P1. The pre-monsoon values at different stations fluctuated between 19.58 (station P5) and 30.77 (station P4). Salinity during post-monsoon varied from the low value of 2.97 at station P5 (October) to a maximum of 28.33 at station P1 during December.

The salinity showed well-marked seasonal variation. The pre-monsoon values were always high compared to monsoon and post-monsoon. The seasonal averages for different stations ranged from 23.09 to 26.79 during pre-monsoon, 3.99 to 6.20

during monsoon and 15.50 to 16.71 during post-monsoon. The annual average for the different stations varied from 14.52 to 18.22% with an average of 15.16 for the entire area.

pH

During the investigation period the pH varied annually between 6.79 and 8.71 (av. 7.74), the minimum being at station P1 (June) and maximum at station P4 (November). Seasonal variation showed that the pre-monsoon average values were high compared to the other 2 seasons except at station P4, where the maximum pH (8.52) was during post monsoon. The average values during pre-monsoon, monsoon and post-monsoon ranged from 7.28 to 8.15, 7.16 to 7.85 and 7.29 to 8.52 respectively.

Dissolved oxygen (ml/l)

Well-oxygenated condition prevailed in the study area throughout the investigation period. The dissolved oxygen fluctuated annually from 2.32 (September) to 6.86 (April), 2.24 (September) to 6.09 (April), 2.23 (December) to 6.60 (August), 2.58 (December) to 7.52 (April), 2.13 (December) to 5.18 (September) and 2.46 (November) to 6.75 (April) at stations P1, P2, P3, P4, P5 and P6 respectively.

The seasonal averages showed that the pre-monsoon values were always higher compared to monsoon and post-monsoon. The seasonal averages for the study area during the respective seasons ranged between 4.06 and 6.51, 3.71 and 5.16 and 3.33 and 5.09. The dissolved oxygen values for the entire study area varied between 2.13 at P5 during December and 7.52 during April at station P4 with an average of 4.30. The annual average for the different stations varied from 3.42 to 4.99 (av. 4.30)

Biological Oxygen Demand (BOD_5) (mg/l)

The biochemical oxygen demand for the entire area varied between 0.0 and 4.89 annually. The seasonal variation showed that in almost all stations the biochemical oxygen demand was not detected during pre-monsoon except at stns. P5 and P6, where the averages were 2.19 and 2.16 respectively. During monsoon months the BOD_5 values ranged between 0.59 and 2.63. During post-monsoon an average value of 2.42 was observed at stn. P2. Rest of the stations showed nil values. The annual average for the different stations varied from 0.22 to 1.43 (av. 0.85).

Nitrite (µmol/l)

The nitrite fall in range of 0.15 to 3.70 at station P1, 0.25 to 2.56 at station P2, 0 to 2.39 at station P3, 0.02 to 2.45 at station P4, 0.22 to 4.67 at station P5, and 0.17 to 2.91 at station P6. The maximum value observed at all stations was during June to September. The seasonal variations for the entire area showed that the monsoonal average was high compared to pre-monsoon and post-monsoon. The pre-monsoon, monsoon and post-monsoon averages for the entire area fall in the range of 0.31 to 0.50, 1.36 to 2.67 and 0.17 to 0.94 respectively. The annual range in nitrite concentration for the study area was between 0.0 and 4.67 with an average of 0.87.

Nitrate (µmol/l)

At stations P1, P2 and P3, the minimum nitrate values were observed in April and the values were 0.30, 0.22 and 0.37 respectively, whereas the maximum values observed were 6.35 at station P1 (July), 7.47 at station P2 (January) and 6.85 at station P3 (January). At station P4, the values ranged from 1.00 (April & June) to 9.71 (January). At stations P5 and P6 the minimum values were during September (0.741 & 0.3) and maximum in August (18.55) and October (9.12) respectively.

The seasonal averages showed that at stations P1, P2 & P3 the post-monsoon values were higher than pre-monsoon and monsoon, where as at stations P4, P5 and P6 the monsoon values were higher than pre-monsoon and post-monsoon. The average for 6 stations ranged from 0.74 to 3.49 during pre-monsoon, 2.19 to 11.95 during monsoon and 3.86 to 6.30 during post-monsoon. The annual range for the entire study area varied from 0.22 to 18.55 (av. 4.31).

Ammonia (µmol/l)

Unlike the other nitrogen compounds the ammonia concentration fluctuated between stations and months. The minimum ammonia concentration observed was 0.38 (January) at station P1, 0.24 (April) at station P2, 0.38 (July) at station P3, 2.05

(January) at station P4, 8.23 (April) at station P5 and 1.38 (February) at station P6. The maximum values were observed during September at stations P1 to P6 and the corresponding values were 146.75, 41.61, 145.5, 34.53, 184.0 and 46.0 µmol/l. Station P5 showed the maximum values throughout the investigation period.

The seasonal variation showed that the monsoon values were always high compared to pre-monsoon and post-monsoon at stations P1 to P6. The average values ranged between 1.55 and 8.57 during pre-monsoon 16.32 and 71.84 during monsoon and 6.12 and 16.89 during post-monsoon. Monsoonal averages for ammonia concentration was 8.5 times higher than pre-monsoon and 3.5 times higher than post-monsoon. The annual ammonia values for the entire area showed a wide range between 0.24 and 184.0 (av. 17.65).

Inorganic Phosphate (µmol/l)

The phosphate values at station P1 to P6 showed the minimum during December and the respective values were 0.90, 4.22, 5.06, 3.84, 4.37 and 2.60. The maximum values were 27.19 (July) at station P1, 54.92 (August) at station P2, 54.25 (September) at station P3, 67.66 (April) at station P4, 40.42 (July) at station P5, and 19.89 (July) at station P6.

The seasonal variation at different stations showed that the monsoon values were very high compared to pre-monsoon and post-monsoon. Except at station P4, where the pre-monsoon values were high compared to the other two seasons. At stations P1 to P6 the values ranged from 9.01 to 50.44 during pre-monsoon, 14.84 to 37.36 during monsoon and 4.31 to 17.32 during post-monsoon. The annual range for the entire area varied from 0.90 to 67.66 with an average of 19.52.

Chlorophyll 'a' (mg/m^3)

Spatial variation in chlorophyll 'a' content showed comparatively low values at stns. P5 & P6 and high values at P4. At stns. P1 to P6, the minimum values were observed during June and the corresponding values were 0.37, 1.25, 1.57, 1.68, 1.94 and 1.20. The maximum values observed were 32.85 (August), 25.06 (July), 36.35

(August), 87.34 (September), 10.74 (April) and 14.44 (August) at stations P1 to P6 respectively.

Seasonal variation was well pronounced during monsoon, the average chlorophyll 'a' ranged between 4.87 and 37.65. The pre-monsoon and post-monsoon showed the range of 7.43 to 25.19 and 2.56 to 19.78 at station P1 to P6. The annual range in chlorophyll 'a' for the six stations varied from 0.37 to 87.34 (av. 12.46) during the investigation period.

Particulate Organic Carbon (mg/l)

Spatial and temporal distribution in POC did not show any particular pattern. Maximum value for POC (98.28) was noticed at station P4. The low value of POC was noticed in December at station P1 to P3 and in June at stations P4 to P6. High values were observed in September at all other stations except P2 and P5 where it was in August. The minimum values at P1 to P6 were 1.89, 1.68, 1.95, 3.40, 2.65 & 0.38 respectively whereas the corresponding maximum values were 13.86, 15.44, 22.68, 28.04, 7.88 and 11.34.

The seasonal variation showed that the monsoon average for the entire area was 2 times higher than pre-monsoon and 3 times higher than post- monsoon. The values ranged from 3.95 to12.81during pre-monsoon, 5.28 to 33.41 during monsoon and 2.38 to13.53 during post-monsoon at stations P1 to P6. The annual average for the entire study area varied from 1.68 to 98.28 with an average of 7.84.

Suspended load (mg/l)

Except for a few low values suspended load was high at all stations irrespective of seasons. At stations P1 to P4 and P6 minimum suspended load was recorded during August whereas P5 showed minimum during December, the values being 9.10, 5.50, 9.20, 22.50, 16.76 and 11.10 respectively. Maximum values at stations P1 & P2 were during November (120.75 and 92.95) and rest of the stations (P3 to P6) showed the maximum during September and the corresponding values were 136.20, 776.60, 79.90 and 98.70.

The values at different stations ranged between 20.93 and 74.79 during pre-monsoon 35.50 and 62.24 during monsoon and 44.90 and 118.83 during post monsoon. Though seasonal variation was not well marked comparatively high values were noticed during post-monsoon and low during monsoon for the entire area. The suspended load for the entire area varied from 5.50 to 136.20 except for an abnormal high value of 776.60 during September at station P4. The annual averages for the different stations varied from 47.39 to 76.37 (av. 57.15).

4.3.2 Sediment characteristics (Figs. 4.4 - 4.5 & Table 4.2)

Grain size distribution (%)

The substratum characteristics of the study area showed temporal and spatial variations. At station P1, the sediment composition such as clayey sand, silty sand, silty clay and sandy clay were observed during the study. The clayey sand was observed during June, September, October, January and February. The substratum was sandy clay in July and December; silty sand in August and silty clay during November and April. The sand, silt and clay percentages varied from 4.36 to 64.05, 2.49 to 30.82 and 22.15 to 64.85 during the study period. At station 2 also monthly variations was observed and substratum was categorized viz. silty clay, silty sand, sandy clay and clayey sand. The sand, silt and clay composition ranged from 6.71 to 71.89, 0.35 to 30.99 and 4.70 to 67.30 respectively. The most common substratum was silty clay during June, November, December, January and February. In July, September and April the substratum was sandy clay, in August it was silty sand and in October the substratum was clayey sand. Clay predominated throughout the study period at station P3 and it varied from 46.20 to 86.60 whereas the ranges for sand and silt percentages were from 0.52 to 35.87 and 0.70 to 39.58 respectively. The substratum was silty clay throughout the investigation period except in June at station 4. In June the percentage composition of sand, silt and clay was 59.31, 13.99 and 26.70 respectively. At this station in rest of the months the sand varied from 1.56 to 13.33, the silt from 1.79 to 34.57 and clay from 26.70 to 96.65. At station 5, sandy clay, silty clay and clayey sand were observed. The composition was sandy clay in all the months except in June, August and September, where as in June it was clayey sand and in August and September it showed the silty clay. At station P6, the substratum was silty clay throughout the investigation period. The sand percentage varied from 0.18 to 2.93, silt percentage from 12.88 to 39.52 and clay percentage from 59.65 to 86.55.

The seasonal variation showed that at station P1 during pre-monsoon and post monsoon the substratum was sandy clay where as during monsoon it was clayey sand. At all other stations the pre-dominance of clay was noticed throughout the investigation period. The sand percentage in the study area from P1 to P5 varied from 2.05 to 36.63 (av. 20.67) during pre-monsoon, 6.93 to 47.16 (av.27.53) during monsoon and 5.84 to 35.59 (av. 20.88) during post-monsoon. The sand portion at station P6 was very low (<2) throughout the period. The silt portion in this area varied from 15.86 to 43.05 (av. 22.24) during pre-monsoon, 16.29 to 29.29 (av. 22.39) during monsoon and 18.06 to 32.84 (av. 24.30) during post-monsoon. Clay portion was high at all stations throughout the period varying from 43.05 to 77.50 (av. 63.93) during pre-monsoon, 36.53 to 70.0 (av. 54.55) during monsoon and 44.77 to 67.76 (av.57.77) during post-monsoon.

The annual variations in sand and silt were from 0.18 (station P6, December) to 71.89 (station P2, August), 0.35 (station P2, July) to 40.50 (station P5, August). Clay portion, except for a low value of 4.70 at station P2 during August varied from 22.15 (station P1, June) to 96.65 (station P4, July). The averages for sand, silt and clay for the entire area were 18.1, 23.01 and 58.73.

Organic matter (%)

The organic matter content was high at stations P1 to P6 throughout the investigation period. The values ranged from 1.37 (February) to 6.54 (June) at station P1, 1.25 (October) to 6.37 (June) at station P2, 3.87 (February) to 7.11 (November) at station P3, 2.74 (June) to 6.69 (November) at station P4, 2.02 (October) to 6.78 (February) at station P5 and 2.50 (January) to 5.47 (February and December) at station P6.

Seasonal variation in organic matter content was not well marked in the area. The pre-monsoon values varied from 1.95 to 5.16 (av. 4.04) where as the monsoon and post monsoon values were in the range of 4.10 to 5.13 (av. 4.59) and 3.04 to 5.79

(av. 4.27) respectively. The annual variation for the entire area was from 1.25 to 7.11 with an annual average of 4.30.

Energy content (J/g dry weight)

The energy content was high at stns. P1 to P6 throughout the investigation period. The values ranged from 295.90 (February) to 1412.90 (June) at stn. P1, 270.00 (October) to 1375.90 (June) at stn. P2, 835.90 (February) to 1535.80 (November) at stn. P3, 591.80 (June) to 1445.00 (November) at stn. P4, 436.30 (October) to 1464.50 (February) at stn. P5 and 540.00 (January) to 1181.50 (February and December) at stn. P6.

Seasonal variation in energy content was not well marked in the area. The pre-monsoon values varied from 421.20 to 1114.60 (av. 871.74) where as the monsoon and post monsoon values were in the range of 886.65 to 1132.38 (av. 979.28) and 656.63 to 1250.65 (av. 923.95) respectively. The annual variation for the entire area was from 270.00 to 1535.80 with an annual average of 924.99.

4.3.3 Bottom fauna (Figs 4. 6 - 4. 18 & Tables 4.3 - 4.5)

Standing stock (Density-No./m^2 and Biomass- g/m^2) - Fig. 4.6 & Tables 4.3 - 4.4

A total number of 27226 specimens were recorded during the study period at station P1. The density ranged between 126 (October) and 13002/m^2 (September) with an annual average of 2723/m^2. Average value during the monsoon (4772/m^2) was high compared to pre-monsoon (615/m^2) and post-monsoon (1727/m^2). The total biomass recorded was 136.42g and the biomass ranged from 3.19 (February) to 33.24g/m^2 (July) with an annual average of 13.64g/m^2. The seasonal averages during pre-monsoon, monsoon and post-monsoon were 6.19g/m^2, 17.61g/m^2 and 13.40g/m^2 respectively.

A total density of 12192 was noticed during the investigation period at station P2. The values ranged from 21 (April) to 3738/m^2 (November) with an average of 1219/m^2. The seasonal observations showed the maximum average density during post-monsoon (2025/m^2) compared to pre-monsoon (646/m^2) and monsoon (699/m^2).

The total biomass recorded at this station was 135.10g with an average of 13.51g/m^2. The biomass ranged between 0.46 (April) and 24.56g/m^2 (October). The seasonal averages for pre-monsoon, monsoon and post-monsoon were 3.55g/m^2, 15.51g/m^2 and 16.50g/m^2 respectively.

A total value of 21206 was recorded at station P3 with an average of 2121/m^2. The density varied from 84 (June) to 7917/m^2 (September). Averages for the monsoon were high (2825/m^2) compared to pre-monsoon (698/m^2) and post-monsoon (2127/m^2). The total biomass recorded was 237.32g ranging between 2.02 (June) and 118.15g/m^2 (July) with an average of 23.73g/m^2. Monsoon averages (42.13g/m^2) were high compared to pre-monsoon (6.37g/m^2) and post-monsoon (14.02g/m^2)

The total number of specimens recorded at station P4 was 6698. The density ranged between 84 (October) and 1688/m^2 (June and July) with an annual average of 670/m^2. The seasonal averages were 659/m^2, 980/m^2 and 215/m^{2}during pre-monsoon, monsoon and post-monsoon respectively. A total biomass of 101.05g was recorded with an annual average of 10.11g/m^2 and the values ranged between 2.76 (January) and 24.91g/m^2 (June). The pre-monsoon, monsoon and post-monsoon averages were 14.01g/m^2, 12.70g/m^2 and 5.56g/m^2 respectively.

A total numerical abundance of 35634 recorded at station P5 with the values ranging from 105 (October) to 19502/m^2 (September) with an average of 3563/ m^2. Monsoon average was much higher (7110/m^2) compared to Pre-monsoon (793/ m^2) and post-monsoon (1402/ m^2). Biomass showed a total of 257.43g ranging between 2.60 (February) and 50.07g/m^2 (August) with an annual average of 25.74g/m^2. The monsoon averages (29.40g/m^2) was high compared to pre-monsoon (17.56 g/m^2) and post-monsoon (11.19 g/m^2) periods.

A total density of 53343 was recorded at station P6 with an annual average of 5334/m^2 and values ranged between 1811 (October) and 20898/m^2 (September). The seasonal average showed its maximum during monsoon (9345/m^2) followed by pre-monsoon (3219/m^2) and post-monsoon (2382/m^2). The total biomass obtained was

240.32g ranging between 8.31 (January) and 79.04g/m^2 (September) with an annual average of 24.03g/m^2. The monsoon average was high (37.83g/m^2) compared to pre-monsoon (13.15g/m^2) and post-monsoon (15.67g/m^2).

Community structure (Figs. 4.7 to 4.18 & Table 4.5)

Station P1

Ten faunal groups were noticed at station P1. Of these tanaidaceans were present in all months except April with a maximum abundance in September (83.96%) followed by 50.35% in July. Except June, polychaetes were present in all the other months with a maximum contribution of 70.31% in November. Amphipods were present in October and April and contributed the maximum percentage of 84.50% in June followed by 63.43% in August. Gastropods contributed 3.48% in July, 26.31% in December and 94.84% in April. Juvenile fishes were noticed only during September, January and April contributing 0.16%, 1.90% and 2.58% respectively. Isopods and mysids occurred in 2 months each and bivalves, decapods and anthozoans were obtained only once.

Tanaidaceans were the most abundant and common group with a total density of 15152, contributing 55.65% of the benthic community. The density ranged from 42 (June and December) to 10917/m^2 (September) with an annual average of 1515/m^2. The frequency of occurrence was 9/10. The seasonal averages showed the maximum abundance in monsoon (3370/m^2) followed by post-monsoon (366/m^2) and pre-monsoon (105/m^2).

Apseudes gymnophobium and *A. chilkensis* were the two species obtained during the study and showed a total number of 10024 and 5128 respectively. The frequency of occurrence of both species was 8/10. *Apseudes gymnophobium* showed the maximum abundance in September (7542/m^2) followed by 1292/m^2 in July and minimum density was in October and February (21/m^2) followed by 42/m^2 in June and was absent in December and April. *Apseudes chilkensis* was absent in June and April and the density ranged from 42 (October and December) to 3375/m^2 (September).

Both the species were present during pre-monsoon, monsoon and post-monsoon with higher density during monsoon. *Apseudes chilkensis* showed the total abundance of 189, 4104 and 835 during pre-monsoon, monsoon and post-monsoon respectively. The corresponding density for *Apseudes gymnophobium* were 21, 9376 and 627.

Amphipods were the next abundant group numbering 6026, which contributed 22.13% of the benthic population. The density ranged between 168 (February) and 1980/m^2 (September) with an annual average of 603/m^2. The frequency of occurrence were 8/10 and the averages for pre-monsoon, monsoon and post-monsoon were 84, 1146 and 319/m^2 respectively.

The species viz. *Melita zeylanica, Grandidierella gilesi* and *Quadrivisio bengalensis* were obtained during the study. Out of these *Melita zeylanica* showed higher abundance (5774) compared to *Grandidierella gilesi* (147) and *Quadrivisio bengalensis* (105). The frequency of occurrence of the three species was 8/10, 2/10 and 3/10 respectively. *Melita zeylanica* was absent in October and April and the density ranged from 84 (December) to 1938/m^2 (September). *Grandidierella gilesi* was present in November (63/m^2) and December (84/m^2) and *Quadrivisio bengalensis* in July (42/m^2), September (42/m^2) and January (21/m^2).

The seasonal variations showed that *Melita zeylanica* was observed in all the three seasons. The seasonal averages during pre-monsoon, monsoon and post-monsoon were 84, 1125 and 277/m^2 respectively. *Grandidierella gilesi* was present only during post-monsoon (av. 37/m^2) and *Quadrivisio bengalensis* during monsoon (av. 21/m^2) and post-monsoon (av. 4/m^2).

Polychaetes were the third in abundance with a total number of 4794, forming 17.61% of the benthic community. High density was observed in November (3709/m^2) followed by 791/m^2 in July and a low density of 21/m^2 was observed in August, February and April. The frequency of occurrence was 9/10. The seasonal variation showed highest average density (975/m^2) during post-monsoon, which reduced to 214/m^2 during monsoon and 21/m^2 during pre-monsoon.

Lycastis indica (family – Nereidae), *Prionospio polybranchiata* (family – Spionidae), *Capitella capitata* (family – Capitellidae) and *Sternaspis scutata* (family – Sternaspidae) were the 4 species of polychaetes encountered with a frequency of occurrence of 3/10, 2/10, 7/10 and 3/10 respectively. *Lycastis indica* showed a density of 21/m^2 in October, November and January and *Prionospio polybranchiata* was present in October (21/m^2) and April (21/m^2). *Capitella capitata* showed the minimum density of 21/m^2 in August, October, December and January and maximum density of 3688.m^2 in November followed by 791/m^2 in July. *Sternaspis scutata* was present in December (21/m^2), January (42/m^2) and February (21/m^2).

The seasonal variation showed that all the 4 species (*Lycastis indica, Prionospio polybranchiata, Capitella capitata* and *Sternaspis scutata*) were present during post-monsoon with a total density of 63, 21 3751 and 63 respectively. During pre-monsoon *Prionospio polybranchiata* (21) and *Sternaspis scutata* (21) were observed and during monsoon only *Capitella capitata* (854) was observed.

The fourth dominant group was gastropods with a numerical abundance of 981 forming 3.60% of the benthic population. The density ranged between 105 (July and December) and 771/m^2 (April) and the frequency of occurrence was 3/10. The pre-monsoon showed the seasonal average of 386/m^2, which reduced to 26/m^2 during monsoon and post-monsoon.

Littorina littorea and *gastropod* sp. were observed during the study period. *Littorina littorea* was observed only in April (771/m^2) and gastopod sp. in July and December contributing 105/m^2 in both the months. gastropod sp. was observed during monsoon (105) and post-monsoon (105) and *Littorina littorea* during pre-monsoon (771).

Mysids represented 0.39% of the benthic population with a total number of 105 formed the next abundant group. This group was present in November (63/m^2) and December (42/m^2) and the frequency of occurrence was 2/10. The seasonal average was 26/m^2 during pre-monsoon.

Juvenile fishes and isopods ranked sixth and seventh in abundance contributing 0.23% and 0.15% respectively. Total density of juvenile fishes was 63 and was observed in three seasons with an average of 11/m^2 during pre-monsoon and 5/m^2 during monsoon and post-monsoon. The total number of isopods was 42 and was observed in September (21/m^2) and November (21/m^2). The seasonal average was 5/m^2 during monsoon and post-monsoon. Isopods were represented by only one species viz. *Asellus* sp. in this station Decapods, bivalves and anthozoans were the rare groups, each with a numerical abundance of 21, contributing 0.08% of the benthic population. All the three groups showed the frequency of occurrence of 1/10. Penaeid prawns representing decapods were present in November (21/m^2) and the seasonal average was 5/m^2 during post-monsoon. *Bivalve* sp. was present only in September and the average was 5/m^2 and the anthozoans were present in February with a seasonal average of 11/m^2 during pre-monsoon.

Station P2

Nine groups were recorded from station P2. Of these amphipods were the only group present through out the study period and the percentage contribution ranged between 3.14 (August) and 100% (April). Tanaidaceans and polychaetes were the next groups observed in 8 months followed by miscellaneous groups in 3 months. Juvenile fishes were present in 2 months and decapods, mysids, gastropods and bivalves were noticed in one month each. Tanaidaceans showed the maximum percentage contribution in February (57.36%) followed by 53.47% in January and minimum in July (4.57%). Polychaetes were the maximum in September (89.9%) and minimum in January (10.49%).

Tanaidaceans ranked first in numerical abundance with a total density of 4526 forming 37.11% of the benthic population. The density fall within the range of 42 (June, July and August) to 1918/m^2 (January) and the frequency of occurrence was 8/10; October and April showed their absence. The seasonal observation showed high average values during post-monsoon (901/m^2), which decreased to 365/m^2 during pre-monsoon and 47/m^2 during monsoon.

Apseudes chilkensis and *A. gymnophobium* were the 2 species encountered during the study and their total abundance were 3751 and 775 respectively and their corresponding frequency of occurrence were 6/10 and 7/10. Both the species showed the maximum abundance in November (1312/m^2 and 271/m^2) and minimum in June and September (21/m^2) for *Apseudes chilkensis* and in June for *Apseudes gymnophobium*. Post-monsoon showed the highest total number (3146 & 460) compared to pre-monsoon (563 & 168) and monsoon (42 & 147) for *Apseudes chilkensis* and *A. gymnophobium.*

Polychaetes were the second group in abundance (3450) forming 28.30% of the benthic population. The frequency of occurrence was 8/10 with high density (1176/m^2) in November followed by 935/m^2 in September. The minimum density (42/m^2) was observed in June and October. This group was absent during pre-monsoon and the average numbers for monsoon and post-monsoon were 438/m^2 and 425/m^2 respectively.

Lycastis indica, Dendronereis aestuarina and *Perinereis cavifrons* (family – Nereidae), *Prionospio polybranchiata* (family – Spionidae), *Capitella capitata* (family – Capitellidae) and *Sternaspis scutata* (family – Sternaspidae) were the six species of polychaetes encountered during the study. *Prionospio polybranchiata* (649) and *Capitella capitata* (2175) were the common species with a frequency of occurrence 6/10 followed by *Dendronereis aestuarina* (458) with a frequency of occurrence of 5/10. The other 3 species were observed in one month each. *Capitella capitata* showed the maximum occurrence in November (882/m^2) followed by 708/m^2 in September and the minimum in December (21/m^2). *Prionospio polybranchiata* was high in abundance in November (189/m^2) followed by 167/m^2 in July and low in June (42/m^2). *Dendronereis aestuarina* was abundant in September (227/m^2) and low in December (21/m^2). *Lycastis indica* (42/m^2) was present in July and *Perinereis cavifrons* (21/m^2) and *Sternaspis scutata* (105/m^2) were present in January only. Seasonal variation showed that *Lycastis indica* (av.10/m^2), *Dendronereis aestuarina* (av. 73/m^2), *Prionospio polybranchiata* (av. 84/m^2) and *Capitella capitata* (av. 271/m^2) were observed during monsoon and *Dendronereis aestuarina* (av. 42/m^2), *Perinereis cavifrons* (av. 5/m^2), *Prionospio polybranchiata* (av. 79/m^2), *Capitella capitata* (av. 273/m^2) and *Sternaspis scutata* (av. 26/m^2) were observed during post-monsoon.

Amphipods were the third in abundance numbering 3443 forming 28.25% of the benthic community. This group was the common one and the frequency of occurrence was 10/10 with a high density of 1292/m^2 in January followed by 916/m^2 in November and a minimum of 21/m^2 in August and April. The seasonal average was high during post-monsoon (673/m^2), which reduced to 282/m^2 during pre-monsoon and 47/m^2 during monsoon.

Two species of amphipods namely, *Melita zeylanica and Quadrivisio bengalensis* were obtained during the study period with a frequency of occurrence 9/10 and 3/10 respectively. The maximum abundance of *Melita zeylanica* was observed in January (1292/m^2) followed by 916/m^2 in November and the minimum in July and April (21/m^2). *Quadrivisio bengalensis* showed the abundance of 21/m^2 in July, August and December. *Melita zeylanica* was observed during pre-monsoon, monsoon and post-monsoon whereas *Quadrivisio bengalensis* was observed during monsoon and post-monsoon.

Anthozoa numbering 584 and forming 4.80% of the benthic population was the next abundant group and the frequency of occurrence was 3/10. This group was present in July (375/m^2), August (167/m^2) and November (42/m^2) and was present during monsoon and post-monsoon.

Gastropods were the next abundant group with a total density of 63 and the frequency of occurrence was 1/10. *Dentalium* sp. was the only representative of this group and was present only in August and the seasonal average during monsoon was 16/m^2.

Bivalves and juvenile fishes each numbering 42 forming 0.34% of benthos were the next rare groups. Their frequency of occurrence was 1/10 and 2/10 respectively. *Cardium* sp. representing bivalves was present in October only (42/m^2) and the seasonal average for post-monsoon was 11/m^2. Juvenile fishes were present in July ($21/m^2$) and November ($21/m^2$) and the seasonal averages for pre-monsoon and post-monsoon were $5/m^2$ each.

Decapods (penaeid prawn) and mysids were the least represented groups with a percentage contribution of 0.17 with a numerical abundance of $21/m^2$. They were present only during monsoon.

Station P3

Eight groups were encountered from this station Polychaetes, amphipods and tanaidaceans were obtained in all the months. Polychaetes showed the maximum percentage contribution (69.02%) in November and minimum (2.1%) in February whereas amphipods and tanaidaceans ranged from 12.89 (September) to 68.18% (April) and 6.14 (July) to 76.32% (September) respectively. All the other groups were below 10% in all months.

Tanaidaceans were the most dominant group with a numerical abundance of 9713 contributing 45.81% of benthic population. This group showed the frequency of occurrence of 10/10 with a high density of $6042/m^2$ in September followed by $1521/m^2$ in August. Low densities were obtained during June ($21/m^2$) and July ($63/m^2$).

Apseudes chilkensis (4773) and *A. gymnophobium* (4940) were the 2 species obtained with a frequency of occurrence 6/10 and 8/10 respectively. Both the species were maximum in September ($3354/m^2$ and $2688/m^2$) and minimum in June ($21/m^2$). The seasonal observations showed the maximum values during monsoon compared to other seasons. *Apseudes chilkensis* was not recorded during pre-monsoon months. The total number of *Apseudes chilkensis* during monsoon and post-monsoon were 3980 and 793 where the pre-monsoon, monsoon and post-monsoon values for *Apseudes gymnophobium* were 563, 3667 and 710 respectively.

Polychaetes were the next abundant group contributing 26.95% to the benthic population with a numerical abundance of 5718 and the frequency of occurrence was 10/10. The minimum density of $21/m^2$ was obtained in June, February and April and a maximum of $3438/m^2$ in November followed by $833/m^2$ in September. The pre-monsoon, monsoon and post-monsoon averages were $21/m^2$, $386/m^2$ and $1032/m^2$ respectively.

Dendronereis aestuarina (family – Nereidae), *Glycera longipinnis* (family – Glyceridae), *Prionospio polybranchiata* (family – Spionidae) and *Capitella capitata* (family – Capitellidae) were the 4 species of polychaetes with a total number of 670, 21, 898 and 4129 respectively and the corresponding frequency of occurrence were 6/10, 1/10, 7/10 and 6/10. The densities ranged from 21 (December) to $250/m^2$ (September), 21 (June, November, January and April) to $583/m^2$ (November) and $21/m^2$ (February) to $3375/m^2$ for *Dendronereis aestuarina, Prionospio polybranchiata* and *Capitella capitata* respectively. *Glycera longipinnis* was present only in December ($21/m^2$).

The seasonal variation showed that *Prionospio polybranchiata* and *Capitella capitata* were obtained during the three seasons. The numerical abundance during pre-monsoon, monsoon and post-monsoon were 21, 835 and 42 for *Prionospio polybranchiata* and 21, 271 and 3837 for *Capitella capitata. Dendronereis aestuarina* was noticed during monsoon (439) and post-monsoon (231) whereas *Glycera longipinnis* was observed during post-monsoon (21) only.

Amphipods ranked third in numerical abundance (5250) contributing 24.76% to the benthic population with a frequency of occurrence 10/10. The highest density was in November ($1146/m^2$) followed by $1021/m^2$ in September and the minimum density of $42/m^2$ was in June. The post-monsoon average ($677/m^2$) was high which reduced to $438/m^2$ during monsoon and $395/m^2$ during pre-monsoon.

Melita zeylanica (5166), *Grandidierella gilesi* (63) and *Quadrivisio bengalensis* (21) were the three species of amphipods with the frequency of occurrence 10/10, 1/10 and 1/10 respectively. The density of *Melita zeylanica* ranged between 42 (June) to $1146/m^2$ (November) and the seasonal averages were 395, 438 and $656/m^2$ during pre-monsoon, monsoon and post-monsoon respectively.

Grandidierella gilesi and *Quadrivisio bengalensis* were observed only in December ($63/m^2$) and October ($21/m^2$) respectively.

Anthozoans contributing 0.98% with a total number of 210 ranked fourth and the frequency of occurrence was 4/10. This group was observed in July ($105/m^2$), August ($63/m^2$), October ($21/m^2$) and November ($21/m^2$). The seasonal averages were $42/m^2$ and $11/m^2$ during monsoon and post-monsoon respectively.

Gastropods were the next group in abundance (105) forming 0.50% with a frequency occurrence of 2/10. The densities were $84//m^2$ in July and $21/m^2$ in January. Seasonal averages of $21/m^2$ and $5/m^2$ were observed during monsoon and post-monsoon respectively.

Littorina littorea and *Dentalium* sp. were the 2 species of gastropods and obtained in January ($21//m^2$) and July ($84/m^2$) respectively. *Littorina littorea* was present during post-monsoon and *Dentalium* sp. during pre-monsoon.

Decapods consisting of penaeid prawn and crabs were the next group in abundance (84) forming 0.40% of the benthic population with a frequency of occurrence of 2/10. Penaeid prawn was noticed in July ($21/m^2$) and crab in December ($63/m^2$). Seasonal average of $5/m^2$ and $16/m^2$ were observed during monsoon and post-monsoon respectively.

Bivalves and juvenile fishes with an abundance of 63 contributing 0.30% to the benthic population were the least abundant group. The frequency of occurrence was 1/10 for bivalves and 3/10 for fishes. Seasonal average of $16/m^2$ during monsoon was obtained for bivalves whereas fishes showed an average of $5/m^2$ during monsoon and $11/m^2$ during post-monsoon. *Bivalve* sp. ($21/m^2$), *Cavolina* sp. ($21/m^2$) and *Cardium* sp. ($21/m^2$) were observed in July and the juvenile fishes were obtained in September, October and January contributing $21/m^2$ in each month.

Station P4

Ten groups viz. Polychaetes, amphipods, tanaidaceans, decapods, mysids, gastropods, bivalves, insects, juvenile fishes and miscellaneous groups (foraminifera and anthozoa) were obtained during the investigation period (Fig.). Polychaetes were the most common group followed by tanaidaceans, juvenile fishes, amphipods and gastropods. The percentage contribution varied from 2.49 (July) to 58.29 (November) for polychaetes, 4.98 (July) to 87.38 (August) for tanaidaceans, 4.24 (July) to 17.78 (February) for fishes, 20.00 (September) to 67.14 (April) for amphipods and 37.52 (November) to 64.22 (June) for gastropods, 14.36 (February) to 20.0 (September) for anthozoa. Foraminifera showed the percentage contribution of 14.29 in December.

Insects were the most dominant group numbering 1604 forming 23.96% of the benthic population though the frequency of occurrence was 2/10. This group was present only in July (1541/m^2) and October (63/m^2). The seasonal average showed a value of 385/m^2 during monsoon and 16/m^2 during post-monsoon. Water beetle was the only representative of the group insects.

The second abundant group was the gastropods forming 20.25% with a numerical abundance of 1356. The frequency of occurrence was 3/10 with densities of 1084/m^2 in June, 188/m^2 in November and 84/m^2 in December. The monsoon and post-monsoon averages were 271/m^2 and 68/m^2 respectively.

Gastropod sp. and *Littorina littorea* were the 2 species of gastropods observed during the study. Gastropod sp. was present in June (21/m^2) and December (84/m^2) and *Littorina littorea* in June (1063/m^2) and November (188/m^2). Both the species were present during monsoon and post-monsoon only.

Polychaetes were the third abundant group numbering 1355 forming 20.24% of the benthic population with a frequency of occurrence 9/10. The maximum density was observed in June (604/m^2) followed by 312/m^2 in April and 292/m^2 in November. The minimum density of 21/m^2 was observed in September, October, December, January and February and 42/m^2 in July. Polychaetes were absent in

August. The seasonal observations showed that pre-monsoon and monsoon recorded the averages of $166/m^2$ and $167/m^2$ respectively followed by $89/m^2$ during post-monsoon.

Lycastis indica and Dendronereis aestuarina (family – Nereidae), *Prionospio polybranchiata* (family – Spionidae) and *Capitella capitata* (family – Capitellidae) were the 4 species representing the polychaete fauna. *Lycastis indica* was obtained in November, December and April with density of $21/m^2$ each. *Dendronereis aestuarina* was present in September ($21/m^2$) and *Prionospio polybranchiata* in October ($21/m^2$) and February ($21/m^2$). *Capitella capitata* showed the frequency of occurrence of 6/10 with a maximum density of $604/m^2$ in June followed by $291/m^2$ in April and $250/m^2$ in November. The minimum density of $21/m^2$ was observed un October and January. The *Capitella capitata* was observed during pre-monsoon (av. $146/m^2$), monsoon (av. $162/m^2$) and post-monsoon (av. $73/m^2$) where as *Lycastis indica* and *Prionospio polybranchiata* was present during pre-monsoon and post-monsoon. *Dendronereis aestuarina* represented only during the monsoon (av. $5/m^2$).

Amphipods were the fourth abundant group forming 17.74% of the benthic fauna with a total number of 1189 and a frequency of occurrence of 4/10. This group was represented in September ($21/m^2$), January ($63/m^2$), February ($189/m^2$) and April ($895/m^2$). The pre-monsoon, monsoon and post-monsoon averages were $542/m^2$, $11/m^2$ and $16/m^2$ respectively.

Melita zeylanica and *Quadrivisio bengalensis* were the 2 species representing the amphipods having a frequency of occurrence of 3/10 and 1/10 respectively. *Melita zeylanica* was present in January ($63/m^2$), February ($189/m^2$) and April ($895/m^2$). *Quadrivisio bengalensis* was present only in September ($42/m^2$). *Melita zeylanica* was observed during pre-monsoon (av. $542/m^2$) and post-monsoon (av. $16/m^2$) and *Quadrivisio bengalensis* during monsoon (av.$11/m^2$).

Tanaidaceans with a frequency of occurrence 6/10 was the next abundant group with a numerical abundance of 774 forming 11.55% of benthic fauna. They were present during July to September and January to April. The maximum density of $291/m^2$ was in August and minimum in January ($21/m^2$). The seasonal observations showed the averages of $147/m^2$, $115/m^2$ and $5/m^2$ during pre-monsoon, monsoon and post-monsoon respectively.

Apseudes chilkensis and *A. gymnophobium* were the 2 species with a frequency of occurrence of 3/10 and 5/10 respectively. *Apseudes chilkensis* was present in July ($63/m^2$), September ($84/m^2$) and April ($42/m^2$). *Apseudes gymnophobium* showed the maximum density in August ($291/m^2$) following $189/m^2$ in February where the minimum density of $21/m^2$ was observed in July and January. The seasonal variation showed that *Apseudes chilkensis* was present during pre-monsoon (av.$21/m^2$) and monsoon (av.$37/m^2$) where as *Apseudes gymnophobium* was observed in all the three seasons with an average density of $126/m^2$, $78/m^2$ and $5/m^2$ respectively.

Juvenile fishes contributed 3.12% of the benthic population with a total number of 210 and the frequency of occurrence of 6/10. The maximum density of $105/m^2$ was observed in February and the minimum of $21/m^2$ during July to September and November & December. The average density for monsoon and post-monsoon were $16/m^2$ and $11/m^2$ respectively. Juvenile fishes were not recorded during pre-monsoon.

Foraminifera and anthozoa numbering 147 were the next abundant group forming 2.20% of the benthic fauna with a frequency of occurrence 3/10. Foraminifera were present in December ($21/m^2$) and anthozoa in September ($42/m^2$) and February ($84/m^2$). The seasonal observations showed that these groups were noticed during pre-monsoon, monsoon and post-monsoon with an average of $42/m^2$, $11/m^2$ and $5/m^2$ respectively.

Penaeid prawns, mysids and *bivalve* sp. numbering $21/m^2$, each forming 0.31% of the benthic fauna were the rare and least abundant groups. Penaeid prawn was present in January, mysids in April and bivalves in August.

Station P5

Six groups of organisms namely polychaetes, amphipods, tanaidaceans, decapods, gastropods and juvenile fishes were obtained during the study at this station The corresponding ranges of the percentage contribution of the above groups during the different months were from 2.72 (January) to 82.42 (June), 4.16 (June) to 66.64 (April), 9.26 (June) to 87.49 (August), 2.01 (December) to 6.29 (July), 0.98 (November) to 4.16 (June) and 3.2 (April) to 4.54 (September).

The faunal composition of major groups of benthos indicated dominance of tanaidaceans followed by amphipods and polychaetes. Tanaidaceans forming 79.64% with a total density of 28376 was the dominant group. The frequency of occurrence was 10/10 with a maximum abundance in September (18062/m^2) and minimum in October (42/m^2). The pre-monsoon, monsoon and post-monsoon averages were 250/m^2, 6125/m^2 and 844/m^2 respectively.

Apseudes chilkensis and *A. gymnophobium* were the 2 species obtained with a frequency of occurrence of 9/10 and 8/10 respectively. *Apseudes chilkensis* was absent in June and the total number varied from 42 (October) to 13896 (September), whereas the total number of *Apseudes gymnophobium* varied from 42 (July & February) to 4166/m^2 (September). The seasonal observations showed that the monsoon values were high compared to pre-monsoon and post-monsoon for both the species. The pre-monsoon, monsoon and post-monsoon averages were 94/m^2, 4667/m^2 and 771/m^2 respectively for *Apseudes chilkensis* whereas the corresponding values for *Apseudes gymnophobium* were 156/m^2, 1458/m^2 and 73/m^2.

The second dominant group was the amphipods with a total number of 4585 forming 12.87% of the benthic fauna. This group showed the frequency of occurrence 10/10 with the densities varying from 21 (July and October) to 1167/m^2 (September). The averages during pre-monsoon, monsoon and post-monsoon were 490/m^2, 401/m^2 and 500/m^2 respectively.

Three species of amphipods were encountered at this station and the species were *Melita zeylanica, Grandidierella gilesi* and *Quadrivisio bengalensis* with a frequency of occurrence of 10/10, 1/10 and 2/10 respectively. *Melita zeylanica* was the most abundant and common species with a total density of 4334 compared to *Quadrivisio bengalensis* (209) and *Grandidierella gilesi* (42). *Melita zeylanica* was the only one species observed during pre-monsoon (av. $490/m^2$), monsoon (av. $354/m^2$) and post-monsoon (av. $484/m^2$), *Quadrivisio bengalensis* was present during monsoon (av. $47/m^2$) and post-monsoon ($5/m^2$) and *Grandidierella gilesi* only during post-monsoon (av. $11/m^2$).

Polychaetes were the third group in abundance with the total number of 2336 forming 6.55% of the benthic population. The frequency of occurrence was 7/10 with a maximum density in June ($1664/m^2$) and minimum in October ($42/m^2$). The seasonal variations showed that the average values for pre-monsoon, monsoon and post-monsoon were $32/m^2$, $521/m^2$ and $47/m^2$ respectively.

Dendronereis aestuarina (family – Nereidae), *Prionospio polybranchiata* (family – Spionidae) and *Capitella capitata* (family – Capitellidae) were the 3 species encountered during the study. The numerical abundance of these 3 species were 105, 1627 and 604 respectively. *Prionospio polybranchiata* showed the frequency of occurrence of 5/10 where the maximum abundance was in June ($1396/m^2$) and minimum in November ($21/m^2$). *Dendronereis aestuarina* was present in August ($21/m^2$), September ($21/m^2$), October ($42/m^2$) and January ($21/m^2$). *Capitella capitata* was abundant in June ($268/m^2$) and low in April ($21/m^2$). *Prionospio polybranchiata* and *Capitella capitata* were observed in all the 3 seasons where as *Dendronereis aestuarina* was present in monsoon and post-monsoon only.

Juvenile fishes were the next group in abundance with a total number of 147 forming 0.41% and were present in September ($105/m^2$) and April ($42/m^2$) only representing the pre-monsoon and post-monsoon seasons.

Gastropods were the fifth group in abundance with a total number of 126 forming o.35% of benthos. The frequency of occurrence was 3/10 and was present in June ($84/m^2$), August ($21/m^2$) and November ($21/m^2$). The averages during monsoon and post-monsoon were $26/m^2$ and $5/m^2$ respectively.

Gastropod sp. and *Littorina littorea* were the 2 species representing the group. *Gastropod* sp. was present in November ($21/m^2$) and *Littorina littorea* in June ($84/m^2$) and August ($21/m^2$).

Decapods were the least dominant group with a total number of 63 and the frequency of occurrence was 3/10. Penaeid prawn was present in July ($21/m^2$) and September ($21/m^2$) and crab in December ($21/m^2$) only.

Station P6

The seven groups encountered at this station during the investigation period were polychaetes, amphipods, tanaidaceans, decapods, gastropods, juvenile fishes and miscellaneous groups (foraminifera and anthozoa). Amphipods and tanaidaceans were present in all the months followed by polychaetes in 6 months. The percentage contribution of amphipods ranged between 5.39 (September) and 45.77 (January) and tanaidaceans ranged from 53.46 (January) to 89.89 (August). Polychaetes were present from June to November and their percentage contribution ranged between 1.06 (August) and 9.60 (June).

Tanaidaceans numbering 43126 was the most dominant group forming 80.85% of the benthic population. The frequency of occurrence was 10/10 with the maximum density of $19438/m^2$ in September followed by $8897/m^2$ in August. The minimum density was $1250/m^2$ in April. Monsoon average ($8167/m^2$) was high compared to pre-monsoon ($2021/m^2$) and post-monsoon ($1604/m^2$).

Apseudes chilkensis and *A. gymnophobium* were the 2 species obtained during the study. The maximum number of *Apseudes chilkensis* was in September ($16646/m^2$) and minimum in April ($84/m^2$) where as *A. gymnophobium* was maximum in August ($2834/m^2$) and minimum in November ($270/m^2$). The seasonal averages for *Apseudes chilkensis* were $449/m^2$, $6115/m^2$ and $1062/m^2$ during pre-monsoon, monsoon and post-monsoon respectively where as the corresponding values for *A. gymnophobium* were $1573/m^2$, $2053/m^2$ and $542/m^2$.

Amphipods were the second dominant group in abundance numbering 9046 forming 16.95% of the benthic population. The frequency of occurrence was 10/10 with maximum abundance in February (1645/m^2) followed by 1479/m^2 in June. The low abundance was in October (271/m^2) followed by 291/m^2 in November. The seasonal observations showed that the average values for pre-monsoon, monsoon and post-monsoon were 1177, 948 and 725/m^2 respectively.

Melita zeylanica, Grandidierella gilesi and *Quadrivisio bengalensis* were the 3 species obtained during the study. *Melita zeylanica* observed through out the study period with an abundance of 8920 with the densities ranging between 271 (October) and 1479/m^2 (June). *Grandidierella gilesi* was observed in December (63/m^2) only and *Quadrivisio bengalensis* in December (42/m^2) and January (21/m^2). The averages for *Melita zeylanica* were 1177/m^2 during pre-monsoon, 948/m^2 during monsoon and 694/m^2 during post-monsoon. *Grandidierella gilesi* and *Quadrivisio bengalensis* were observed in post-monsoon only with an average of 63/m^2 each.

Polychaetes were the third abundant group with a total density of 898 forming 1.68% of the benthic population. The frequency of occurrence was 6/10 with the densities ranging between 21/m^2 (July and October) and 458/m^2 (June). This group was observed during monsoon and post-monsoon with the average values of 193/m^2 and 32/m^2 respectively.

Dendronereis aestuarina (family – Nereidae), *Prionospio pinnata* and *P. polybranchiata* (family – Spionidae) and *Capitella capitata* (family – Capitellidae) were the 4 species encountered with the total densities of 21, 84, 354 and 439 respectively. Out of these *Capitella capitata* was observed from June to November with the densities ranging from 21/m^2 (July, August and October) to 188/m^2 (September). *Prionospio polybranchiata* (354/m^2), *P. pinnata* (84/m^2) and *Dendronereis aestuarina* (21/m^2) were observed in June, August and November respectively. *Dendronereis aestuarina* (5/m^2) was observed during post-monsoon, *Prionospio pinnata* (21/m^2) and *P. polybranchiata* (84/m^2) during monsoon and *Capitella capitata* during monsoon (84/m^2) and post-monsoon (26/m^2).

Penaeid prawns and juvenile fishes were the fourth and fifth abundant groups with a total density of 84 forming 0.16% of the benthic population. Both the groups showed the frequency of occurrence of 2/10. Penaeid prawn was observed in September (63/m^2) and January (21/m^2) and juvenile fish in September and November with an abundance of 42/m^2 each.

Bivalves were the next group in abundance with a total density of 63 forming 0.12% of the benthic population. This group was observed in September (21/m^2) and February (42/m^2).

Foraminifera and anthozoa were the least dominant group with a density of 42 forming 0.08%. Foraminifera was observed in November (21/m^2) and anthozoa in September (21/m^2)

A total of 28 groups/ species were encountered from the mangrove area of Puduvypin (Table 4.12). Tanaidaceans were the dominant group represented by 2 species. Amphipods were the second dominant group having 3 species followed by polychaetes with 8 species. Penaeid prawns and juvenile fishes were observed at all stations but with low densities. Among polychaetes the Spionid worm, *Prionospio polybranchiata* and the capitellid, *Capitella capitata* that are abundant in highly organic rich area, were recorded here.

4.3.4 Statistical inferences (Figs. 4.19 – 4.24 & Tables 4.60 – 4.12)

Community structure

Species richness index ranged between 0.95 (June) and 5.31 (December), 5.29 (January) at station P2, at station P1, between 1.48 (February and 7.76 (July) at station P3, between 1.54 (February) and 7.65 (July), at station P4, between 0.71 (June) and 4.16 (November) at station P5, between 1.89 (February) and 4.29 (September) and at station P6 between 1.40 (April) and 4.11 (November). The average temporal distribution ranged between 2.55 (station P6) and 3.71 (station P2) with variability over season having least value (10.87%) at station P6 and maximum (57.26%) station P2. Seasonal distribution showed a normal pattern for temporal variation increasing from station P1 with a peak value at station P2 and values decreased in other stations.

Species concentration index ranged between 0.10 (April) and 0.81 (December) at station P1, between 0.48 (September) and 0.77 (July) in station P2, between 0.46 (April) and 0.84 (July) at station P3, between 0.16 (July) and 2.26 (August) at station P4, between 0.41 (July) and 0.64 (October) in station P5 and between 0.34 (September) and 0.6847 (June) in station P6. Average species concentration index was more or less same in the study area. The temporal variability was least (12.90%) at station 5 and highest (38.65%) in station P1 and P4.

Species diversity index varied between 0.35 (April) and 2.58 (December) in station P1, between 1.34 (September) and 2.66 (July) at station P2, between 1.11 (April) and 2.93 (July) in station P3, between 0.59 (July) and 3.83 (September) in station P4, between 1.19 (July) and 1.55 (November) in station P5 and between 1.00 (September) and 1.87 (June) at station P6. Average distribution of diversity was maximum (1.87) at station P1 and least (1.40) at station P4 with maximum (41.54%) temporal variation at station P1, station 2 (40.77%) and station P4 (40.65%) and least (8.21%) at station P5.

Species dominance index ranged between 0.31 (February) and 1.28 (November) at station P1, between 0.51 (February) and 0.85 (October) at station P2, between 0.38 (April) and 0.83 (September) at station P3, between, 0.62 (April) and 2.25 (August) at station P4, between 0.82 (April) and 1.02 (February) at station P5 and between 0.54 (April) and 0.89 (November) at station P6. Average distribution of dominance index showed that temporally maximum (1.48) dominance was obtained at station P4 and least (0.62) at station P3 the temporal variability showed the same pattern as that observed for species diversity index. The dominance distribution showed a double mode normal pattern with peak dominance at station P1 and a second peak at station P4.

Species evenness index which invariably related to dominance showed comparatively higher value at station P1, (but with higher seasonal variability) and least value at station P5 with comparatively more seasonal uniformity. The evenness index ranged between 0.21 (April) and 2.13 (October) at station P1, between 0.71 (September) and 1.94 (October) at station P2, between 0.46 (November) and 1.78 (July) at station 3, between 0.48 (August) and 1.83 (September) at station P4, between 0.30 (September) and 1.79 (October) at station P5 and between 0.60 (November) and 1.37 (June) at station P6.

The average temporal distribution showed peak value (1.25) at station 4 and low value (0.87) at station 5. The variation in the evenness distribution was between 33.87% (station 6) and 57.98 (station 1).

Species niche breadth

In mangrove area the niche breadth was dependent on the temporal variation but not on the spatial variation in each station. In station 1 to station 6 the range of number of species was 13 (station 5) to 18 (station 6) and the range for niche breadth was 1.09 (*Littorina littorea* $\overline{X}$ = 77/m^2 C.V. 300%) and high correlation with dissolved oxygen r = 0.72 to 4.52 (Juvenile fish and *Lycastis indica* $\overline{X}$ = 6/m^2 C.V. 152.75%) high correlation with nitrate r = 0.38) for *Lycastis indica*, ammonia (r = 0.43) and chlorophyll a (r = 0.48) for juvenile fish and (*Melita zeylanica* had the maximum niche breadth (5.35, $\overline{X}$ = 577/m^2, C.V. 116.2%) and with high correlation with nitrate (r = 0.38) at station 1.

At station 2 niche breadth varied between 2.35 (*Lycastis indica* $\overline{X}$ = 4.20/m^2 C.V. 300%) and high correlation with biological oxygen demand (r = 0.80), nitrate (r = -0.48) and clay (r = 0.58). and 5.43 (*Prionospio polybranchiata* $\overline{X}$ = 65/m^2 C.V. 105.43%) and highly controlled by chlorophyll a (r = 0.35) for 87.5% of the species. For the remaining 13% of species it was less than < 2.0.

At station 3, for 83.33% of the species, the range of niche breadth was 2.03 (*Capitella capitata* $\overline{X}$ = 413/m^2 C.V.241%) has high relation with silt (r = 0.85), organic matter (r = 0.63) and sand (r = 0.50) to 7.78 (*Melita zeylanica* $\overline{X}$ = 517/m^2 C.V.68.95%) and was dependent on sand (r = 0.63) ammonia (r = 0.46) and organic matter (r = 0.42). For the remaining species niche breadth was very low being < 1.95.

At station 4, the range for niche breadth was narrower than at stations 1 to 3 and 82% of the species, it ranged between 2.01 (*Melita zeylanica* $\overline{X}$ = 115/m^2 C.V. 232.35%) and highly correlated with phosphate (r = 0.74), dissolved oxygen (r= 0.49) and salinity (r = 0.42) to 4.92 (Juvenile fish ($\overline{X}$ = 21/m^2, C.V. = 140.75%) and highly dependent on organic matter (r = 0.64).

At station 5, the maximum niche breadth (6.55) was for (*Melita zeylanica* X = 433/m^2, C.V. 87.41%) and it was observed to be highly dependent on organic matter (r = 0.31) and minimum value of niche breadth was (2.35) for *Grandidierella gilesi* ($\overline{X}$ = 4.20/m^2 C.V. 300%) and highly controlled by salinity (r =. 0.51) and for (*Littorina littorea* $\overline{X}$ = 11/m^2 C.V. = 240.83) and highly dependent on temperature (r = -0.65) nitrite (r = 0.57) and biological oxygen demand (r = -0.58). For *Quadrivisio bengalensis* and *Prionospio polybranchiata* ($\overline{X}$ = 163/m^2, $\overline{X}$ = 21/m^2) which have the same seasonal variation C.V. = 260% have low niche breadth, latter being dependent on nitrite, suspended load and silt (r = 0.38, 0.31 and 0.43) respectively. The trend observed here was higher abundance, lower seasonal variation, higher is the niche breadth.

At station 6 a wide variation for niche breadth was obtained with a range of 2.69 (Penaeid prawn $\overline{X}$ = 8.40/m^2 C.V. 229.13%) and high correlation with chlorophyll a (r = 0.63) to 8.57 (*Melita zeylanica*. $\overline{X}$ = 892/m^2 C.V 52.9%) with high correlation with phosphate (r = - 0.62), suspended load (r = 0.53) and silt (r = 0.51). For *Prionospio pinnata*, ($\overline{X}$ = 55/m^2), *Prionospio polybranchiata* (43. 9/m^2), *Grandidierella gilesi* ($\overline{X}$ = 6/m^2), the niche breadth was < 2. These species were moderately rare. For Apseudes *chilkensis* ($\overline{X}$ = 2960/m^2, C.V= 163.3%) high correlation with ammonia (r = 0.80, chlorophyll 'a' (r = 0.76) and silt (r =0.50) and *Apseudes gymnophobium* ($\overline{X}$ = 1352/m^2, C.V = 69.87) and highly correlated with dissolved oxygen (0.60), ammonia (0.54) and suspended solid (0.42) have a niche breadth of 4.21 and 7.76 increasingly higher niche breadth for higher abundance and lower seasonal variation

Predictive regression model

In the mangrove area, total benthic density was related to the parameters such as dissolved oxygen, phosphate, nitrite, ammonia, organic matter, particulate organic matter, BOD, suspended load and silt (which were found to have moderately high correlation with benthic density) using (1) standardised original effects of both depended variable (Y) and independent variables (X1-X9), (2) standardised log values of Y and (X_1 X_9) and (3) standardised square root values of Y and (X_1 X_9), it was found that the standardised original values of the parameters, dissolved oxygen (X1), phosphate (X2), nitrite (X3), ammonia (X4), organic matter (X5), particulate organic matter (X6), BOD (X7), suspended load (X8) and silt (X9) and their first order interaction effects could predict total benthic density (Y) from the equation.

$$Y = 0.2524 + 0.2608\ X_1 - 0.3442\ X2 - 0.13166\ X_3 + 0.91314\ X4 - 0.19837\ X_5 + 1.0571\ X_6 - 0.3119\ X_7 - 0.2699\ X8 + 0.1734\ X9 - 1.8696\ X1.\ X_2 - 0.2421\ X_1.\ X_3 - 0.0441\ X_1.\ X_4 + 0.7127\ X_1.\ X_5 - 0.0989\ X_1.\ X_6 + 0.9441\ X_1.\ X_7 + 0.01144\ X_1.\ X_8 - 0.6842\ X_1.\ X_9. - 0.04596\ X_2.\ X_3 + 2.1086\ X_2.\ X_4 - 1.5651\ X_2.\ X_5 - 0.01071\ X_2.\ X_6 - 0.1658\ X_2.\ X_7 + 0.10826\ X_2.\ X_8 - 0.1862\ X_2.\ X_9 - 0.1989\ X_3.\ X_4 - 0.4952\ X_3.\ X_5 + 0.09177\ X_3.\ X_6 + 0.06183\ X_3.\ X_7 + 0.4609\ X_3.X_8 + 0.09997\ X_3.\ X_9 +).14215\ X_4.\ X_5 - 0.53247\ X_4.\ X_6 + 4.2004\ X_4.\ X_7 - 1.39204\ X_4\ X_8 - 2.4921\ X_4.\ X_9 - 0.20715\ X_5.\ X_6 - 0.23964\ X_5.\ X_7 - 0.20202\ X_5.\ X_8 + 0.0027477\ X_5.X_9 + 0.1632\ X_6.X_7 - 0.30745\ X_6.\ X_8 - 0.112098\ X_6.\ X_9 + 0.1799\ X_7.\ X_8 + 0.054067\ X_7.\ X_9 - 0.02534\ X_8.\ X_9.$$

This model was highly significant F (45, 14) = 13.9510, P = < 0.05) and it explained about 90.81% of seasonal and spatial variation in the total benthic density. This group of parameters could make the predictive better than any other combination of (512 combinations) of these parameters. The individual as well as the interaction effects of the water quality and sediment characteristics were graded as follows along with their significance standard error and confidence interval given as lower confidence limit (LCL) and upper confidence lever (UCL).

Parameters	Relative Importance	Standard Error	Statistic 't'	95% confidence interval	
				LCL	UCL
$X_4 \cdot X_7$	4.2004	0.4285	9.8017	(3.2605	5.0404)
$X_4 \cdot X_9$	-2.4921	0.3763	-6.6236	(-3.2296	-1.7547)
$X_2 \cdot X_4$	2.1086	0.1009	20.8975	(1.9108	2.3064)
$X_1 \cdot X_2$	-1.8696	0.1878	-9.9568	(-2.2376	-1.5016)
$X_2 \cdot X_5$	-1.5651	0.1370	-11.4217	(-1.8337	-1.2965)
$X_4 \cdot X_8$	-1.3920	0.4607	-3.0218	(-2.2949	-0.4891)
X_6	1.0571	0.0947	0.1674	(0.8716	1.2426)
$X_1 \cdot X_7$	0.9441	0.1506	6.2686	(0.6489	1.2393)
X_4	0.9131	0.2774	3.2924	(0.3695	1.4568)
$X_1 \cdot X_5$	0.7127	0.3059	2.3300	(0.1132	1.3122)
$X_1 \cdot X_9$	0.6842	0.2046	-3.3440	(-1.0852	-0.2831)
$X_4 \cdot X_6$	0.5325	0.7730	-0.6888	(-2.0476	0.9826)
$X_3 \cdot X_5$	0.4952	0.2982	-1.6606	(-1.0797	0.0893)
$X_3 \cdot X_8$	0.46.09	0.2926	1.5753	(-0.1126	1.0345)
X_2	-0.3442	0.1495	-2.3020	(-0.6373	-0.0511)
X_7	0.3119	0.1831	-1.7037	(-0.6707	0.0469)
$X_6 \cdot X_8$	-0.3075	0.9763	-0.3149	(-2.2210	1.6061)
X_8	- -.02699	0.1333	-2.0244	(-0.5312	-0.0086)
X_1	0.2608	0.1573	1.6584	(-0.0474	0.5691)
$X_1 \cdot X_3$	-0.2421	0.4491	-0.5390	(-1.1222	0.6381)
$X_5 \cdot X_7$	-0.2396	0.3782	-0.6336	(-0.9810	0.5017)
$X_5 \cdot X_6$	-0.2072	0.4147	-0.4996	(-1.0199	0.6056)
$X_5 \cdot X_8$	-0.2020	0.8327	-0.2426	(-1.8342	1.4.301)
$X_3 \cdot X_4$	-0.1989	0.4371	-0.4552	(-1.0558	0.6578)
X_5	-0.1984	0.0846	-2.3446	(-0.3642	-0.0325)
$X_2 \cdot X_9$	-0.1862	0.1785	-1.0433	(-0.5361	0.1636)
$X_7 \cdot X_8$	0.1760	1.1037	0.1595	(-1.9873	2.3393)
X_9	0.1734	0.1418	1.2226	(-0.1046	0.4514)
$X_2 \cdot X_7$	-0.1658	0.3117	-0.5320	(-0.7767	0.4450)
$X_6 \cdot X_7$	0.1632	0.6682	0.2442	(-1.1464	1.4728)
$X_4 \cdot X_5$	0.1421	0.4658	0.3052	(-0.7708	1.0551)
X_3	0.1317	0.2880	-0.4572	(-0.6961	0.4348)
$X_6 \cdot X_9$	-0.1121	0.8165	-0.1373	(-1.7124	1.882)
$X_2 \cdot X_8$	0.1083	0.2374	0.4561	(-0.3570	0.5735)
$X_3 \cdot X_9$	0.0997	0.2753	0.3632	(-0.4396	0.6395)
$X_1 \cdot X_6$	0.0989	0.4561	-0.2169	(-0.9928	0.7949)
$X_3 \cdot X_6$	0.1917	0.4568	0.2022	(-0.7977	0.9813)
$X_3 \cdot X_7$	0.0618	0.4020	9.1538	(-0.7260	0.8497)
$X_7 \cdot X_9$	0.0540	1.6202	0.0334	(-3.1228	3.2309)
$X_2 \cdot X_3$	-0.0459	0.2017	-0.2279	(-0.4413	0.3494)
$X_1 \cdot X_4$	-0.0441	0.1422	-0.3098	(-0.3228	0.2347)
$X_8 \cdot X_9$	-0.0253	-	-	-	-
$X_1 \cdot X_8$	0.0114	0.1737	0.0659	(-0.3291	0.3520)
$X_5 \cdot X_9$	0.0027	0.5273	0.0052	(-1.0308	1.0363)
$X_2 \cdot X_6$	-0.0011	0.2999	-0.0036	(-0.5889	0.5868)

This shows that the interaction effects are far more significant than the individual factor effects. The relatively most important controlling factors are (phosphate * ammonia) > (ammonia * biological oxygen demand) > (dissolved oxygen * biological oxygen demand) > ammonia > (dissolved oxygen * organic matter) and the relatively most important limiting factors were (phosphate * organic matter) > (dissolved oxygen * phosphate) > (ammonia * silt) > (ammonia * suspended load)

Similarity between months

The seasonal similarity was studied using Bray Curtis and community coefficient methods. At station 1, April showed invariably high similarity with other months of the year where June to September showed high similarity with October and December. The common occurrence of species was observed more in January and other months (40 to 60%) than any other months (< 50%). At station 2, between months of the monsoon season high similarity for abundance was observed. In particular October and April showed almost the same species in the same abundance when compared to November to February. In February and during November to January only 45 to 50% similarity could be observed based on abundance of common species. Using presence/ absence 30 to 60% similarity could be observed between June to September and November to January.

At station 3, different picture was observed for between months similarity. June showed high similarity (> 90%) with other months of the year except April with a decreasing trend in the similarity values from August to January. Similarity in September also showed 70 to 80%. Similarly with other months except with July and August it was observed that unlike at stations 1 and 2, October showed less commonness with other months of the year (< 60%). During December to April, also low similarity has been (< 60%) observed for the common species to occur in the same abundance. Based on presence/ absence of species August to November showed 50 to 85% similarity where as in other months of the year only < 50% common species has been obtained.

At station 4 unlike the other study area throughout the study period 80 to 100% similarity was observed except during June and November (< 70%) and during August and February (< 60%) based on the abundance of the species. When the presence/ absence was considered July was found to be more similar to months (20 to 50%) except December (10 to 20%) and so also August and February (32%) and January and April (43%). However the common species were very less at station 4 during the study period showing the fluctuations in the environmental conditions.

At station 5, June to November showed > 70% similarity in the abundance of common species except August and September (51%) and August and November (56%). However during November to April different species with varying abundance was observed producing 40 to 70% similarity between the months of this cluster indicating ecological changes during this period. Further it indicated the ecological changes were not steadily varying, but were subjected to low periodicity (persistent only for a short period). Based on presence/ absence of species it has been observed that higher similarity in common species was only between June and August (71%) August and January (71%) November and April (71%). In all other combinations of months, only < 60% similarity could be observed. Anyhow this similarity between months was higher when compared to other stations of this region.

At station 6, a strange pattern for similarity between months has been observed. It showed a striking difference when compared to other 5 stations. All combinations of months, other than with September (> 70%), showed < 50% similarity in the abundance of the common occurrence of species. Similarity based on presence/ absence of species a strange difference was observed in this station in all the months (< 33%). Common species occurred but in different abundance as indicated by Bray Curtis similarity index.

4.4 DISCUSSION

4.4.1 Water quality

The various environmental parameters indicated well-defined differences; the variability to a certain extent being imposed by monsoonal regime, as monsoonal discharges directly affected the concentration of nutrients, salinity and suspended loads.

The overall picture of water quality of Puduvypin mangrove area revealed little fluctuation between stations, seasonal variation was pronounced having high values during pre-monsoon compared to other two seasons. The spatial variation in salinity was not pronounced since the stations are very close. Freshwater conditions prevailed during monsoon. Seasonal average values varied from 23.09 to 26.79, 3.99 to 6.20 and 15.50 to 16.71 psu during pre-monsoon, monsoon and post-monsoon respectively.

Temperature did not show any marked spatial variation. Seasonal fluctuations were noticed, pre-monsoon having high values followed by post-monsoon and the minimum during monsoon months.

Well-oxygenated condition prevailed in the study area throughout the period and all the dissolved oxygen values were above 2ml/l. The dissolved oxygen levels for the entire area ranged between 2.13 and 7.52ml/l (av.4.3ml/l). The results of the hydrographic parameters of the ecosystem were in good agreement with the observations of Sunilkumar (1994) for the other mangrove ecosystems of Cochin backwaters.

Biochemical Oxygen Demand values were very low (<5mg/l) which is within the limit for unpolluted coastal waters.

Distribution of nitrite-N and nitrate-N showed the same trend for stations P1 to P4 and a slight increase for stations P5 and P6. The averages for the area were 0.87µmol/l for nitrite and 4.31µmol/l for nitrate respectively. Unlike other nitrogen compounds the ammonia concentrations fluctuated between stations and between months. Low values (<1µmol/l) observed at stations 1, 2 and 3 whereas stations 4, 5 and 6 showed high values showing spatial variability. Seasonal variation was well marked, monsoon values were very high at all stations and the average values recorded for different seasons were 4.24, 36.98 and 11.74µmol/l respectively. The annual range in ammonia concentration was between 12.40 and 32.20μmol/l, except for a stray value of 1.79μmol/l at station P3 and an average value of 17.65μmol/l. The relatively high concentration in the area may be attributed to the heavy freshwater discharge during this period, in addition to the non-point sources. Inorganic phosphate values were high during monsoon months; the averages reached upto 24.80μmol/l during monsoon, 21.76μmol/l during pre-monsoon and 12.01μmol/l during post-monsoon.

Chlorophyll content was high during the observation period and comparatively high values were noticed during monsoon. The averages for the pre-monsoon, monsoon and post-monsoon were 13.02, 15.62 and 8.75mg/m^3 respectively and the peak value of 87.34mg/m^3 was observed during September (station P4). The range for different stations varied from 6.29 to 27.54mg/m^3 with an annual average of 12.46mg/m^3. Since chlorophyll 'a' is a better indicator of standing stock and primary production, this parameter was of much use in establishing the high biological fertility of the backwaters. These values were slightly low compared to the values reported by other workers; Naidu (1973); Venugopalan and Rajendran (1975); Bhosle *et al.*, (1978); Paropkari (1979) and Manikandavelu and Ramdhas (1994) from the different mangrove ecosystems.

Particulate Organic Carbon content also showed high values recording a maximum of 98.28mg/l at station P4. Monsoonal values were comparatively high (av. 12.39 mg/l) than pre-monsoon (av. 6.28mg/l) and post-monsoon (av. 4.84mg/l). The annual average for the entire area was 7.84mg/l.

Suspended load was very high in this area. Excluding one or two stray values this showed a wide range between 5.5 and 136.20 mg/l and most of the values were between 40.0 and 80.0 mg/l. The average for the three seasons in the entire area was 54.70, 49.20 and 67.54 mg/l respectively and these values found to be well above the limit for coastal waters, possibly contribute to the levels of suspended load in estuarine / coastal waters.

In general phosphate, chlorophyll `a', POC and suspended load showed an inter relationship. High values of NO_2, NO_3 and PO_4 might have contributed to the high phytoplankton growth and thereby high pigment content. The shallow nature of the area and the litter fall from the mangrove trees contributed substantially to the suspended load and thereby increase in POC.

Waters of the mangrove environment are generally turbid because they are shallow regions and subjected to action of tides, waves and currents. The constant wave action and currents disturb surface sediments in the mangrove substratum resulting in high suspended matter in the mangrove ecosystem (Jagtap, 1987). The present values are well comparable with the reported values of Satyanarayana, (1973); Bhosle *et al.*, (1978) and Paropkari, (1979) for estuarine and coastal waters. From the mangrove environments of Goa, Jagtap (1987) recorded high suspended load varying from 3.0-373.0 mg/l. The corresponding POC content of the above area ranged from 0.06-9.94 mg/l. The author also opined that the seasonal variation in POC might be attributed to change in biological and physico-chemical conditions caused by fresh water discharge, domestic and agricultural seepages.

4.4.2 Sediment characteristics

The importance of the substratum as an abiotic factor in respect of its physical characters as consistency, water content and grain size etc. and as a biological factor as regards to its content of the organic matter and its microbial turnover was stressed by Muus (1967). Generally the state of preservation depends partly on its texture. Association of organic matter with fine-grained material is well established by several workers (Jayapalan *et al.*, 1976 and Hashimi *et al.*, 1978).

In the present study the substratum was dominated by clayey silt with rich organic matter content. The annual average of clay, silt and sand content of the area varied from 42.22 to 71.01 %, 18.45 to 35.06 % and 1.10 to 39.28 %. Except at station P6, seasonal variation was not well pronounced between stations for clay and silt whereas sand portion showed higher values during monsoon.

The organic matter percentage showed good relationship with the fine-grained material and the values for the study area varied from 1.25 to 7.11 % with an annual average 4.36%. Seasonal variation showed no definite pattern and comparatively low values were noticed at P1 and this may be attributed to the low litter content in this station Seasonal variation in organic matter content in sediments could be attributed to their oxidation and living organisms present in the top few centimeters of sediment at the time of sampling (Jagtap, 1987). The average organic matter (4.36%) of the study area during the present study is higher than the values reported by Swamy (1971), Satyanarayana (1973), Naidu (1973) and Seralathan and Seetharamaswamy (1979) and is well comparable with the result of Jagtap (1987) for the mangrove eco-systems of Goa.

The energy content varied from 270.00 to 1535.80 J/g, which is lower than the reported values (224.0 to 7949.40 J/g) for the retting yards of Cochin backwater by Remani *et al.*, (1981), the values (699.78 to 5134.30 J/g) of the retting zones of Ashtamudi estuary (Bijoy Nandan and Abdul Aziz, 1996) and the values (12.26 to 2286.79 J/g) of the polluted environment of the present study.

4.4.3 Bottom fauna

The total number of specimens of the bottom fauna recorded from the mangrove area varied from 6698 (stationP4) to 53343 (station P6), Second peak of 35634 was observed at P5. The average density for different stations varied from 670 (station P4) to 5334/m^2 (station P6) with an average for the area 2605/m^2. The annual average for benthic biomass for different stations in the study area varied from 10.11 (station P4) to 25.74g/m^2 (station P5) with an average of 18.46g/m^2 for the whole mangrove area studied. Station P3, P5 and P6 showed high biomass compared to other stations. Seasonal variation showed higher biomass and density during monsoon followed by post-monsoon and pre-monsoon.

The groups namely polychaetes, amphipods, tanaidaceans,decapods and juvenile fishes ere commonly noticed at all stations. Total number of polychaetes at different stations varied from 898 (station P6) to 5718 (station P3), whereas the percentage composition varied from 1.68 (station P6) to 28.30 (station P2).

Amphipods dominated at station P6 with a total number of 9046 and a minimum (1189) was noticed at station P4. The percentage contribution of this group was minimum (12.87) at station P5 and maximum (28.25) at P2. Tanaidaceans dominated at station P6 (43126) and showed minimum number (774) at station P4. Decapods were represented in smaller numbers at all the stations with a total number ranging between 21 (stations P1, P2 and P4) and 84 (stations P3 and P6) and percentage composition of this group varied from 0.16 (station P6) to 0.40 (station P3). The total number of juvenile fishes noticed at different stations varied from 42 (station P2) to 210 (station P4). Percentage contribution of this group was highest at station P4 (3.12) and lowest at station P6 (0.16). Bivalves and anthozoans were observed except at station P5. The density of the former ranged between 21 (station P1) and 63 (station P3) with a percentage contribution ranging between 0.08 (station P1) and 0.34 (station P2). The corresponding range for the latter was 21 (station P1) and 584 (station P2) and the percentage contribution ranged to a 0.08 (station P6) and 4.80 (station P2). Gastropods were noticed at all stations except station P6 and the total number ranged between 63 (station P2) and 1356 (station P4). The percentage contribution varied from 0.35 (station P5) and 20.25 (station P4). Mysids were noticed at stations P1, P2 and P4 and the total density were 21 at stations P2 and P4 and 105 at station P1. The percentage contribution was <1. Isopods were present at station P1 with a total number of 42 and a percentage contribution of 0.15. Insects contributed 23.96% with a total number of 1604 at station P4.

Though 11 groups were encountered from this area, the number and percentage composition of different groups varied from station to station. Of the 10 groups noticed at station P1; tanaidaceans contributed 55.65% followed by amphipods (22.13%) and polychaetes (17.61%). The gastropods contributed 3.60%, other groups namely isopods, decapods, mysids, bivalves and anthozoa contributed <1%.

The total number of groups recorded from station P2 was 9. Here also tanaidaceans dominated with 37.11% followed by amphipods (28.30%) and polychaetes (28.25% each). Anthozoans amounted to 4.80% whereas decapods, mysids, gastropods, bivalves and fishes showed only <1%. Of the eight groups recorded from station P3, tanaidaceans (45.81%) were the dominant group followed by polychaetes (26.95%) and amphipods (24.76%). Rest of the groups namely decapods, gastropods, bivalves, fishes and anthozoans contributed <1%. Maximum number of groups (10) was noticed at station P4, with highest contribution of insects (23.96%) followed by polychaetes (20.24%), gastropods (20.25%), amphipods (17.74%) and tanaidaceans (11.55%). Juvenile fishes and miscellaneous groups (foraminifera and anthozoa) contributed 3.12, and 2.20% respectively. Decapods, mysids and bivalves showed <1%. Station P5 recorded minimum number of groups (6) of which tanaidaceans contributed 79.64% followed by amphipods (12.87%) and polychaetes (6.55%). Decapods, gastropods and juvenile fishes showed very low percentage (<1). The number of groups recorded at station P6 was seven. Tanaidaceans contributed 80.85% at station P6 followed by amphipods (16.95%) and polychaetes (1.68%). The contribution of decapods, bivalves, juvenile fishes, and miscellaneous groups (foraminifera and anthozoa) was <1%.

Species composition of the different stations in the mangrove area showed that tanaidaceans, the dominant and common group was represented by two species namely *Apseudes gymnophobium* and *A. chilkensis*. The second dominant group amphipod was represented by *Melita zeylanica, Quadrivisio bengalensis and Grandidierella gilesi* of which the first two were recorded from all stations and *Grandidierella gilesi* was noticed at stations P1, P3, P5 and P6. The third dominant and common group was the polychaete represented by 8 species belonging to 5 families. The spionid worm. *Prionospio polybranchiata* was recorded from all the stations where as *P. pinnata* was noticed at station 6 only. The capitellid species also were recorded from all stations. *Dendronereis aestuarina* was seen in 5 stations except at station P1. *Lycastis indica* was noticed at stations P1, P2 and P4. *Sternaspis scutata* was encountered from stations P1 and P2. *Perinereis cavifrons and Glycera longipinnis* were collected from stations P2 and P3 respectively. Among decapods, penaeid prawns were collected from all the stations while crab was found at stations P3 and P5. The isopod *Asellus* sp, was recorded from station P1 only. *Mysid* sp. was collected from station P1, P2 and P4. *Littorina littorea, gastropod* sp, and *Dentalium* sp. were noticed at stations P1, P3, P4 & P5; P1, P4 & P5 and P2 & P3 respectively. The *bivalve* sp. was present at stations P1, P3, P4 and P6 whereas

Cardium sp. was noticed at stations P2 and P3 and *Cavolina* sp. at station P3 only. The insects Chironomid sp. and water beetle were observed at station P1 and P4 only. Juvenile Fishes were collected from all stations. Anthozoans were encountered from all stations except at station 5 and foraminifera were noticed at station P4 and P6 only.

A total of 28 groups/ species were encountered from the mangrove area of Puduvypin. Tanaidaceans were the dominant group represented by 2 species. Amphipods were the second dominant group having 3 species followed by polychaetes with 8 species. Penaeid prawns and juvenile fishes were observed at all stations but with low densities. Among polychaetes the spionid worm, *Prionospio polybranchiata* and the capitellid, *Capitella capitata* that are abundant in highly organic rich area, were recorded here. In the mangrove ecosystems dominance of crustaceans were noticed. It is well established that the distribution of bottom fauna mainly depends on the substratum characteristics as well as organic matter content. Many of the decapod crustaceans depend on detritus for food, in spite of being carnivorous. In the energy food web of coastal ecosystem detritus appears to be one of the primary source of carbon and nitrogen (Odum, 1971; Benner *et al.*, 1986).

Mangrove forest being an important component of estuarine ecosystems has been identified as producers and exporters of organic matter. The ground litter on the substratum produced by trees, shrubs and herbaceous plants contribute substantial amount of organic matter to the complex estuarine food webs and energy transfer, consequently, litter production in the mangrove ecosystem has been used as a measure of productivity in view of the importance of litter to detritivorous organisms (Ghosh *et al.*, 1990).

Chandramohan *et al.*, (1997) observed abundance of prawn larvae and other decapod crustaceans in the vicinity of mangrove areas of Godavari. In the study area the number of polychaete species were low (8) compared to the observation of Sunil Kumar (1993) who recorded 27 species of the group from 3 different mangrove environments of Cochin backwaters. The low diversity noticed during the study may be attributed to the nature of the substratum. Faunal distribution in relation to the type of the sediment showed high species diversity and richness in the sandy substratum followed by clayey sand. High population density and species diversity with the sandy substratum was reported by earlier workers (Sanders, 1968; Damodaran, 1973; Stickney and Stringer; 1957; Horikoshi, 1970 and Chandran *et al.*, 1982). In the study area the number of groups / species is less compared to the results of other mangrove ecosystem of Cochin backwaters having more sandy bottom (Sunil Kumar, 1996). Clay and silt with high organic matter content (av. 4.36%) dominated the substratum in the mangrove ecosystem of Puduvypin, which favoured the group of detritivorous organisms like tanaidaceans and amphipods.

Margalef (1957), Sanders (1968), Slobodkin (1961) and Whitlatch (1980) were of the opinion that in physically unstable condition only a limited number of species would be successful whereas a less variable habitat would be more suitable for the existence of greater number of species. Rhoads (1974) has reviewed the interaction of the environment and communities in predominantly multisubstratum in particular reference to bioturbation, sediment resuspension and pelletization. Not only the sediment disturbances but also the general feeding habits of the dominant species can result in several species being excluded from an environment despite its suitability and hence low diversity is maintained.

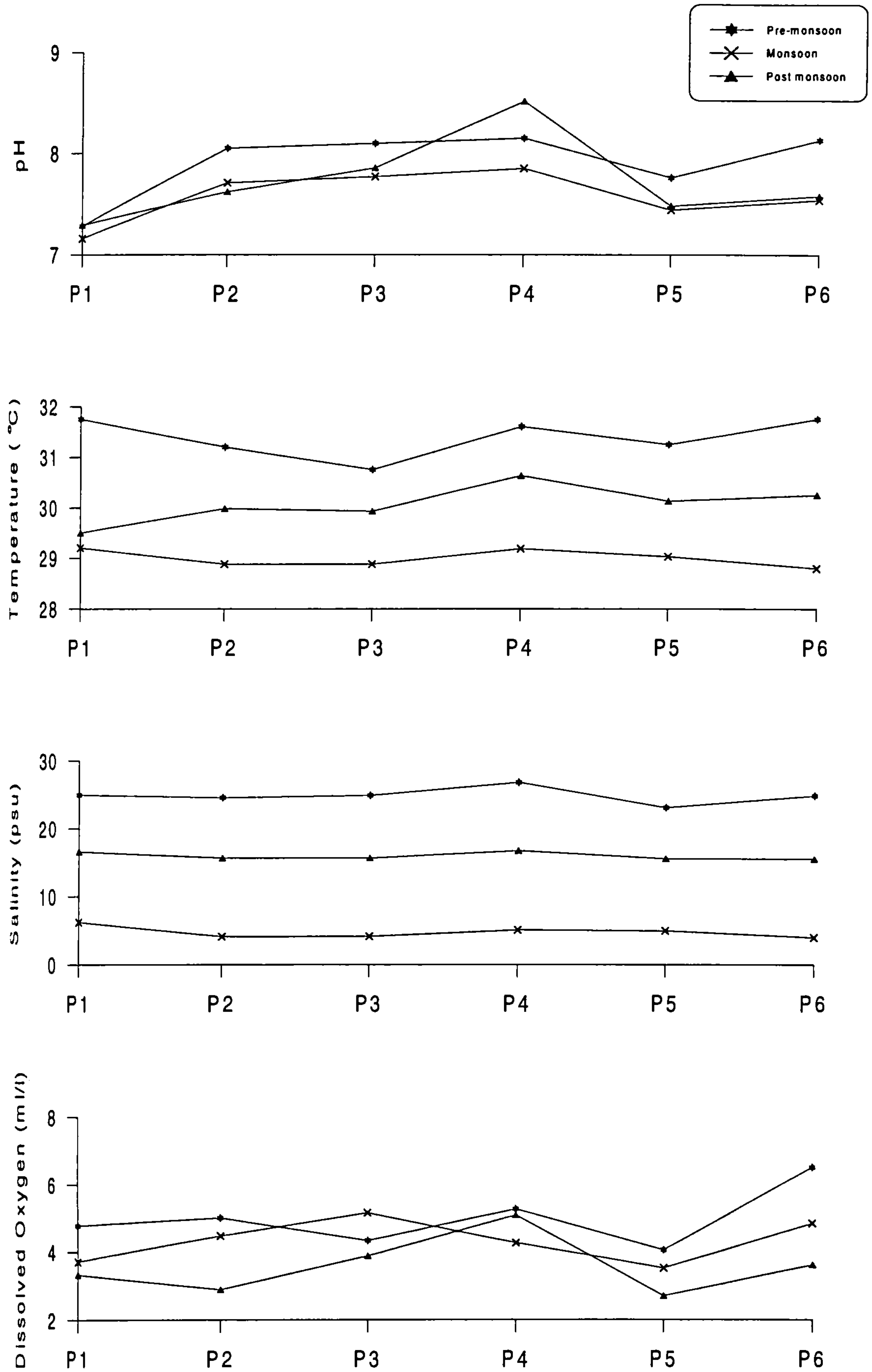


Fig. 4.1. **Seasonal distribution of different parameters at stations P1 to P6**

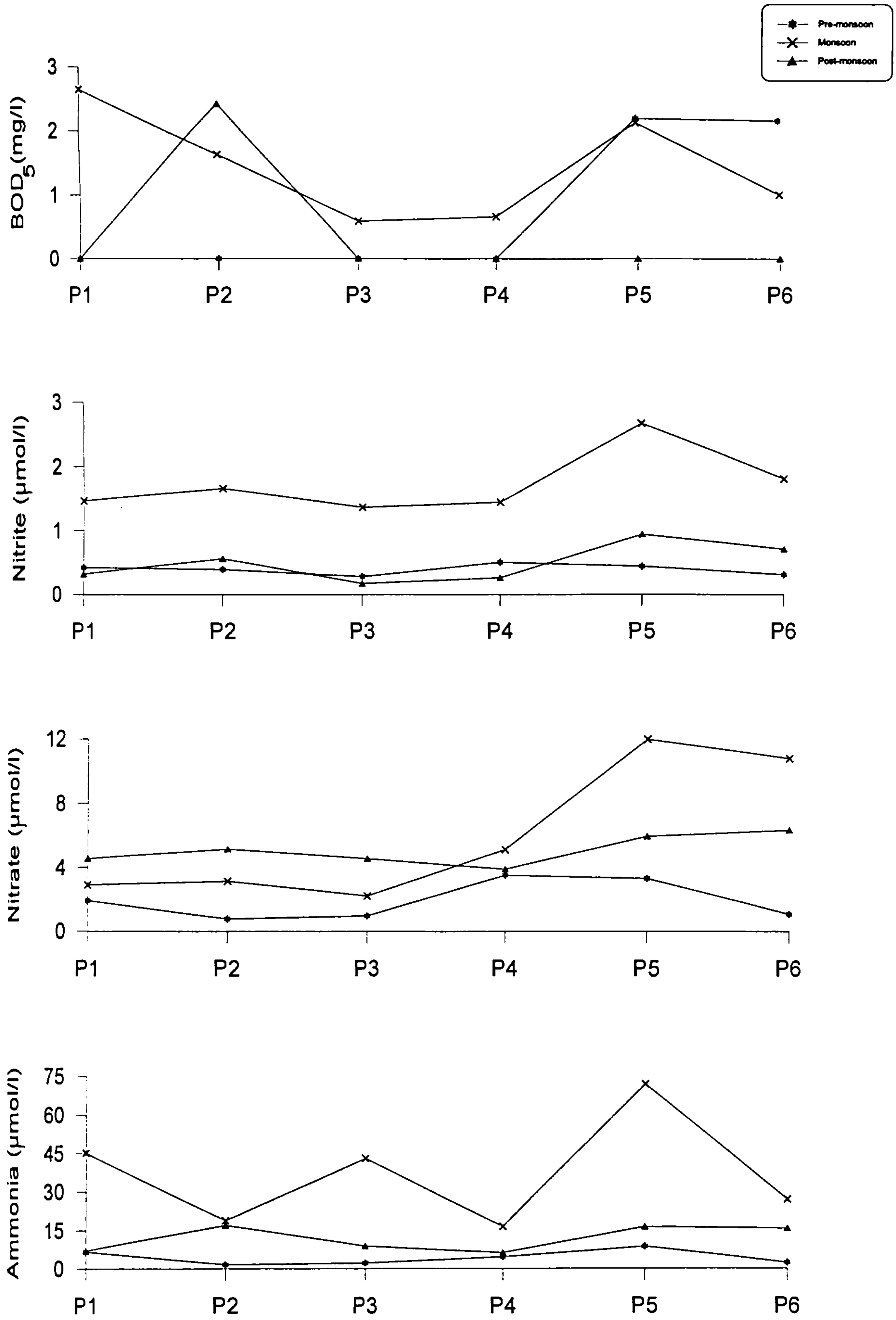


Fig. 4.2. **Seasonal distribution of different parameters at stations P1 to P6**

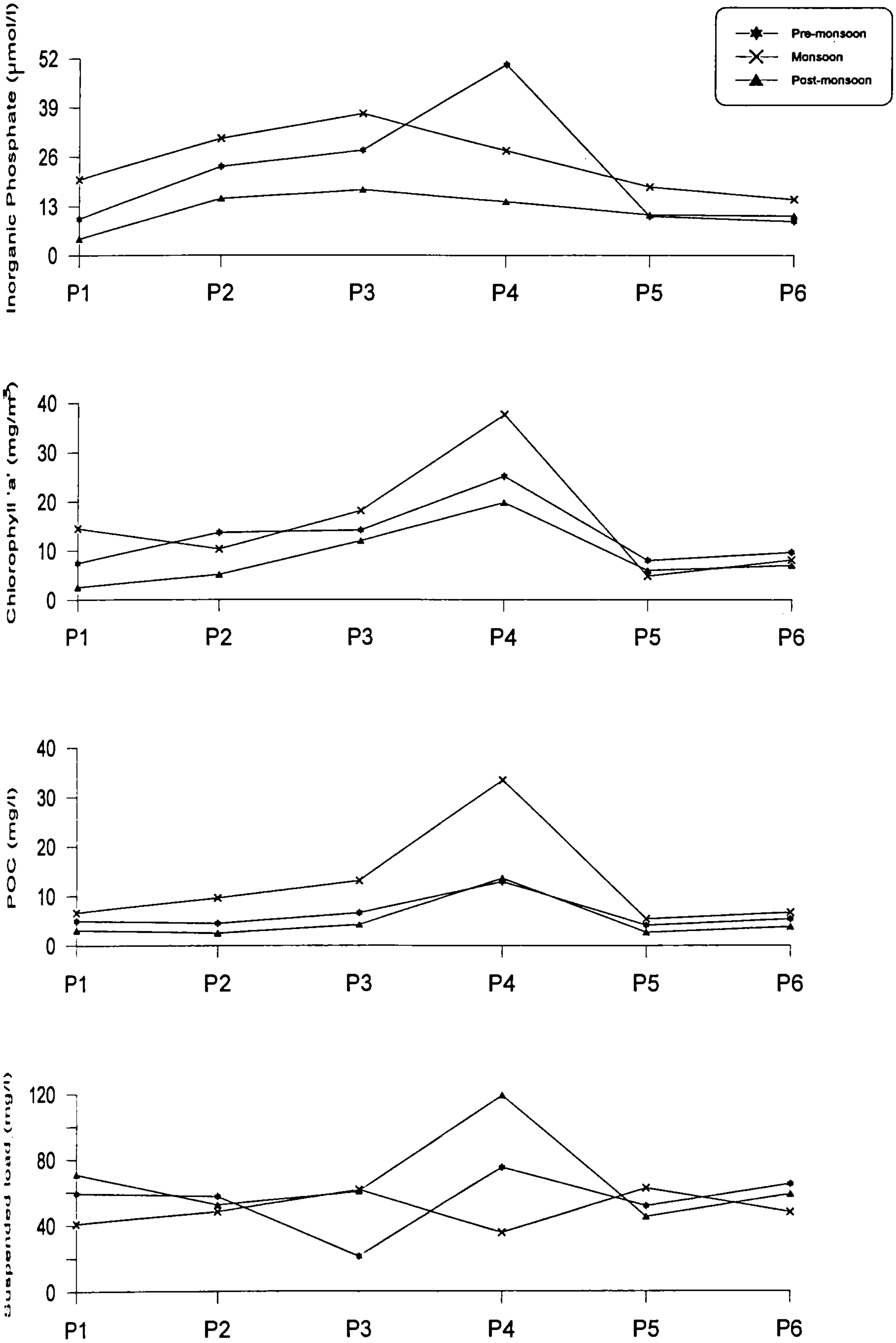


Fig. 4.3. **Seasonal distribution of different parameters at stations P1 to P6**

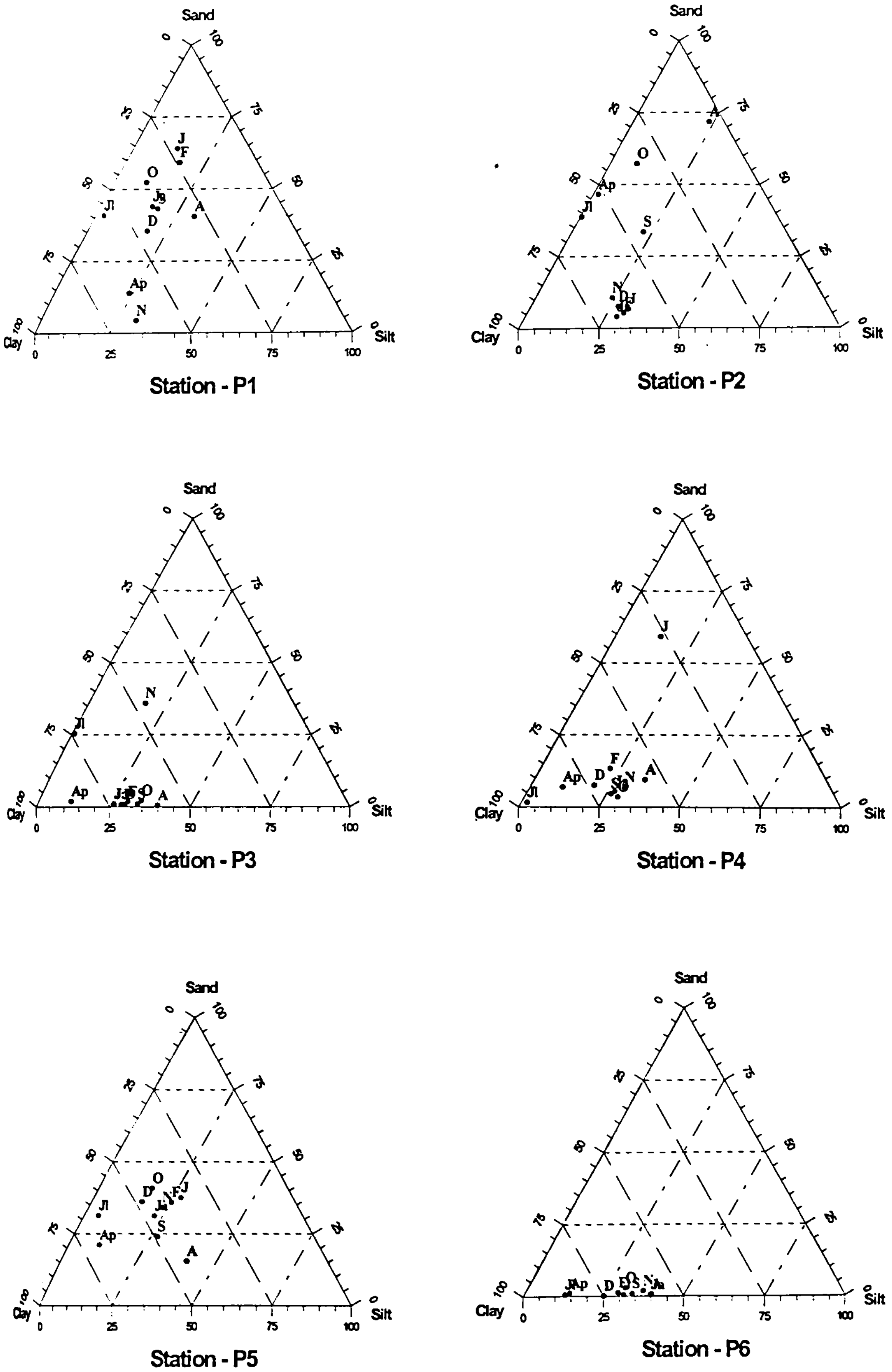


Fig. 4.4. Grain size distribution at different stations

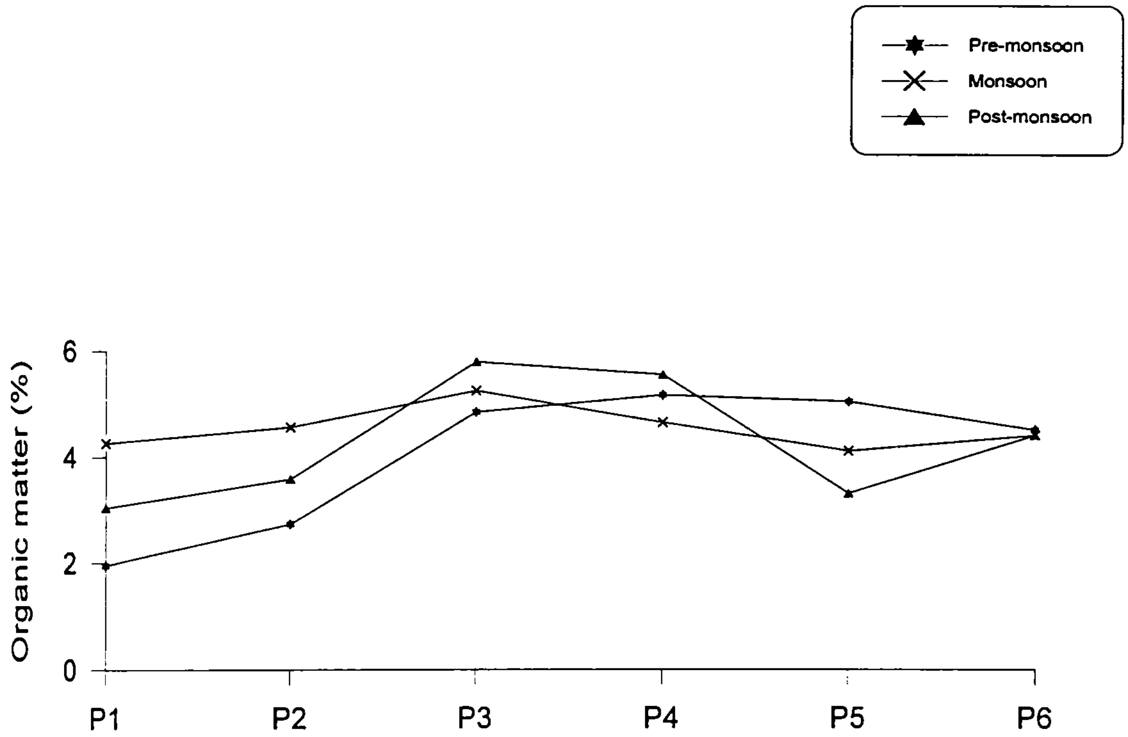
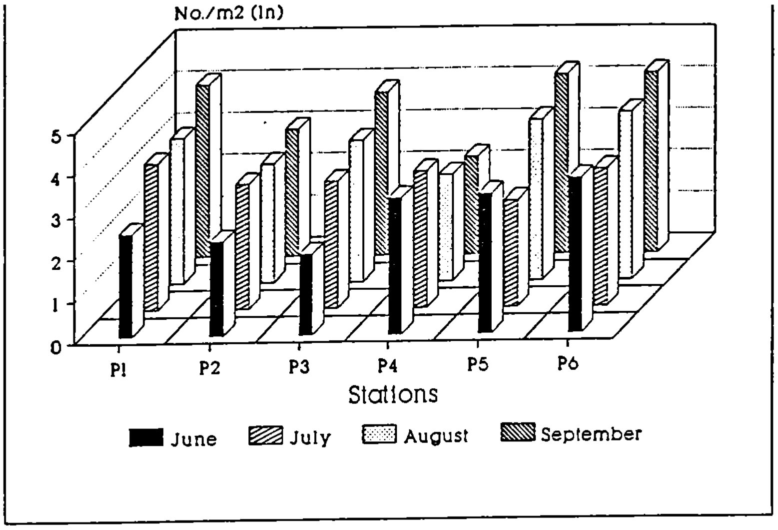
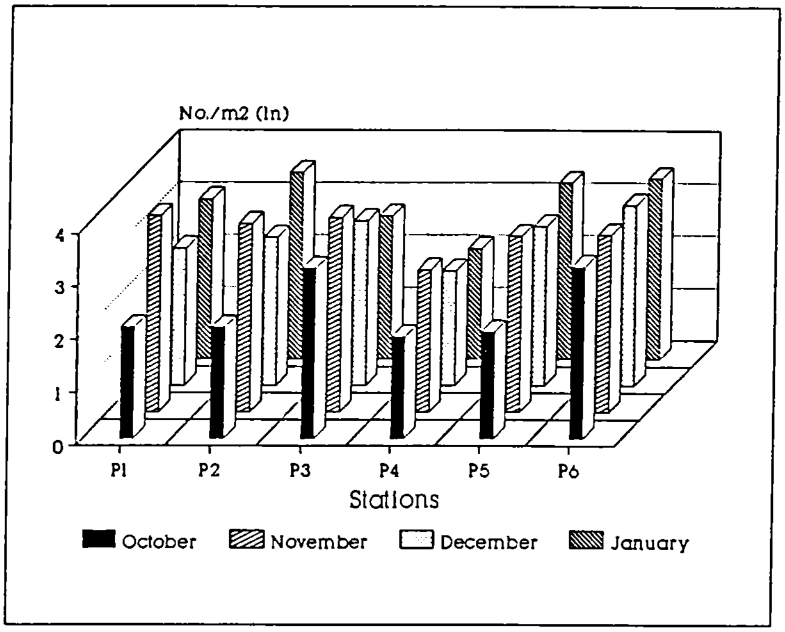


Fig. 4.5. **Seasonal distribution of organic matter at stations P1 to P6**





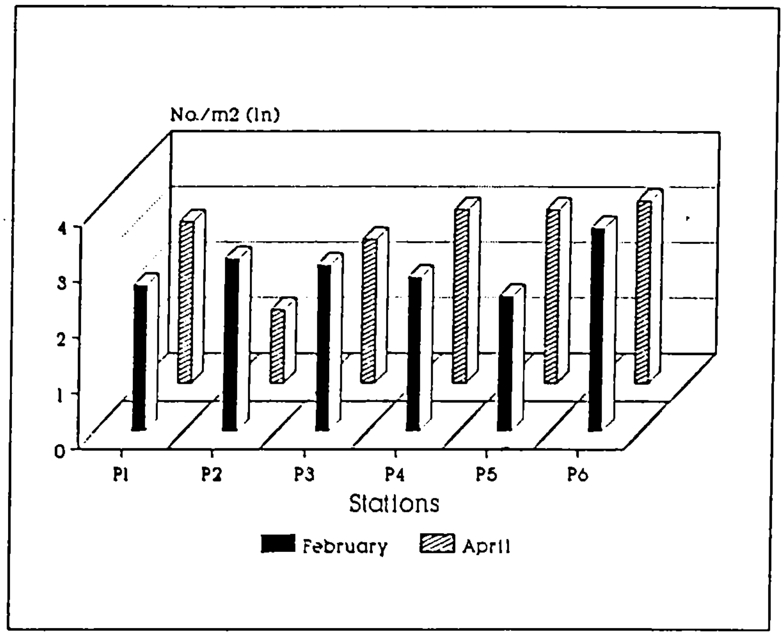


Fig. 4.6. Total benthic density (no./m²) at different stations

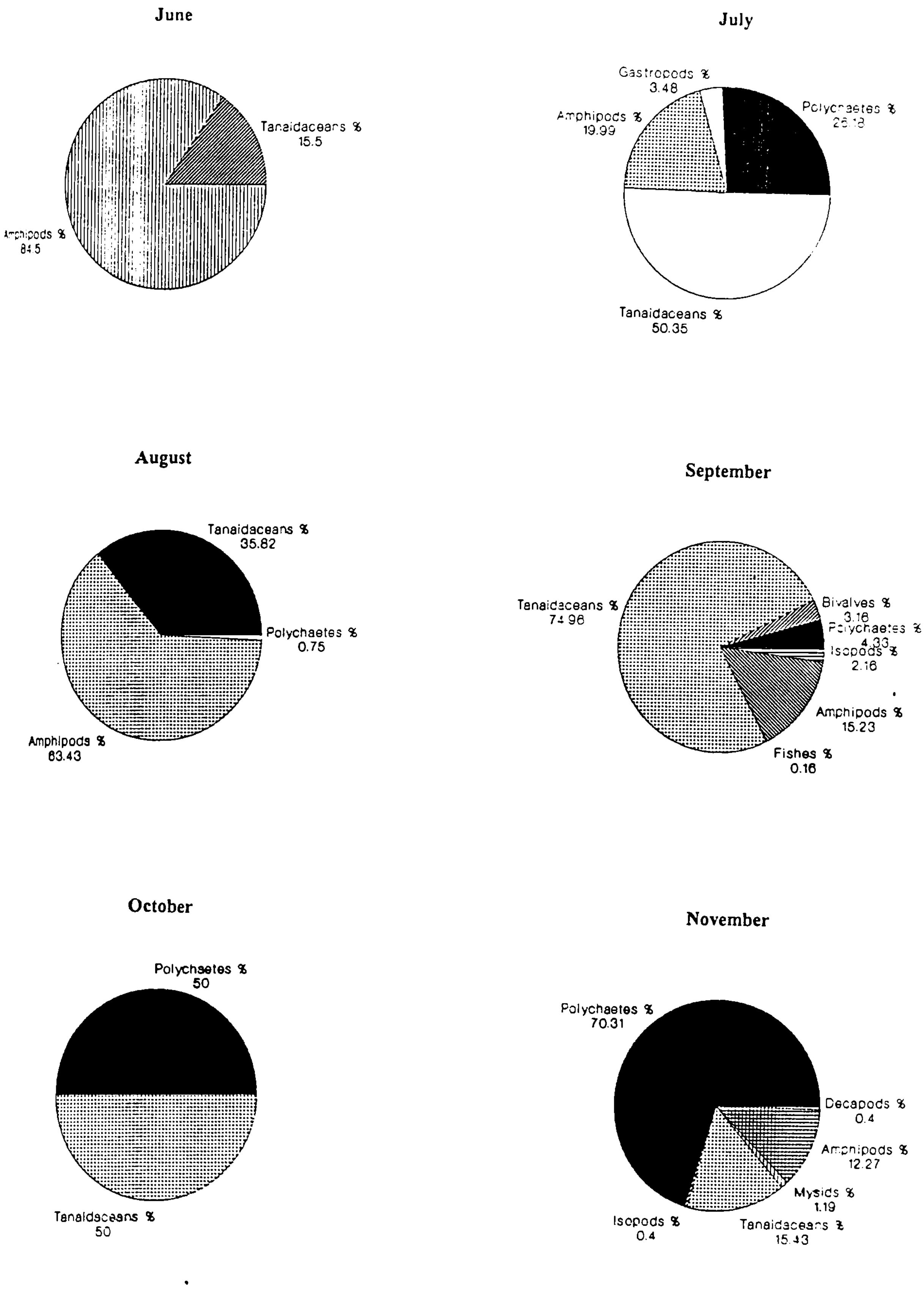


Fig. 4.7. Percentage distribution of major groups of benthos at Station P1

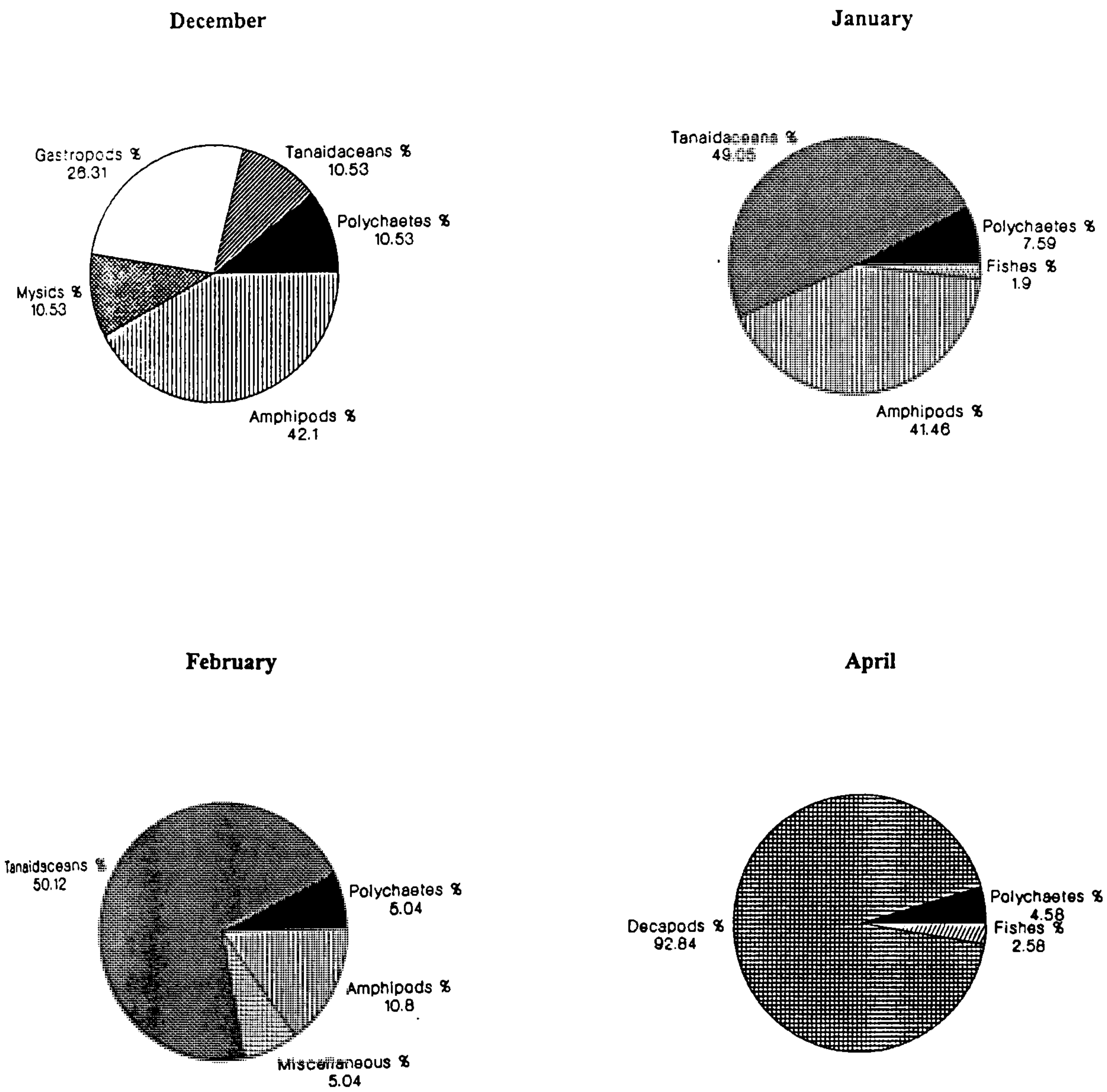


Fig. 4.8. Percentage distribution of major groups of benthos at Station P1

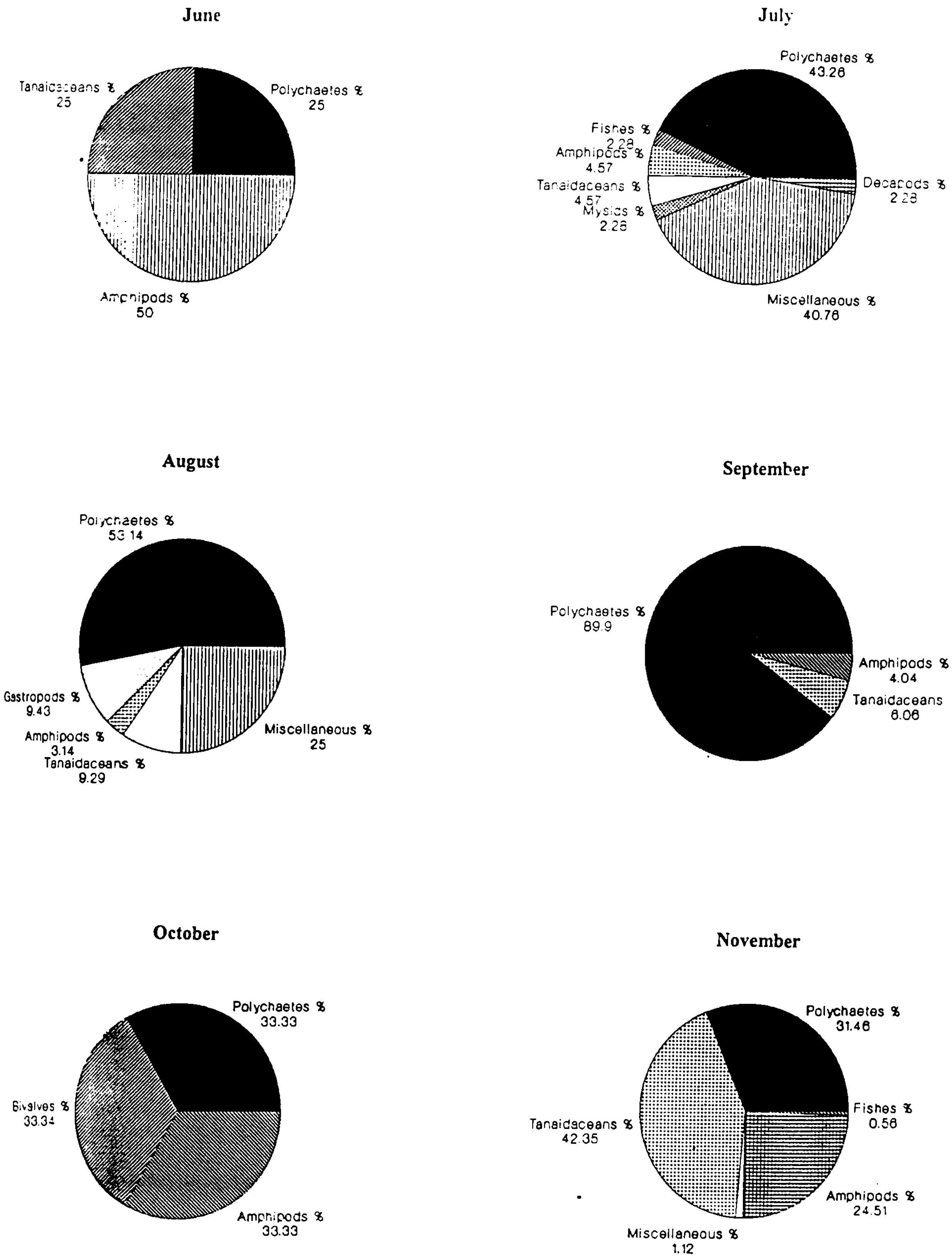


Fig. 4.9. Percentage distribution of major groups of benthos at Station P2

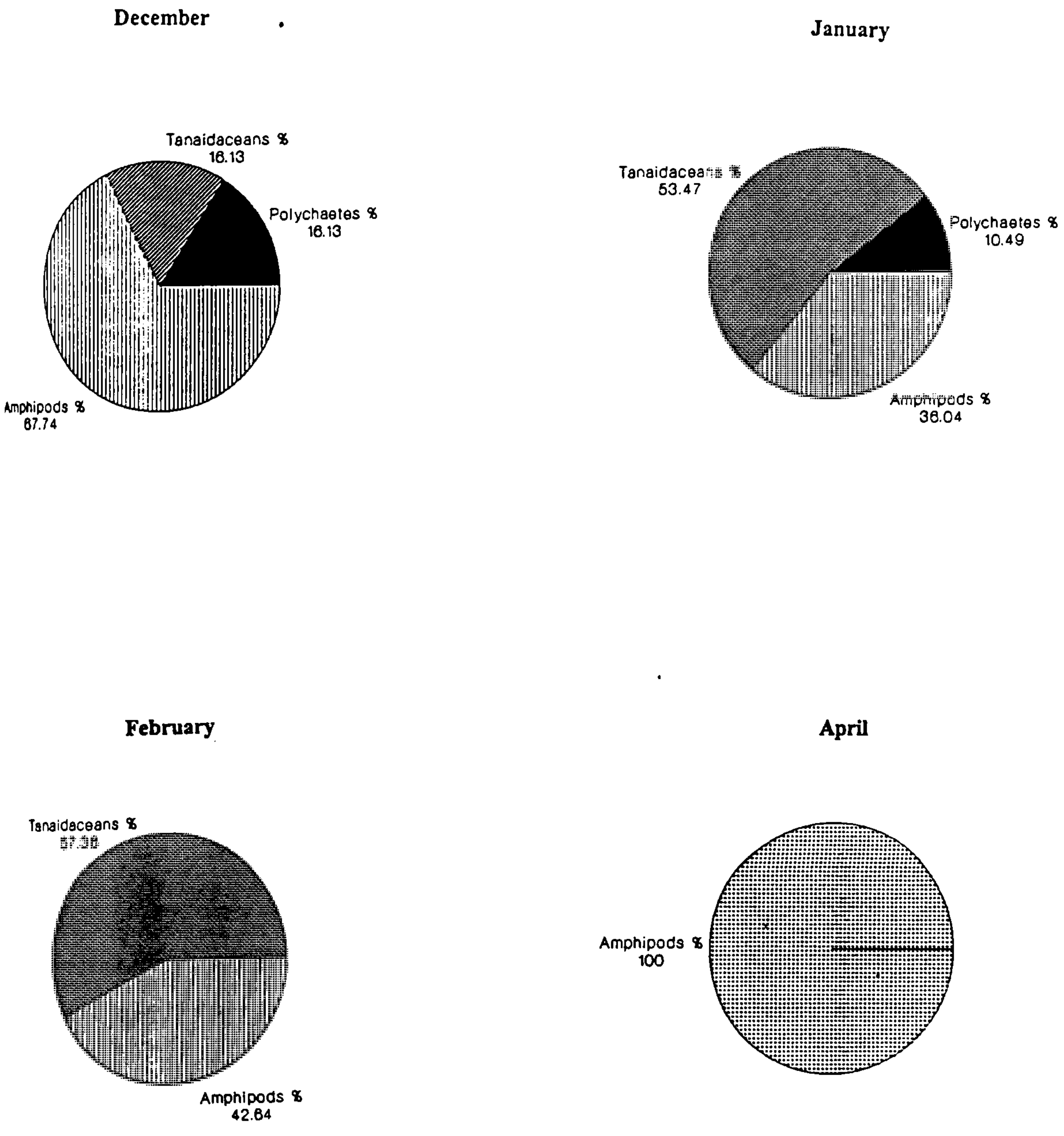


Fig. 4.10. Percentage distribution of major groups of benthos at Station P2

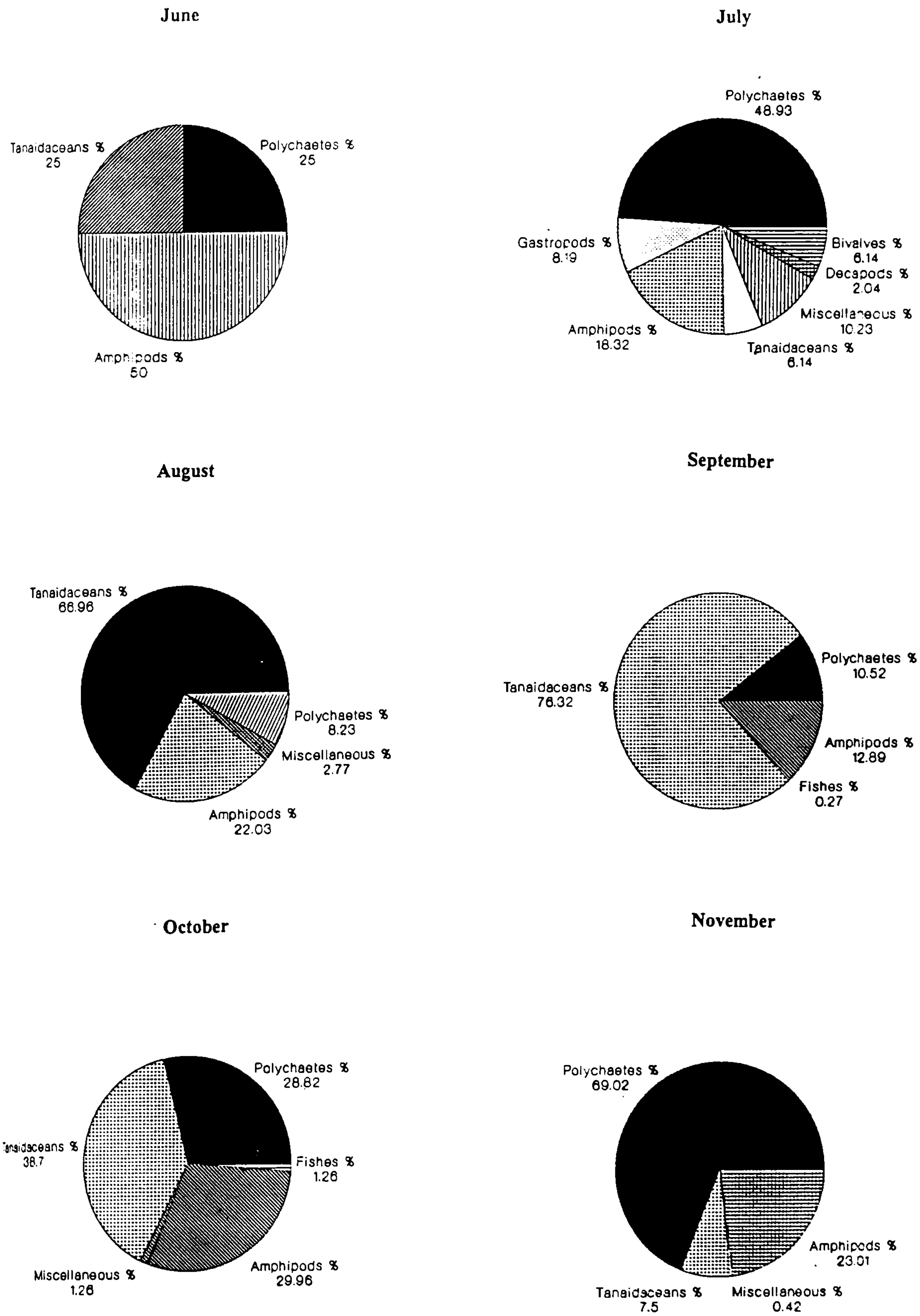


Fig. 4.11. Percentage distribution of major groups of benthos at Station P3

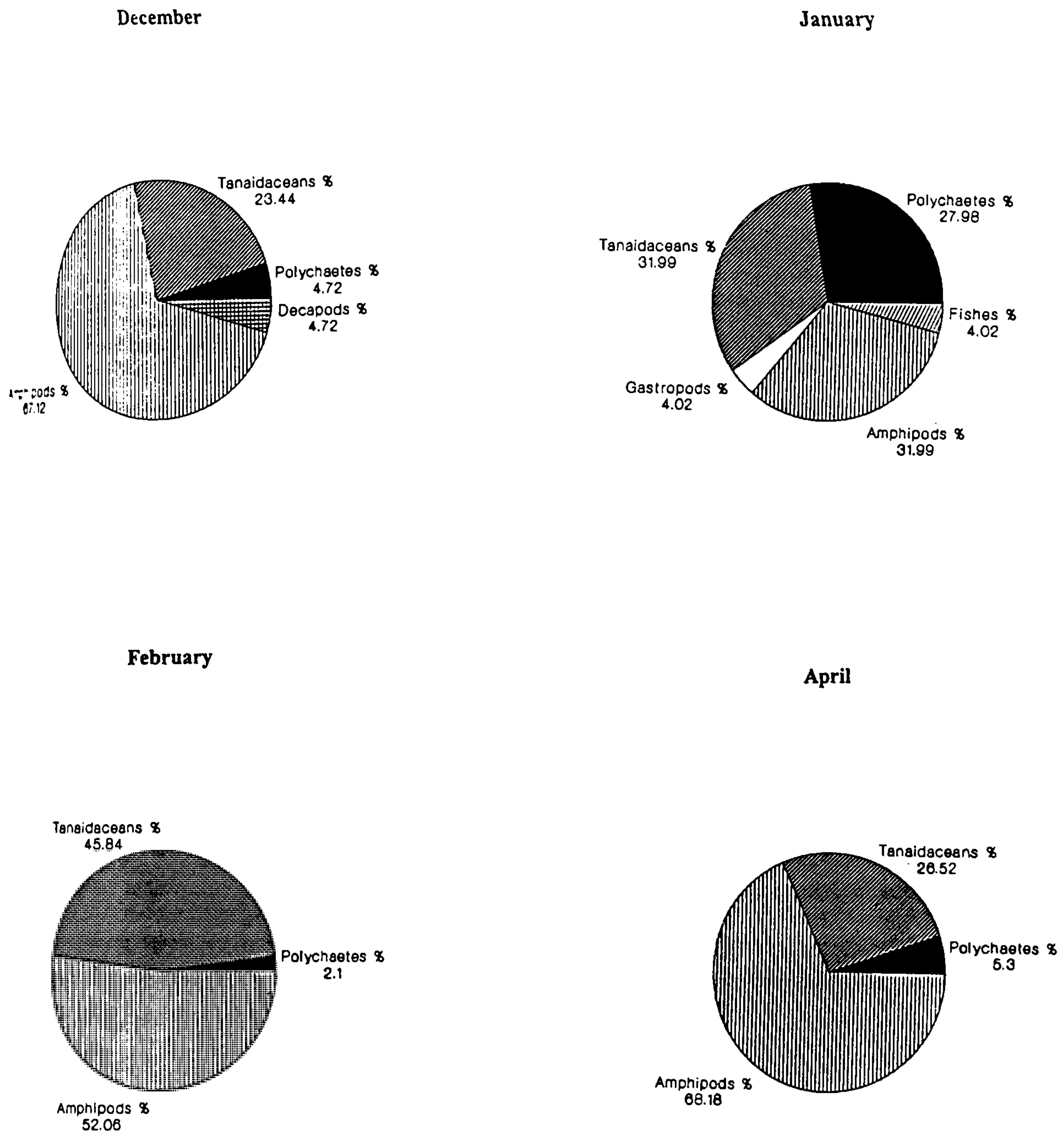


Fig. 4.12. Percentage distribution of major groups of benthos at Station P3

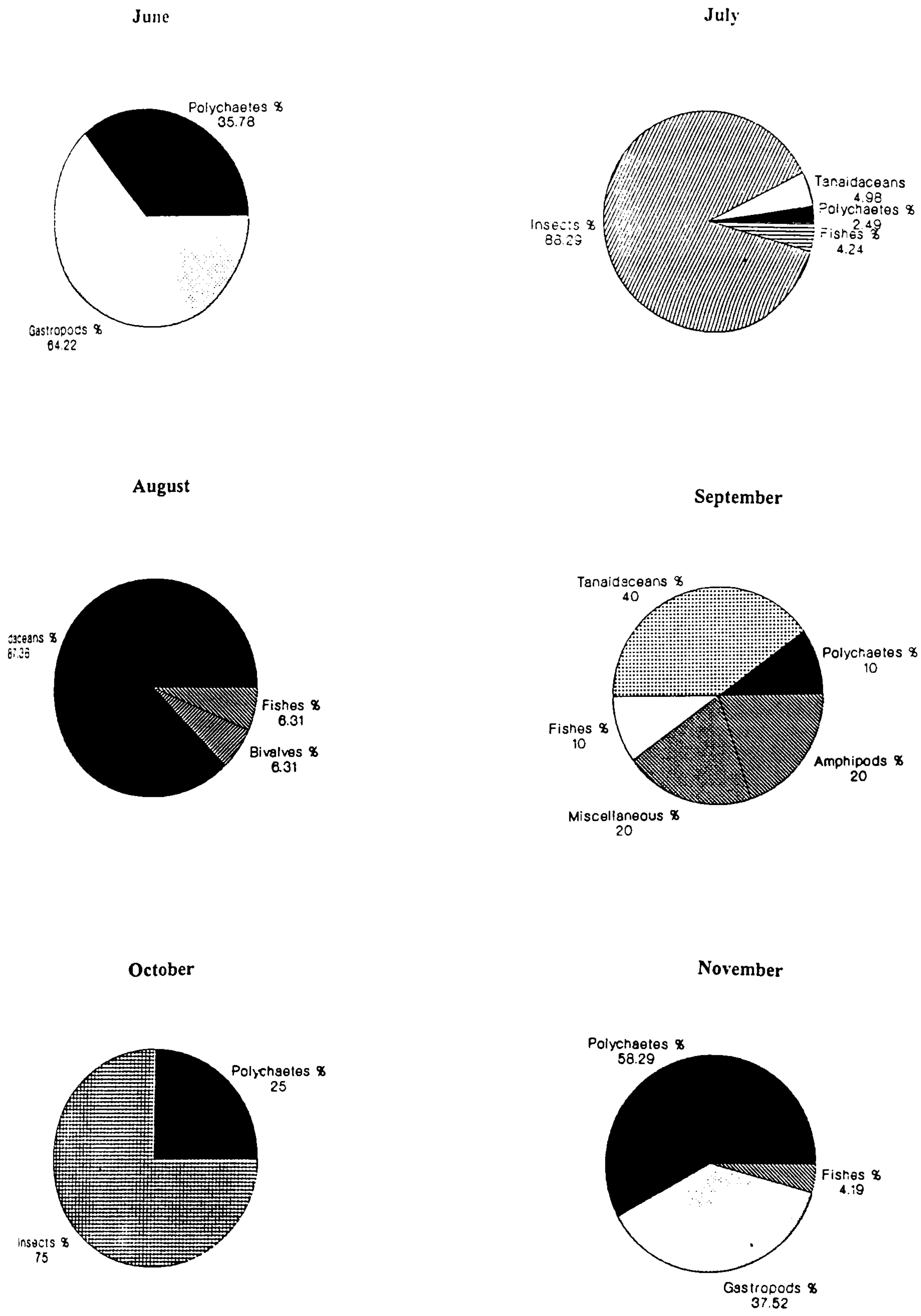


Fig. 4.13. Percentage distribution of major groups of benthos at Station P4

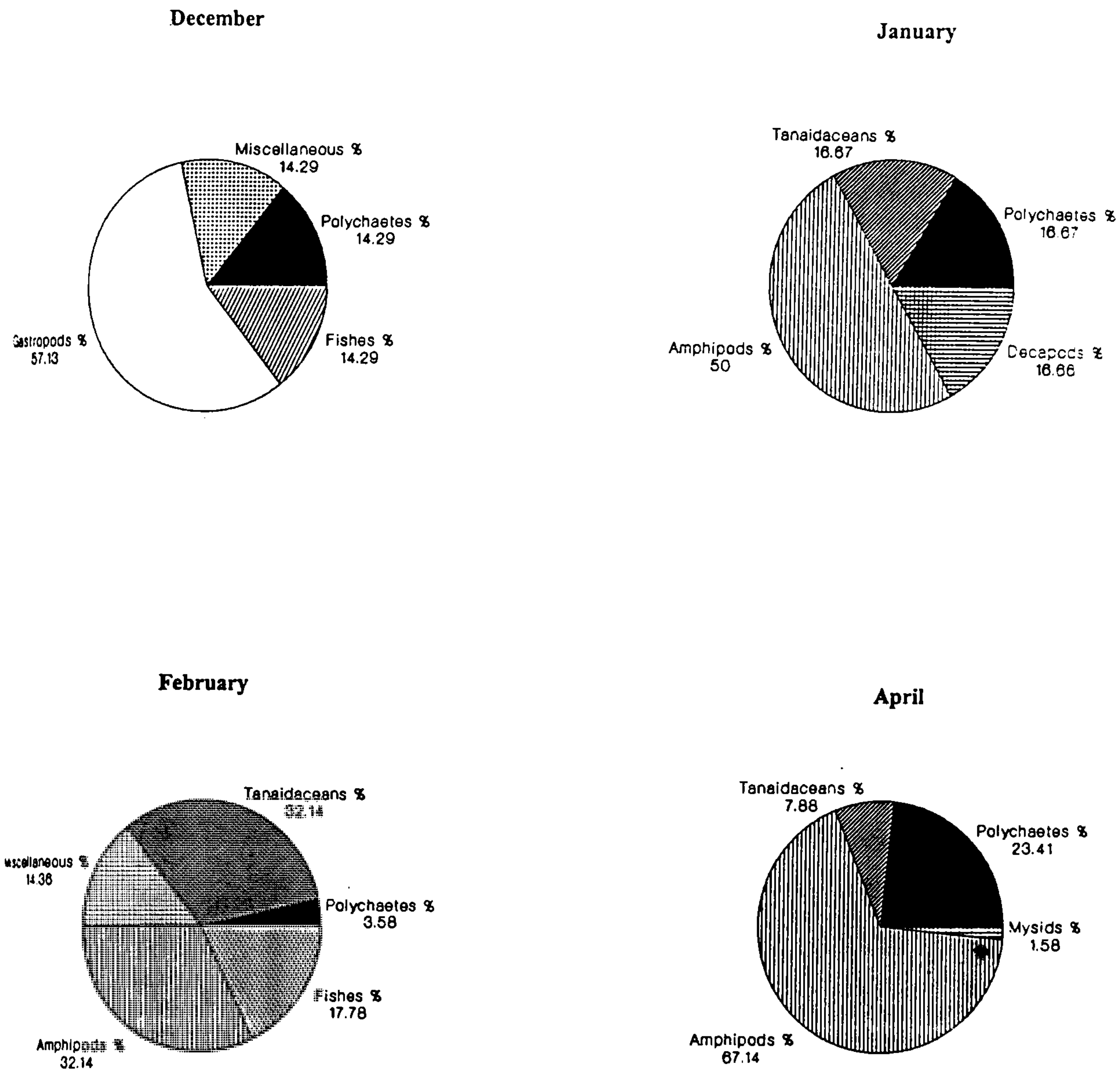


Fig. 4.14. Percentage distribution of major groups of benthos at Station P4

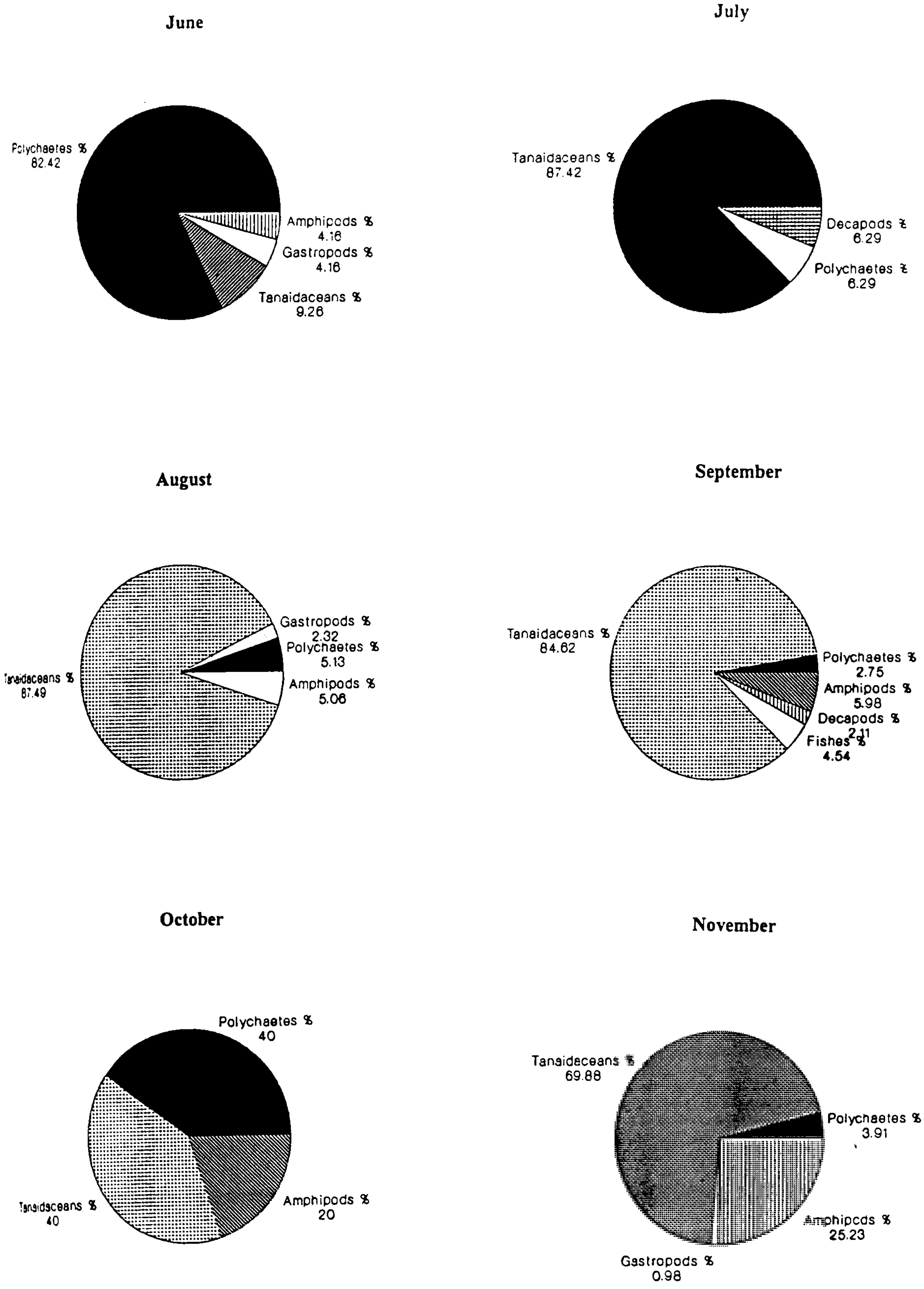


Fig. 4.15. Percentage distribution of major groups of benthos at Station P5

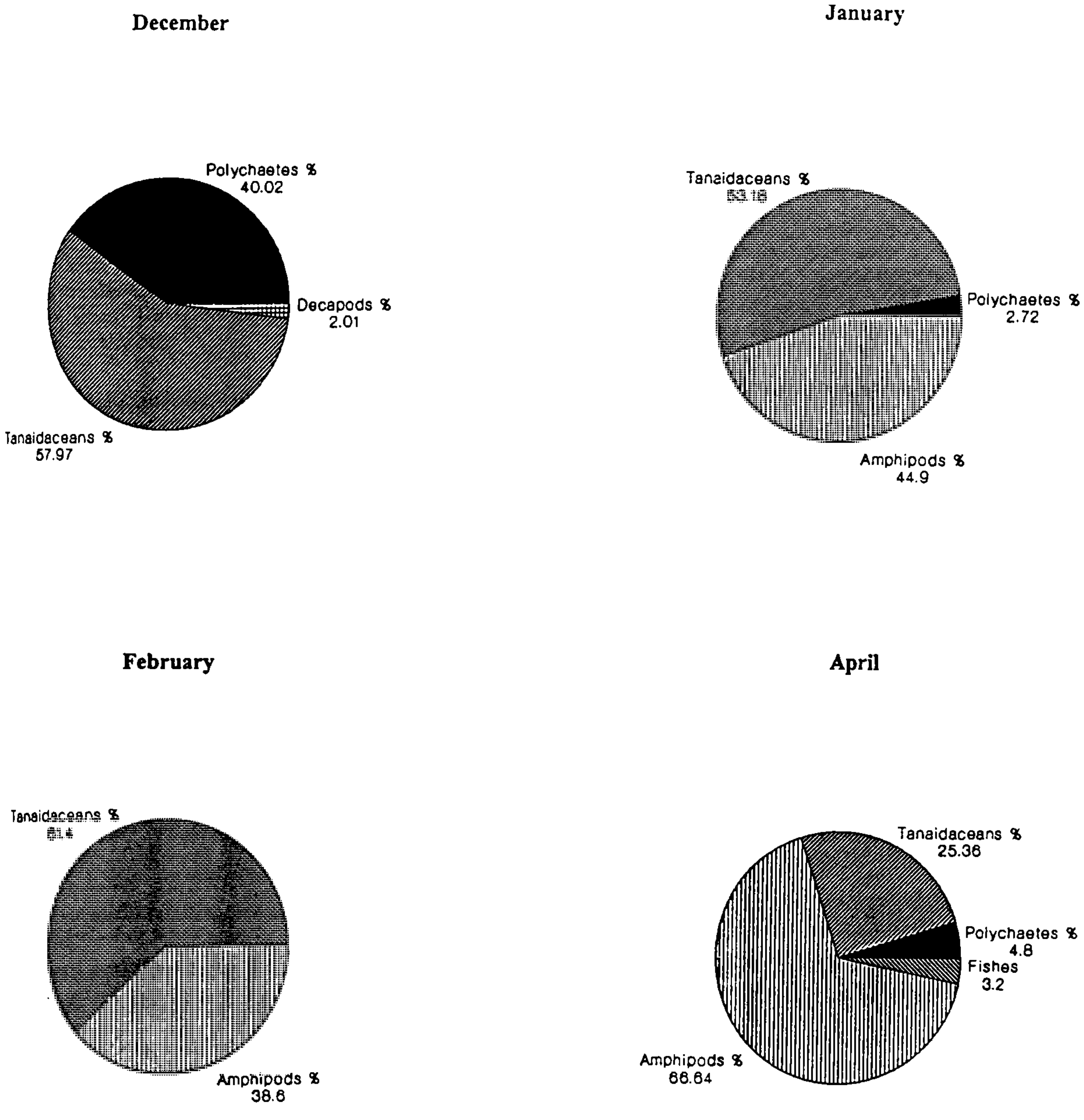


Fig. 4.16. Percentage distribution of major groups of benthos at Station P5

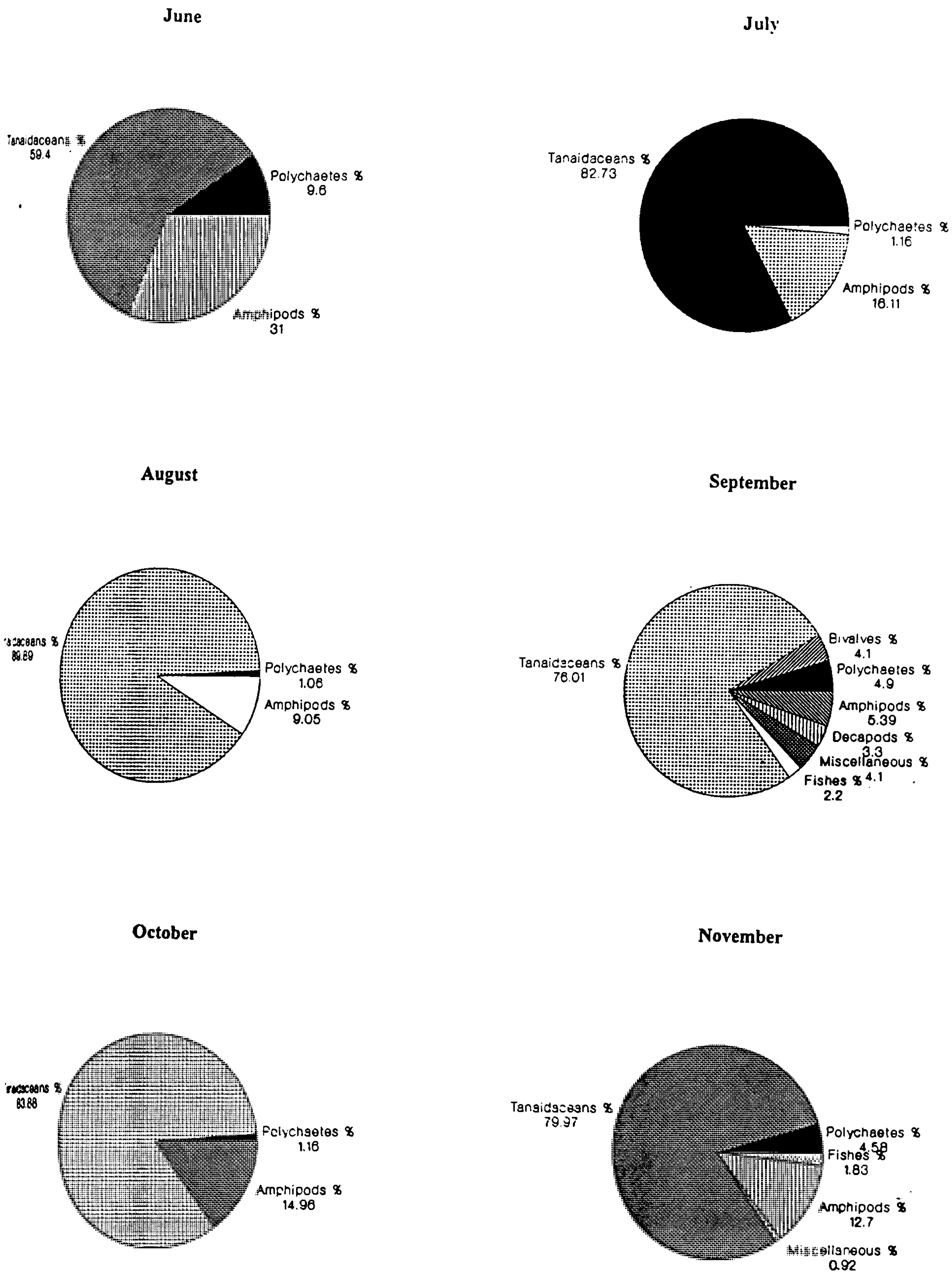


Fig. 4.17. Percentage distribution of major groups of benthos at Station P6

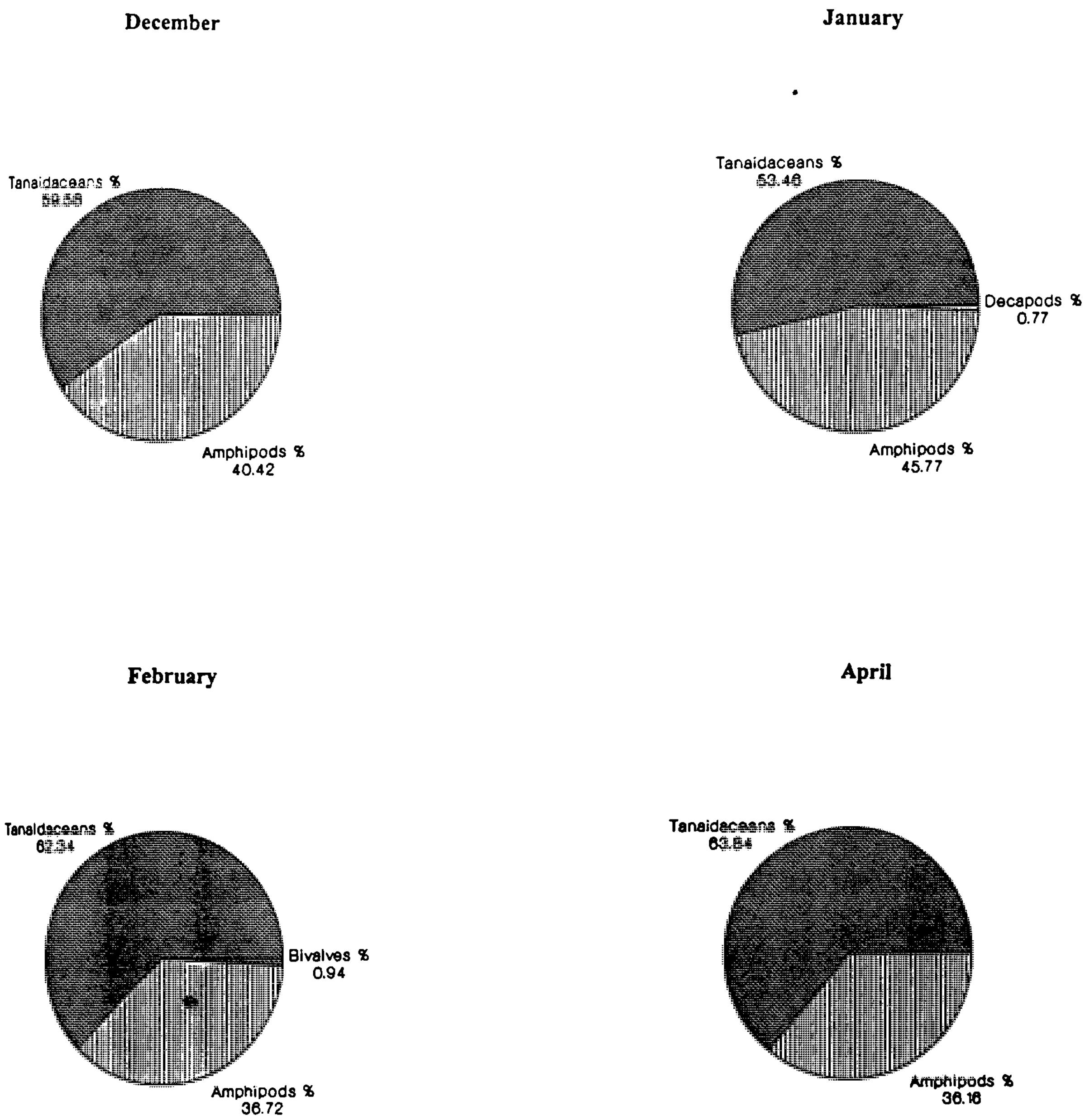


Fig. 4.18. Percentage distribution of major groups of benthos at Station P6

Stn. P1

	J	J	A	S	O	N	D	J	F	A
J	–	◕	◕	●	◕	●	◑	◔	⊕	●
J	84	–	◷	◑	●	◷	◕	◔	◑	●
A	82	55	–	◔	●	◔	●	⊕	◑	●
S	96	73	65	–	●	◕	●	◕	●	●
O	89	95	94	99	–	●	◑	◕	◑	●
N	90	50	65	84	96	–	●	◑	◕	●
D	75	85	91	98	76	91	–	◑	◔	●
J	61	61	49	85	83	72	78	–	⊕	●
F	46	78	77	94	77	87	64	48	–	●
A	100	100	100	100	95	100	100	98	100	–

Stn. P2.

	J	J	A	S	O	N	D	J	F	A
J	–	◕	◕	◕	◑	●	◔	●	◕	◑
J	85	–	⊕	◑	◕	◑	◕	◕	●	●
A	85	39	–	◔	●	◑	◕	◕	●	●
S	86	74	66	–	◕	◔	◕	◕	●	●
O	71	88	100	86	–	●	◕	●	●	◑
N	91	79	79	62	96	–	◑	⊕	⊕	●
D	64	81	84	88	84	71	–	◑	⊕	●
J	91	89	86	87	98	27	71	–	⊕	●
F	83	94	96	91	94	49	45	48	–	●
A	78	96	100	96	71	99	94	99	97	–

40–50 ⊕ , 50–60 ◷ , 60–70 ◔ , 70–80 ◑ , 80–90 ◕ , 90–100 ●

Fig. 4.19. Bray Curtis similarity coefficient (%) between months at stations P1 and P2

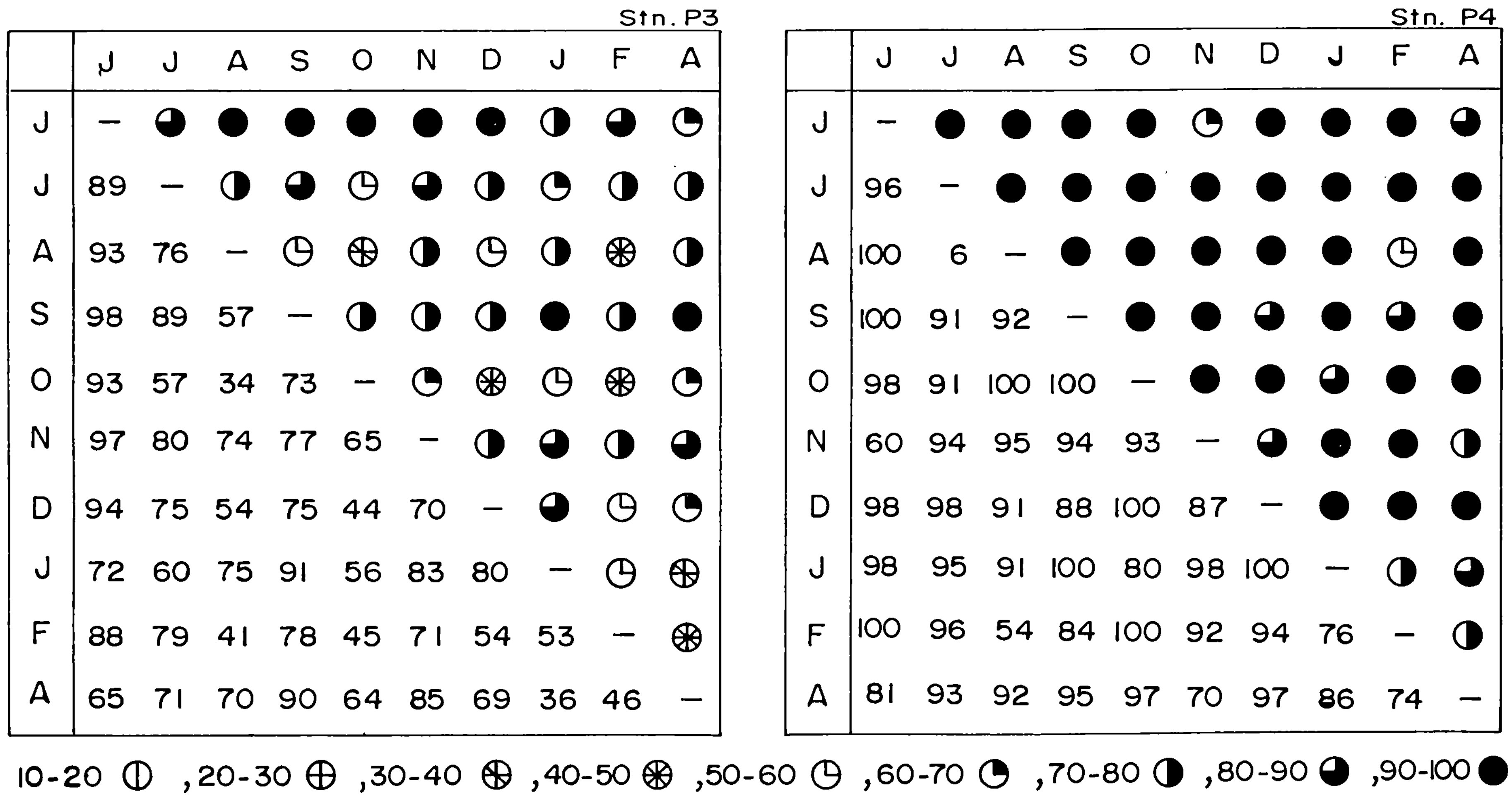


Fig. 4.20. Bray Curtis similarity coefficient (%) between months at stations P3 and P4.

Stn. P5	J	J	A	S	O	N	D	J	F	A
J	–									
J	95	–								
A	87	91	–							
S	96	97	51	–						
O	98	71	97	99	–					
N	83	75	56	80	94	–				
D	95	61	75	90	89	40	–			
J	90	76	63	79	93	19	43	–		
F	89	38	92	97	67	78	65	79	–	
A	80	85	82	87	91	57	65	42	74	–

Stn. P6	J	J	A	S	O	N	D	J	F	A
J	–									
J	51	–								
A	49	69	–							
S	68	85	37	–						
O	45	31	69	84	–					
N	60	24	66	81	51	–				
D	44	28	60	78	53	27	–			
J	34	24	63	78	49	38	13	–		
F	9	48	49	69	43	59	40	31	–	
A	42	52	67	83	24	70	51	47	39	–

0-10 , 10-20 , 20-30 , 30-40 , 40-50 , 50-60 , 60-70 ,
70-80 , 80-90 , 90-100

Fig.4.21. Bray Curtis similarity coefficient (%) between months at stations P5 and P6.

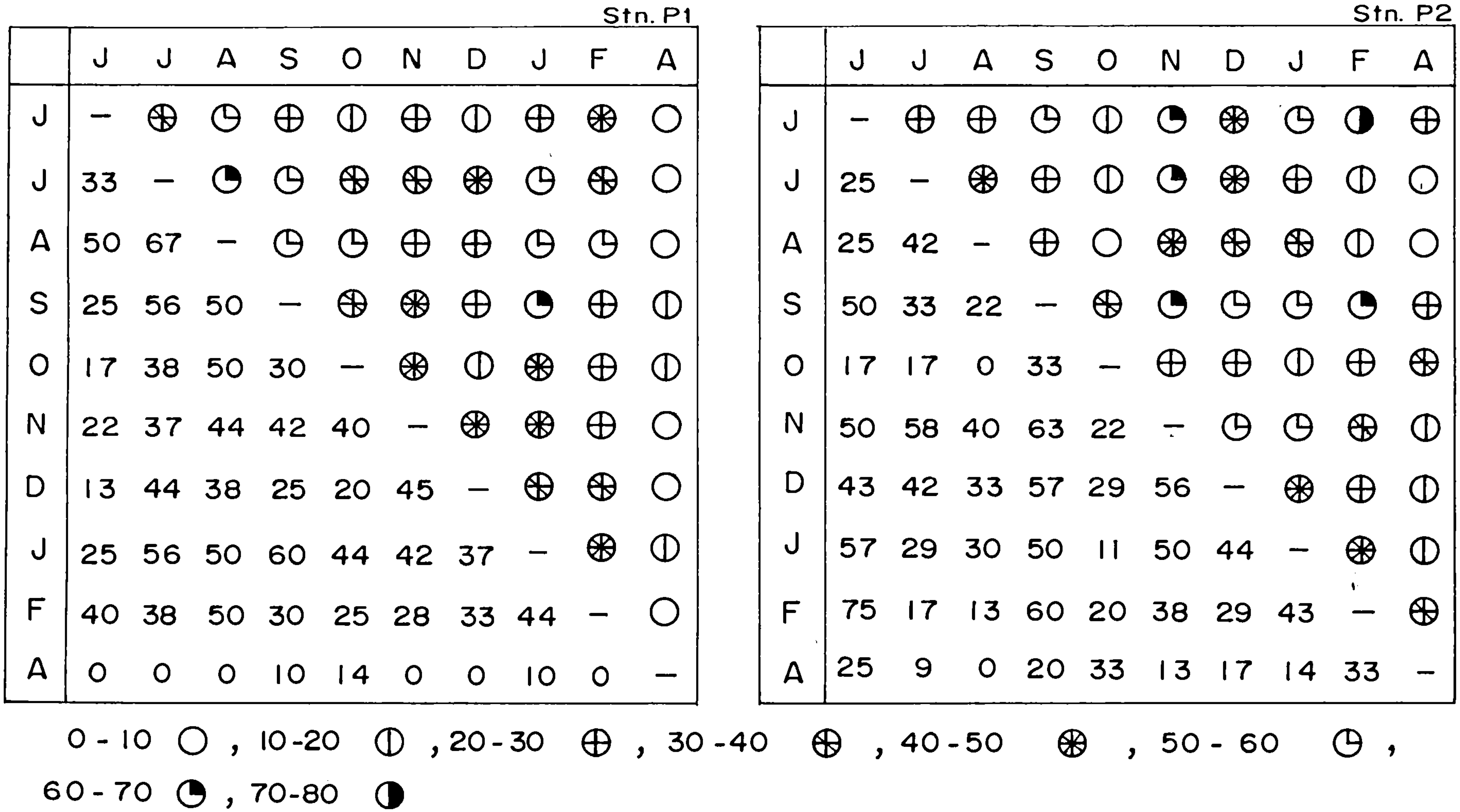


Fig. 4.22. Community coefficient (%) between months at stations P1 & P2.

Stn. P3

	J	J	A	S	O	N	D	J	F	A
J	—									
J	17	—								
A	50	42	—							
S	50	31	71	—						
O	22	36	56	56	—					
N	43	50	86	63	67	—				
D	11	29	30	30	37	40	—			
J	50	21	33	50	40	44	19	—		
F	50	17	29	29	38	43	25	50	—	
A	100	17	50	50	22	43	11	50	50	—

Stn. P4

	J	J	A	S	O	N	D	J	F	A
J	—									
J	14	—								
A	0	33	—							
S	0	25	14	—						
O	25	40	0	0	—					
N	33	25	14	11	17	—				
D	17	13	17	13	0	29	—			
J	17	29	17	0	20	13	0	—		
F	0	25	33	25	0	25	13	29	—	
A	13	38	13	10	14	22	11	43	22	—

10-20 , 20-30 , 30-40 , 40-50 , 50-60 , 60-70 , 70-80 , 80-90 , 90-100

Fig.4.23. Community coefficient (%) between months at stations P3 & P4.

Stn. P5

	J	J	A	S	O	N	D	J	F	A
J	–									
J	29	–								
A	71	38								
S	40	44	60	–						
O	14	40	43	33	–					
N	57	43	63	50	29	–				
D	11	29	20	27	33	22	–			
J	43	50	71	56	60	57	25	–		
F	33	75	43	33	50	50	33	60	–	
A	57	43	63	67	29	71	22	57	50	–

Stn. P6

	J	J	A	S	O	N	D	J	F	A
J	–									
J	80	–								
A	67	80	–							
S	44	50	44	–						
O	80	100	80	50	–					
N	50	57	50	50	57	–				
D	43	50	43	30	50	33	–			
J	43	50	43	40	50	33	67	–		
F	50	60	50	50	60	38	50	50	–	
A	60	75	60	38	75	43	60	60	75	–

10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100

Fig.4.24. Community coefficient(%) between months at stations P5 & P6.

Table 4.1 Station locations

STATIONS	LATITUDE (°N)	LONGITUDE (°E)
P1	09° 59. 44'	076°14. 10'
P2	09° 59.42'	076°14. 12'
P3	09° 59.46'	076°14. 16'
P4	09° 59.45'	076°14. 15'
P5	09° 59. 36'	076°14. 12'
P6	09° 59. 34'	076°14 .13'

Table 4.2 Variation in energy content (J/g dry weight) at stations P1 to P6

MONTHS	P1	P2	P3	P4	P5	P6
JUN	1412.60	1375.90	1272.20	591.80	797.00	976.30
JUL	810.00	719.30	1041.10	1067.00	872.60	835.90
AUG	438.50	632.90	1047.60	1086.50	695.50	892.10
SEP	1015.20	1207.40	1168.60	1259.30	1181.50	1105.90
OCT	680.40	270.00	1360.80	1028.20	436.30	1015.20
NOV	699.80	1356.50	1535.80	1445.00	533.50	1073.50
DEC	591.80	719.30	1207.40	1233.40	989.30	1181.50
JAN	654.50	745.30	898.60	1080.00	898.60	540.00
FEB	295.90	578.90	835.90	1438.60	1464.50	1181.50
APL	546.50	598.30	1252.80	790.60	712.80	764.60

Table 4.3 Benthic density (No/m^2) at Stations P1 to P6

STATIONS	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	APL	TOTAL
P1	271	3021	2792	13002	126	5275	399	1107	420	813	27226
P2	168	920	668	1040	126	3738	651	3587	1273	21	12192
P3	84	1026	2273	7917	1669	4981	1335	526	999	396	21200
P4	1688	1688	333	210	84	501	147	126	588	1333	6698
P5	2019	334	6585	19502	105	2148	1042	2313	273	1313	35634
P6	4770	1813	9898	20898	1811	2291	2694	2731	4479	1958	53348

Table 4.4 Benthic biomass (g/m^2) at Stations P1 to P6

STATIONS	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	APL	TOTAL
P1	7.45	33.24	23.84	5.92	7.24	24.40	11.40	10.56	3.19	9.18	136.42
P2	3.13	22.00	17.40	19.50	24.56	15.76	8.36	17.30	6.63	0.46	135.10
P3	2.02	118.15	27.46	20.87	18.08	15.57	12.63	9.80	10.14	2.60	237.32
P4	24.91	4.98	11.13	9.79	4.01	10.28	5.18	2.76	23.16	4.85	101.05
P5	14.46	69.4	50.07	43.41	14.70	19.11	12.44	10.59	2.60	20.65	257.43
P6	34.02	10.01	28.26	79.04	19.42	23.44	11.52	8.31	15.20	11.10	240.32

Table 4.5 Total No. of specimens, numerical abundance and percentage contribution of different groups of benthic fauna at stations P1 to P6.

Station No.	No. of specimens	Polychaetes	Amphipods	Tanaidaceans	Isopods	Decapods	Mysids	Gastropods	Bivalves	Insects	Fishes	Misc. groups
P 1	27226	4794 (17.61)	6026 (22.13)	15152 (55.65)	42 (0.15)	21 (0.08)	105 (0.39)	981 (3.60)	21 (0.08)	--	63 (0.23)	21 (0.08)
P 2	12192	3450 (28.30)	3443 (28.25)	4526 (37.11)	--	21 (0.17)	21 (0.17)	63 (0.52)	42 (0.34)	--	42 (0.34)	584 (4.80)
P 3	21206	5718 (26.95)	5250 (24.76)	9713 (45.81)	--	84 (0.40)		105 (0.50)	63 (0.30)	--	63 (0.30)	210 (0.98)
P 4	6698	1355 (20.24)	1189 (17.74)	774 (11.55)	--	21 (0.31)	21 (0.31)	1356 (20.25)	21 (0.31)	1604 (23.96)	210 (3.12)	147 (2.20)
P 5	35634	2336 (6.55)	4585 (12.87)	28376 (79.64)	--	63 (0.18)	--	126 (0.35)	--	--	147 (0.41)	--
P 6	53343	898 (1.68)	9046 (16.95)	43126 (80.85)	--	84 (0.16)	--	--	63 (0.12)	--	84 (0.16)	42 (0.08)

(Values in the brackets indicates the %)

Table 4.6 Average ($\bar{X}$) and Coefficient of Variation (C.V. (%)) of total benthic density, water quality parameters and sediment characteristics at stations P1 to P6

Parameters	P1		P2		P3		P4		P5		P6	
	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)
Density (No./m^2)	272.30	138.42	1218.80	105.16	2120.00	110.38	674.50	92.05	3563.20	157.20	5334.30	106.60
Temperature (°C)	29.83	5.37	29.78	5.02	29.67	4.92	30.24	5.28	29.91	5.38	29.97	6.07
Salinity (psu)	14.09	67.34	12.78	78.78	12.87	78.03	14.05	74.92	12.81	73.90	12.77	79.39
DO (m/l/)	3.77	38.00	3.95	45.52	4.58	33.97	4.80	34.21	3.30	29.40	4.69	33.68
BOD (ml/l)	0.70	206.93	0.97	200.00	0.18	300.00	0.20	300.00	1.29	128.27	0.76	125.98
NO_2-N (µmol/l)	0.79	128.80	0.96	80.24	0.67	115.88	0.78	92.03	1.53	87.89	1.07	82.41
NO_3-N (µmol/l)	3.35	55.94	3.44	70.41	2.87	73.09	3.05	85.79	5.32	96.39	3.84	83.93
NH_4-N (µmol/l)	21.99	190.30	14.57	90.13	21.12	198.04	9.88	106.58	36.93	135.66	17.46	77.06
PO_4-P (µmol/l)	11.64	73.30	23.06	58.89	27.41	55.46	26.84	69.38	13.59	71.97	11.92	46.51
Chlorophyll 'a' (mg/m^3)	8.29	114.78	8.92	75.14	14.85	62.61	28.01	88.28	5.95	42.43	8.10	43.92
POC (ml/l)	4.77	72.08	5.64	72.28	8.13	74.79	21.34	125.43	3.91	43.94	5.13	58.31
Suspended load (mg/l)	52.96	62.05	51.54	54.59	48.52	81.36	150.63	145.40	52.18	46.21	54.18	52.62
Sand (%)	39.82	44.26	28.25	83.28	7.08	167.02	11.88	135.65	30.79	24.80	1.08	71.17
Silt (%)	18.13	45.82	19.71	56.64	24.98	44.47	21.43	44.88	21.37	44.73	29.16	30.76
Clay (%)	42.06	34.41	52.03	36.12	67.87	14.57	66.69	25.65	47.83	21.15	69.76	13.04
Organic matter (%)	3.31	41.67	3.80	42.54	5.38	17.32	5.10	22.91	3.97	33.49	4.43	20.11

Table 4.7 Average ($\bar{X}$) and Coefficient of Variation (C.V.(%)) of species at stations P1 to P6

SPECIES	P1		P2		P3		P4		P5		P6	
	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)
POLYCHAETES												
Lycastis indica	6.30	152.75	4.20	300.00	--	--	6.30	152.75	--	--	--	--
Dendronereis aestuarina	--	--	45.80	150.88	66.6	126.25	2.10	300.00	10.50	134.16	2.10	300.00
Perenereis cavifrons	--	--	2.10	300.00	--	--	--	--	--	--	--	--
Glycera longipinnis	--	--	--	--	2.10	300.00	--	--	--	--	--	--
Prionospio pinnata	--	--	--	--	--	--	--	--	--	--	8.40	300.00
Prionospio polybranchiata	4.20	200.00	64.90	105.43	89.80	192.40	4.20	200.00	162.70	253.71	35.40	300.00
Capitella capitata	460.50	238.97	217.50	139.48	412.80	240.74	122.90	155.15	60.30	133.00	43.90	135.28
Sternaspis scutata	8.40	165.83	10.40	300.00	--	--	--	--	--	--	--	--
AMPHIPODS												
Melita zeylancia	577.20	116.17	338.00	127.17	516.60	68.95	114.60	232.35	433.40	87.41	892.00	52.92
Grandidierella gilesi	14.70	202.53	6.30	152.75	6.30	300.00	--	--	4.20	300.00	6.30	300.00
Quadrivisio bengalensis	10.50	161.20	375.10	160.68	2.10	300.00	4.20	300.00	20.90	268.19	6.30	213.44
TANAIDACEANS												
Apseudes chilkensis	512.70	189.03	--	--	477.30	204.94	18.90	160.63	2193.80	187.30	2960.40	163.27
Apseudes gymnophobium	1002.40	220.87	77.20	117.64	493.90	158.18	58.40	163.14	643.80	193.01	1352.20	69.87
DECAPODS												
Penaeid prawn	2.10	300.00	2.10	300.00	2.10	300.00	2.10	300.00	4.20	200.00	8.40	229.13
Crab	--	--	--	--	6.30	300.00	--	--	2.10	300.00	--	--

Table 4.7 contd…

SPECIES	P1		P2		P3		P4		P5		P6	
	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)
ISOPOD												
Asellus sp.	4.20	200.00	--	--	--	--	--	--	--	--	--	--
MYSIDS												
Mysid sp.	10.50	204.94	21.0	300.00	--	--	2.10	300.00	--	--	--	--
GASTROPODS												
Gastropod sp.	21.00	200.00	--	--	--	--	8.40	300.00	2.10	300.00	--	--
Littorina littorea	77.10	300.00	--	--	2.10	300.00	125.10	253.89	10.50	240.83	--	--
Dentalium sp.			6.30	300.00	8.40	300.00	--	--	--	--	--	--
BIVALVES												
Bivalve sp.	2.10	300.00	--	--	2.10	300.00	2.10	300.00	--	--	6.30	213.44
Cavolina sp.	--	--	4.20	300.00	2.10	300.00	--	--	--	--	--	--
Cardium sp.	--	--	--	--	2.10	300.00	--	--	--	--	--	--
INSECTS												
Water beetle	--	--	--	--	--	--	160.40	287.15	--	--	--	--
Chironomid	--	--	--	--	--	--	--	--	--	--	--	--
FISHES												
Juvenile fish	6.30	152.75	4.20	200.00	6.30	152.75	20.90	140.75	14.70	221.77	8.40	200.00
MISCELLANEOUS GROUPS												
Foraminifera	--	--	--	--	--	--	2.10	300.00	--	--	2.10	300.00
Anthozoa	2.10	300.00	58.40	199.82	21.00	161.25	12.60	213.44	--	--	2.10	300.0

Table 4.8 Average ($\bar{X}$) and Coefficient of Variation (C.V. (%)) for each month at stations P1 to P6 based on species distribution

Months	P1		P2		P3		P4		P5		P6	
	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)	$\bar{X}$	C.V.(%)
June	15.94	300.00	10.50	300.00	4.67	300.00	98.06	300.00	155.31	300.00	240.71	300.00
July	177.71	199.62	57.50	163.37	57.00	138.14	99.29	363.43	25.69	256.74	129.50	214.56
August	164.34	300.00	41.75	300.00	126.17	300.00	19.59	300.00	506.46	300.00	707.00	300.00
September	765.82	135.28	65.00	135.28	439.83	135.28	12.35	135.28	1500.15	135.28	1492.71	135.28
October	7.41	52.92	7.88	52.92	92.72	52.92	4.94	52.92	8.08	52.92	129.36	52.92
November	310.29	300.00	233.63	300.00	276.72	300.00	34.41	300.00	165.23	300.00	163.64	300.00
December	23.47	213.44	40.69	213.44	74.17	213.44	3.71	213.44	80.15	213.44	192.43	213.44
January	65.12	163.27	224.06	163.27	29.00	163.27	7.41	163.27	177.92	163.27	195.07	163.27
February	24.53	69.87	79.44	69.87	55.50	69.87	34.41	69.87	20.92	69.87	313.93	69.87
April	47.82	229.13	1.31	229.13	22.00	221.13	78.41	229.13	101.00	229.13	139.86	229.13

Table 4.9 Correlation coefficient (*r*) of total benthic density with water quality parameters and sediment characteristics

Parameters	P1	P2	P3	P4	P5	P6
Temperature (°C)	-0.07	-0.02	0.08	-0.41	-0.17	-0.17
Salinity (psu)	-0.35	0.19	-0.30	-0.30	-0.28	-0.28
DO (m/l/)	-0.43	-0.30	0.12	0.24	0.52	0.44
BOD (ml/l)	-0.19	-0.32	-0.29	0.54	-0.16	-0.08
NO_2-N (μmol/l)	0.81	-0.35	0.22	0.33	0.38	0.07
NO_3-N (μmol/l)	-0.43	0.32	-0.32	-0.38	-0.02	-0.27
NH_4-N (μmol/l)	0.91	0.06	0.81	0.11	0.96	0.79
PO_4-P (μmol/l)	0.47	-0.22	0.64	0.46	-0.23	-0.02
Chlorophyll 'a' (mg/m^3)	0.22	-0.06	0.03	-0.35	0.21	0.01
POC (ml/l)	0.86	-0.15	0.72	-0.34	0.52	0.69
Suspended load (mg/l)	0.46	0.51	0.87	-0.30	0.31	0.36
Sand (%)	-0.21	-0.50	0.26	0.50	-050	-0.14
Silt (%)	0.17	0.37	0.22	-0.84	0.43	0.35
Clay (%)	0.16	0.40	-0.55	0.01	-0.03	-0.34
Organic matter (%)	0.28	0.35	0.32	-0.60	0.28	0.26

Table 4.10a **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance(Pielou's) index (*D*), and Evenness (Heip's) index (*E*) for benthiccommunity structures at stations P1 & P2**

	STATION – P1					STATION – P2				
MONTHS	*M*	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
JUN	0.95	0.26	0.62	0.16	0.86	3.10	0.65	1.75	0.54	1.58
JUL	3.31	0.71	2.02	0.67	1.30	7.77	0.77	2.66	0.83	1.33
AUG	2.00	0.53	1.36	0.73	0.96	4.07	0.75	2.21	0.66	1.63
SEPT	3.92	0.57	1.47	1.12	0.48	3.05	0.48	1.34	0.60	0.71
OCT	4.39	0.78	2.25	0.76	2.13	2.19	0.66	1.58	0.85	1.94
NOV	4.95	0.49	1.52	1.28	0.45	4.51	0.75	2.27	0.62	1.24
DEC	5.31	0.81	2.58	0.99	2.04	4.09	0.54	1.64	0.69	0.83
JAN	5.29	0.67	2.00	0.84	0.91	3.89	0.63	1.78	0.54	0.82
FEB	3.52	0.63	1.70	0.31	1.12	1.48	0.60	1.43	0.51	1.59
APL	1.58	0.10	0.35	0.17	0.21	--	--	--	--	--

Table 4.10b **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance (Pielou's) index (*D*), and Evenness (Heip's) index (*E*) for benthic community structures at stations P2 & P4**

	STATION – P3					STATION – P4				
MONTHS	*M*	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
JUN	2.39	0.62	1.50	0.44	1.74	0.71	0.46	0.94	1.00	1.57
JUL	7.65	0.84	2.93	0.69	1.78	2.85	0.16	0.59	0.71	0.1997
AUG	3.43	0.71	2.01	0.65	1.29	1.83	2.26	1.29	2.25	0.48
SEPT	2.95	0.68	1.89	0.83	1.13	3.97	0.74	3.83	0.86	1.84
OCT	5.00	0.80	2.43	0.51	1.49	1.197	0.37	1.58	2.08	1.25
NOV	3.74	0.48	1.32	0.55	0.46	4.16	0.69	3.23	1.68	1.23
DEC	4.42	0.55	1.61	0.72	0.67	2.56	0.67	2.95	1.90	1.94
JAN	4.24	0.73	2.11	0.45	1.44	3.29	0.67	2.98	2.19	1.67
FEB	1.54	0.52	1.12	0.38	1.04	3.33	0.74	3.84	1.50	1.73
APL	1.78	0.46	1.11	0.38	1.02	3.69	0.50	1.99	0.62	0.63

Table 4.10c **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance (Pielou's) index (*D*), and Evenness (Heip's) index (*E*) for benthic community structures at stations P5 & P6**

	STATION – P5					STATION – P6				
MONTHS	*M*	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
JUN	2.79	0.49	1.45	0.98	0.82	2.50	0.68	1.87	0.82	1.37
JUL	2.74	0.41	1.19	0.92	0.76	2.12	0.60	1.50	0.80	1.15
AUG	3.62	0.48	1.34	0.839	0.47	2.31	0.53	1.34	0.72	0.71
SEPT	4.29	0.44	1.22	1.05	0.30	3.73	0.34	1.08	0.76	0.25
OCT	2.28	0.64	1.52	1.07	1.80	2.12	0.56	1.42	0.81	1.05
NOV	3.46	0.56	1.54	0.96	0.74	4.11	0.50	1.52	0.88	0.60
DEC	3.05	0.55	1.40	0.94	0.76	2.68	0.63	1.65	0.85	1.05
JAN	2.74	0.56	1.36	1.01	0.72	2.68	0.63	1.59	0.83	0.98
FEB	1.89	0.61	1.46	1.02	1.66	1.89	0.64	1.56	0.64	1.26
APL	3.69	0.51	1.48	0.82	0.68	1.40	0.51	1.17	0.54	1.11

Table 4.11 **Station-wise average ($\overline{X}$) and Coefficient of Variation (C.V. (%)) for species richness, concentration, diversity, dominance and evenness indices at stations P1 to P6**

STATIONS		*M*	*SI*	*H*	*D*	*E*
P1	$\overline{X}$	3.52	0.56	1.87	0.79	1.05
	σ	1.48	0.21	0.66	0.33	0.61
	C.V.(%)	42.14	38.65	41.54	41.54	57.98
P2	$\overline{X}$	3.42	0.59	1.67	0.63	1.17
	σ	1.96	0.21	0.68	0.26	0.55
	C.V.(%)	57.26	36.49	40.77	40.76	46.92
P3	$\overline{X}$	3.71	0.64	1.80	0.62	1.20
	σ	1.70	0.13	0.56	0.19	0.41
	C.V.(%)	45.73	19.61	30.94	30.93	33.92
P4	$\overline{X}$	2.76	0.52	1.40	1.48	1.25
	σ	1.11	0.20	0.57	0.60	0.58
	C.V.(%)	40.42	38.66	40.65	40.65	46.60
P5	$\overline{X}$	3.05	0.53	1.40	0.96	0.87
	σ	0.68	0.068	0.11	0.08	0.45
	C.V.(%)	22.32	12.90	8.21	8.21	51.99
P6	$\overline{X}$	2.55	0.56	1.46	0.78	0.95
	σ	0.783	0.09	0.23	0.13	0.322
	C.V.(%)	10.87	16.45	15.99	15.99	33.87

Table 4.12 Niche breadth for benthic species at stations P1 to P6

SPECIES	P1	P2	P3	P4	P5	P6
POLYCHAETES						
Lycastis indica	4.52	2.35	4.66	4.52	--	--
Dendronereis aestuarina	--	3.98	--	3.56	4.79	3.58
Perenereis cavifrons	--	3.56	--	--	--	--
Glycera longipinnis	--	--	3.56	--	--	--
Prionospio pinnata	--	--	--	--	--	1.70
Prionospio polybranchiata	3.862	5.43	3.08	3.88	1.82	1.19
Capitella capitata	1.87	4.12	2.03	3.64	4.66	4.52
Sternaspis scutata	3.98	1.57	--	--	--	--
AMPHIPODS						
Melita zeylancia	5.35	4.67	7.78	2.00	6.55	8.57
Grandidierella gilesi	2.61	--	1.92	--	2.35	1.92
Quadrivisio bengalensis	3.84	4.52	3.56	2.35	1.73	3.16
TANAIDACEANS						
Apseudes chilkensis	3.40	3.24	2.75	3.48	3.14	4.21
Apseudes gymnophobium	2.40	5.15	4.10	3.47	2.97	7.76
DECAPODS						
Penaeid prawn	3.56	3.56	3.56	3.56	3.88	2.69
Crab	--	--	1.92	--	3.56	--
ISOPOD						
Asellus sp.	3.88	--	--	--	--	--
MYSIDS						
Mysid sp.	2.80	3.56	--	3.56	--	--
GASTROPODS						
Gastropod sp.	2.46	--	--	1.70	3.56	--
Littorina littorea	1.09	--	3.56	1.60	2.38	--
Dentalium sp.	--	1.92	1.70	--	--	--
BIVALVES						
Bivalve sp.	3.56	--	3.56	3.56	--	3.16
Cavolina sp.	--	--	3.56	--	--	--
Cardium sp.		2.35	3.56			
INSECTS						
Water beetle	--	--	--	1.23	--	--
Chironomid	--	--	--	--	--	--
FISHES						
Juvenile fish	4.52	3.88	4.52	4.92	2.41	3.03
MISCELLANEOUS GROUPS						
Foraminifera	--	--	--	3.56	--	3.56
Anthozoa	3.56	2.48	3.72	2.58	--	3.56

CHAPTER 5

DREDGING AND DISPOSAL SITE OF COCHIN PORT TRUST AREA

.1 INTRODUCTION

Cochin, also known as "Queen of Arabian sea", is the biggest city along south west coast of India and functions as the nerve centre for the distribution of goods to the different parts of Kerala. The Vembanad Lake, which is the largest backwater system of Kerala, joins the Arabian Sea through Cochin harbour entrance. The major rivers Achankovil, Pampa, Manimala, Meenachil, Muvattupuzha and Periyar debouch in this lake region.

Cochin has played a vital role in shaping the history of the state. In 1870, J.H Aspinwall conceived the idea of developing a safe all weather harbour in Cochin backwaters. Fifty years later, Sir Robert Bristow took charge as Harbour Engineer-in-Chief and was the architect of the present Cochin harbour. Using dredge material, Willington Island, the present seat of Cochin Port, having an area of nearly 365 ha, was reclaimed. This Port is of considerable economic importance among the Indian harbours as it is on the direct route to Australia and the Far East. It is one of the finest natural harbours of India and provides a safe anchorage even during the rough monsoon months.

Major ports or harbours located in and near the coastal zone (many within estuarine bounds) are centres of intense marine activities, depending on the number and frequency of operational vessels at the site. Towards smooth marine traffic operations an important prerequisite is guaranteed adequate depth. Sedimentation is a major conundrum facing many port of the world. Sedimentation is a process of accumulation of suspended material as a part of natural processes in rivers, estuaries or seas by which the depth of the estuary (navigational channel in case of harbours) reduces. The natural and continuous reduction of the depth would adversely affect the usage of waterways within the port and harbour and also inhibits trade, commercial and recreational activities. In India, the major ports namely Calcutta, Bombay, Madras and Cochin are facing serious threat from sedimentation. At all these ports, activities are critically connected and essentially depth dependent for entry/exit of marine vessels. The port authorities are hence constrained to spend large amounts on maintenance dredging to afford smooth harbour operations.

According to Canter (1985) dredging is the counterpart of sedimentation and involves the removal of several variable materials from the bottom of the sea, estuary or lakes and subsequent disposal of dredge spoil in open distant waters or on land. The dredging activities may be conveniently divided into two (Bray, 1979). One is the capital dredging, which involves the construction of a new bed configuration in the marine environment, and the other is maintenance dredging involving the upkeep of channel depths by retaining a constant bed configuration. According to Scott (1991) the efficiency of dredging operations is dependent on many variables within the dredging environment. These are sediment and water properties, current pattern, environmental restrictions, and transportation and disposal requirements of dredge material. Akin to any other artificial process, dredging also brings about positive and negative impacts on the environment.

Dredgers in operation affect the dredging site directly and indirectly. The direct effects after dredging are the possibility of subsidence of adjacent work due to undermining and subsoil failure, alterations of local soil characteristics, change of local flow pattern together with changes in siltation in the dredged channels, destruction of spawning grounds by alterations in the habitat and the destruction of flora and fauna causing a depletion in local fish communities. The indirect effects are the possibility of beach draw down i.e., the movement of material towards the sea due to the removal of offshore deposits, changes in the refraction of waves caused by the change in the seabed, and consequent erosion and deposition, change of tidal flushing characteristics of an estuary consequent alteration of sediment load. habitat damage etc. At the transportation site, the effects are by leakage and loss of spoil enroute which leads to increased turbidity and issues related to short term toxicity.

At the disposal site, direct/indirect effects are noticed during and after dumping the spoil. These include the turbidity generated at the dump site due to the passage of spoil into the adjacent areas, consequent alteration of water quality and bed material, the refraction of waves caused by the alteration of sea bed and consequent changes in the coastal regime. Accessibility of coastal ports, fishing harbours and navigable waterways is vital to the economic growth of coastal regions (Engler et.al., 1991). Unfortunately, these areas are rarely naturally deep and navigable depths have to be maintained by frequent dredging. Every year, dredging results in millions of cubic meters of sediment worldwide that must be disposed of and managed in an economically and environmentally sound manner (Engler et.al., 1991). Dredging and disposal of dredged material constitute one of the most important problems in coastal zone management (Van Dolah et.al., 1984). Alternative methods for disposal of dredged material have been explored but economic considerations make open water disposal a prime option.

There are some positive effects of dredging and dredged spoil disposal. For eg. dredging improves circulation in estuaries and shallow embayments. By increasing nutrient level primary production increases in the system. When environmentally compatible, dredge spoils are utilized in salt marsh creation, island development, beach nourishment and substrate enhancement. As such, dredge spoils have great potential value in the restoration of coastal habitat. During the dredging process the bottom sediments plus water immediately above it get disturbed due to turbulence and the resultant churning action brings sediments and subsurface water to the surface layers. There is a likelihood of bottom sediments releasing considerable amounts of nutrients under such conditions, which may influence the estuarine biological system.

Sediment disposal in open water may be more damaging to the benthic community than to any other part of the aquatic ecosystem because of the relative immobility of most benthic organisms (Morton, 1977). The impact of sediment disposal on benthic communities varies depending upon factors such as the volume and characteristics of the discharged material, water depth. surface and hydrography of the disposal area, the time of the year, the types of organisms inhabiting the disposal sites, the similarity of sediments in dredge and disposal sites, the amount of resulting turbidity and the presence of toxic substances in the dredged material (Windom, 1976). The most severe impacts of the dredge spoil disposal on biotic communities result from physical effects. The removal of bottom sediments and entrained organisms during dredging operations partly destroys the benthic habitat and causes mortality of bottom dwelling organisms. Mortality of the benthos occurs from mechanical damage by the dredge itself and from smothering by the sediment when the organisms are picked up or deposited. Recovery of the benthic communities varies considerably at dredge and disposal sites. It is contingent on the time of dredging or dredged spoil disposal relative to the reproductive periods of endemic benthic populations. Extraction and transport of larval stages also plays an important role.

The affected sites get repopulated fairly soon, after dredging or dredge spoil disposal terminates, but recovery of the communities typically requires months or years to complete. Initial colonizers are usually opportunistic, pioneering fauna that are later supplanted by equilibrium assemblages in a successional sequence. Species that originally inhabited the affected sites usually recolonize the disturbed areas. However when the sediment characteristics of dredge spoils are much different than resident sediments at the dumpsite, significant differences in species composition, abundance and diversity arise. Thus it is essential to conduct a comprehensive assessment of physical, sedimentary and biological criteria before selecting a waste disposal site (Robert and Diane, 1999).

The Cochin estuary (Lat. 9°58'N, Long. 76°58'E) lies extending about 130km parallel to the coast with a breadth varying from a few hundred meters to $13km^2$. Cochin backwaters face serious environmental threat by way of intertidal land reclamation, polluting discharges, harbour development, dredging activities, urbanisation etc. (Gopalan *et al.,* 1983). Extensive studies have been carried out on the physical, chemical and biological aspects in Cochin estuary but the issues dealing with the environmental impacts of dredging was never attempted except for a few reports by Gopinathan and Qasim, 1971; Anto *et al.*, 1977; Sundaresan, 1990; Rasheed and Balchand, 1995.

For the past several decades dredging is carried out in the Cochin harbour area as a part of the maintenance programme and the total quantity of the dredged material is estimated to be about 6 million m^3. Dumping of dredge spoil causes deposition at the dumpsite and again resuspension. Resuspended material may form a deposit elsewhere. This harbour is maintained operational by three dredged channels, one being the approach channel oriented along east–west direction through the Cochin inlet of around 10km length and 500m width and the two inner channels located on either side of the Willington Island, i.e., Ernakulam channel, around 5km length with a width of 250 to 500m and Mattancherry channel, 3km long with a width of around 170 to 250m. All the three dredged channels are maintained at a depth of 10 to 13m. The three channels are intermittently dredged throughout the year, except during monsoon period in the approach channel, due to rough weather conditions in the nearshore region. Efforts are underway to deepen these channels and results in additional amounts of material being removed and disposed and the amount of material dredged during the study period was 10 X $10^6 m^3$ (Thresiamma Joseph *et al.*, 1998).

The present study tries to assess the possible environmental impact of deepening of the navigational channel by dredging. The areas most affected by dredging operations would be the bottom, the water quality and marine life. Hence it became imperative to establish existing conditions of the water body and the bottom to assess the possible impact due to the deepening of the channels on the system and for future comparisons especially with the post dredging and deepening scenario. So the emphasis of the studies was placed more on the most vulnerable aspects such as water quality, channel bed conditions and marine life.

The macrobenthic organisms were selected for the study because they are permanent inhabitants of the sediments with low mobility and are good indicators of the conditions prevailing in the area being studied. In addition they are also an important link of the estuarine food chain (Jones and Candy, 1981). Bottom fauna spend most of their life within or on the substratum. The physical and chemical characteristics of the sediments and its change may be of great significance while studying the bottom fauna (Damodaran, 1973). During dredging operations, the substratum get disturbed, thereby affording a chance for the inhabitants to migrate into deeper layers or nearby areas or they may face mortality.

5.2 LOCATION OF SAMPLING STATIONS (Fig. 5.1)

Thirty eight stations were fixed in and around the Cochin harbour, covering an area of 130km^2 of estuarine and near shore areas for the collection of bottom sediments and benthic fauna. In addition observations were made just before the dredging, immediately after the dredging operations, after 20 minutes and 2 hours of dredging to study the water quality.

For spatial comparison, the study area was divided into seven viz.,

1. Ernakulam channel (stations 1 to 10 and 4 to 10m deep)
2. Mattanchery channel (stations 11 to 16 and 2.5 to 5.5m deep)
3. Vallarpadam (stations 17 to 21 and 2.1 to 4.5m deep)
4. Dredging channel (stations 22 to 28 and 8.5 to 17.0m deep)
5. North of dredging channel (stations 29 to 31 and 6.6 to 14.0m deep)
6. South of dredging channel (stations 32 to 34 and 6.6 to 14.0m deep)
7. Disposal site (stations 35 to 38 and 12.8 to 17.5m deep)

5.3 RESULTS

5.3.1 Water quality (Table 5.1)

Secchi disc visibility, turbidity measurements and amount of suspended load indicated little or no change in the ambient values in and around the dredging period. The bench values of Secchi disc visibility on average were around 50cm. This value was not significantly altered for most of the time during the dredging. A turbidity of 10 to 15 ppm in the surface layer, 15 to 25 ppm at mid depth and 48.55 ppm just above the bottom was observed during the dredging operations whereas the corresponding suspended loads were 10 to 20, 15 to 30 and 35 to 50 mg/l. On lifting of dredger head, The secchi disc reading dropped to 5 cm, the turbidity reached 150 ppm at the surface, 900 ppm at the mid-depth and 1300 ppm in the bottom layer. The suspended load reached upto 120 and 1150 mg/l in the surface and bottom respectively.

The salinity showed strong density stratification and a two-layer structure of the water column with a gradient of 4.06 psu two hours after dredging and 15.49 psu twenty minutes after dredging. Dissolved oxygen values showed saturation levels at the surface upto 5 m depth and the concentration varied from 3 to 6 ml/l at the surface and 2.5 to 4.5 ml/l in the bottom. BOD_5 varied from 0.31 to 5.07 ppm. The phosphate values showed a small vertical gradient within the range of 0.50 to 0.71 µmol/l. Nitrite decreased from 0.54 to 0.24 µmol/l from the surface to the bottom and ammonia was generally absent except at the surface where its concentration was 0.41µmol/l. Immediately after the dredging the nutrient values increased in the range of 1.89 to 3.35 µmol/l (phoshate), 0.58 to 0.75 µmol/l (nitrate) and 0.21 to 5.03 µmol/l (ammonia). Twenty minutes after dredging the phosphate and nitrite values returned to the pre-dredging ambient values but the bottom values for phosphate (1.22 µmol/l) and ammonia (3.49 µmol/l) remained high. After two hours all the nutrient values reverted to their pre-dredging levels.

5.3.2 Sediment characteristics (Figs. 5.2 - 5.3 and Tables 5.2 - 5.3)

Grain size distribution (%)

The sand, silt and clay percentage varied from 0.43 (Area 5) to 24.50 (Area 4), 8.81 (Area 1) to 25.29 (Area 3) and 61.96 (Area 4) to 78.72 (Area 5) respectively during pre-monsoon. The corresponding values during monsoon were 0.63 (Area 7) to 24.30 (Area 2), 44.54 (Area 2) to 62.38 (Area 3), and 30.11 (Area 4) to 41.94 (Area 6). The distribution of sand, silt and clay at different stations in the areas A1 to A7, during pre-monsoon and monsoon are given in the Table (5.).

Organic matter (%)

The percentage of organic matter varied from 3.35 (Area 2) to 4.51 (Area 7) during pre-monsoon and 3.51 (Area 4) to 5.27 (Area 1) during monsoon. The values for the different stations in the areas A1 to A7 ranged between 1.00 (stn.7) and 7.62 (stn.9), 2.02 (stn.13) and 4.76 (stn.11), 1.02 (stn. 21) and 5.36 (stn. 20), 0.24 (stn. 23) and 4.65 (stn. 26), 2.98 (stn. 29) and 3.98 (stn. 31), 2.67 (stn. 32) and 5.26 (stn. 34) and 2.26 (stn. 35) and 6.02 (stn. 37) respectively during pre-monsoon. The corresponding ranges during monsoon were 4.52 (stn. 2) to 6.36 (stn. 9), 2.26 (stn. 15) to 7.90 (stn. 13), 2.74 (stn. 21) to 5.48 (stn. 18), 0.53 (stn. 24) to 4.76 (stn. 27), 2.98 (stn. 30) to 4.52 (stn. 29), 2.84 (stn. 33) to 6.12 (stn.34) and 2.26 (stn. 35) to 5.41 (stn. 36).

Energy content (J/g dry weight)

The energy content varied from 723.60 (Area 2) to 974.16 (Area 7) during pre-monsoon and 758.16 (Area 4) to 1138.32 (Area 1) during monsoon. The values for the different stations in the areas A1 to A7 ranged between 216.00 (stn.7) and 1645.92 (stn.9), 436.32 (stn.13) and 1071.36 (stn.11), 220.32 (stn. 21) and 1157.76 (stn. 20), 51.84 (stn. 23) and 1004.40 (stn. 26), 643.68 (stn. 29) and 859.68 (stn. 31), 576.72 (stn. 32) and 1136.16 (stn. 34) and 488.16 (stn. 35) and 1300.32 (stn. 37) respectively during pre-monsoon. The corresponding ranges during monsoon were 976.32 (stn. 2) to 1373.76 (stn. 9), 488.16 (stn. 15) to 1706.40 (stn. 13), 591.84 (stn. 17) to 1183.68 (stn. 18), 114.48 (stn. 24) to 1028.16 (stn. 27), 643.68 (stn. 30) to 976.32 (stn. 29), 613.44 (stn. 33) to 1321.92 (stn.34) and 488.16 (stn. 35) to 1168.56 (stn. 36).

5.3.3. Bottom fauna (Figs. 5.4 - 5.6 & Tables 5.4 - 5.6)

Pre-monsoon

Standing stock (Density - No/m^2 and Biomass - g/m^2) - Figure 5.4 and Table 5.4

In area 1, a total of 41414 specimens were collected and the density of different stations varied from 42 (stn.10) to 28672/m^2 (stn. 4). The total biomass of this area was 231.34g and ranged between 0.10 (stn. 10) and 164.52 g/m^2 (stn. 1).

Area 2 showed a total of 5027 specimens and a total biomass of 38.17g. The density ranged between 230 (stn.12) and 3104/m^2 (stn.13) and biomass between 0.80 (stn. 16) to 18.33 g/m^2 (stn. 11).

The total number and biomass were 953 specimens and 31.75g respectively in Area 3. The corresponding ranges for different stations were from 21 (stn. 18) to 588/m^2 (stn. 21) and 0.10 (stations. 18 & 19) to 28.50 g/m^2 (stn. 21).

In area 4, the total number was 6882 and was in the range of 42 (stn. 25) and 3355/m^2 (stn. 23). The total biomass was 297.3g and ranged between 1.13 (stn. 25) and 203.09 g/m^2 (stn. 23).

The total number and biomass in the area 5 were 1625 and 61.36g respectively. The density ranged between 167 (stn. 29) and 1062/m^2 (stn. 30) and the biomass from 1.18 (stn. 29) to 47.42 g/m^2 (stn. 30).

Area 6 showed a total of 2483 specimens ranging between 439 (stn. 32) and 1439/m^2 (stn. 33). The total biomass was 37.47g and was in the range of 2.06 (stn. 32) and 21.16 g/m^2 (stn. 33).

In area 7 the total number was 3455 and the range was between 304 (stn. 37) and 2020/m^2 (stn. 35). The total biomass was 175.51 g and ranged between 17.80 (stn. 36) and 90.99 g/m^2 (stn. 37).

In general during pre-monsoon, between the areas the total density varied from 953 (Area 3) to 41414 specimens (Area 1) and biomass between 31.75 (Area 3) and 297.30 g (Area 4).

Community structure (Fig. 5.5 & Table 5.5)

Area 1

Of the 11 groups encountered molluscs dominated the benthic fauna having 54.79% followed by amphipods (21.54%) and polychaetes (11.90%). Isopods, tanaidaceans and oligochaetes contributed 7.90, 1.76 and 1.36% respectively. Segestides, alphieds, other crustaceans, juvenile fishes and miscellaneous group constituted rest of the fauna.

Molluscs were represented by gastropod sp., *Modiolus striatulus and Donax* sp. Of the 3 species *Modiolus striatulus* formed the dominant one (22521 specimens) followed by Gastropod sp. (84) and *Donax* sp. (84). *Modiolus striatulus* were present at stn. 1 (833/m^2), stn. 4 (21584/m^2) and stn. 9 (104/m^2). Gastropod sp. and *Donax* sp. were observed only at stn. 3 and stn. 4 respectively.

Amphipods were represented by 4 species viz. *Grandidierella gilesi* (84 specimens), *Quadrivisio bengalensis* (376 specimens), *Melita zeylanica* (84 specimens) and *Corophium triaenonyx* (8375 specimens). *Grandidierella gilesi* was observed at stn. 7 ($84/m^2$), *Quadrivisio bengalensis* at stn. 4 ($334/m^2$) and stn. 6 ($42/m^2$), *Melita zeylanica* at stn. 1 ($84/m^2$) and *Corophium triaenonyx* at stn. 1 ($6770/m^2$), stn. 4 ($1584/m^2$) and stn. 6 ($21/m^2$).

Eleven species viz. *Ancistrosyllis constricta, Perinereis cavifrons, Nephthys dibranchis, Diopatra neapolitana, Lumbrinereis simplex, Glycera alba, Prionospio pinnata, Capitella capitata, Heteromastus similis, Pista indica* and Sabellid sp. represented the group polychaete. Of these, Perinereis *cavifrons* (1416 specimens) form the dominant species followed by *Prionospio pinnata* (1233 specimens) and least dominant were *Nephthys dibranchis, Glycera alba* with a density of 63 specimens each. *Prionospio pinnata* was present at stns. 1 to 7 & 10. *Perinereis cavifrons* was present at stn. 4 ($1332/m^2$), stn. 5 ($21/m^2$) and stn. 8 ($63/m^2$).

Isopods were present at stn. 1 ($1583/m^2$), stn. 4 ($1666/m^2$) and stn. 5 ($21/m^2$).

Tanaidaceans were represented by *Apseudes chilkensis* (189 specimens) and *Apseudes gymnophobium* (542 specimens), *Apseudes chilkensis* was present at stn. 1 ($84/m^2$), stn. 4 ($84/m^2$) and stn. 6 ($21/m^2$) whereas *A. gymnophobium* was observed at stn. 4 ($500/m^2$), stn. 6 ($21/m^2$) and stn. 7 ($21/m^2$).

Oligochaetes were the least in abundance with a total number of 562 and were present at stns 2, 3, 5 and 7. The corresponding densities at these stations were $166/m^2$, $250/m^2$, $21/m^2$ and $125/m^2$.

Other groups showed minimum representation. Sergestids and Alphieds were present at stn. 7 ($21/m^2$) and stn. 5 ($21/m^2$) respectively. Barnacles were present at stn. 1 ($84/m^2$) and stn. 9 ($21/m^2$). The juvenile fishes occurred at stn. 6 & 7 with a density of $21/m^2$ each. Sea anemone with a density of $21/m^2$ was present at stn. 8 and echinoderms at stn. 4 ($84/m^2$) and stn. 8 ($21/m^2$).

Area 2

Seven faunal groups were noticed in this area. Amphipods constituted by 3 species, was the dominant group having a percentage composition of 58.01 with a numerical abundance of 2916 specimens. *Grandidierella gilesi* (333 specimens), *Quadrivisio bengalensis* (125 specimens) and *Corophium triaenonyx* (2458 specimens) were the three species present in this area. The first 2 species were present at stn 13 and 14 respectively and the third in both stations.

Polychaetes formed 32.42% and were represented by 14 species. The species encountered were *Ancistrosyllis constricta* (Family – Hesionidae), *Lycastis indica, Dendronereis aestuarina* and *Perinereis cavifrons* (family – Nereidae), *Nephthys dibranchis* (Nephthydidae), *Diopatra neapolitana* and *Lumbrinereis simplex* (family – Eunicidae) *Prionospio pinnata* (family – Spionidae), *Cossura coasta* (family – Cossuridae), *Capitella capitata, Heteromastus similis, Heteromastides bifidus, Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis*. *Prionospio pinnata* was the dominant species (565 specimens) followed by *Scyphoproctus djiboutiensis* (291 specimens), *Heteromastides bifidus* (146 specimens) and *Heteromastus similis* (145 specimens). The least dominant species were *Dendronereis aestuarina* and *Diopatra neapolitana* with 21 specimens each. *Prionospio pinnata* and *Nephthys dibranchis* occurred at all the stations in this area except at station. 13. All other species occurred at one or two stations. only.

Isopods numbering 208 were the third abundant group forming 4.14% of the benthic fauna and were noticed at stn. 13 only.

Oligochaetes were the 4^{th} in abundance forming 2.92% with a total number of 147. The *Oligochaete* sp. was present at all the stations in this area showing maximum density at stn.14 ($42/m^2$).

Decapods comprising crabs and decapod sp. were the next group forming 1.25% and the total number was 63 specimens. Decapod sp. occurred at stn. 14 ($42/m^2$) and crab at station 15 ($21/m^2$).

Molluscs constituting *Donax* sp. (21 specimens) and gastropod sp. (21 specimens) formed 0.84% of the benthic fauna representing at stn. 14 16 respectively.

Juvenile fishes were the least in abundance and occurred only at station 14 (21 specimens) forming 0.42% of the benthic fauna.

Area 3

Only 3 groups were noticed in this area. The faunal composition of major groups of benthos indicated dominance of polychaetes (66.11%), molluscs (29.48%) and amphipods (4.41%).

Polychaetes were represented by 7 species viz. *Ancistrosyllis constricta* (family - Hesionidae), *Nephthys dibranchis* (family - Nephthydidae), *Lumbrinereis simplex* (family - Eunicidae), *Prionospio pinnata* and *P. polybranchiata* (family - Spionidae), *Cossura coasta* (family - Cossuridae) and *Scyphoproctus djiboutiensis* (family - Capitellidae). Out of the 630 specimens of polychaetes *Scyphoproctus djiboutiensis* was the dominant species with a density of 336 specimens and this species occurred at stn. 21 only. *Nephthys dibranchis* were present at stations 17 ($42/m^2$) and 20 ($21/m^2$) and *Prionospio polybranchiata* at station 18 ($21/m^2$) and 19 ($42/m^2$). *Ancistrosyllis constricta* (21), *Lumbrinereis simplex* ($84/m^2$) and *Cossura coasta* ($21/m^2$) were observed at stn. 20 only and Prionospio *pinnata* ($42/m^2$) at stn. 17.

Amphipods were represented by a single species *Corophium triaenonyx* and this species was present at stn. 21 only ($42/m^2$).

Molluscs were represented only by gastropod sp. and were present at stations 20 ($71/m^2$) and 21 ($210/m^2$).

The results revealed very low faunal density and diversity in this area.

Area 4

In this area molluscs are the dominant components of macro benthos with a percentage composition of 81.76% followed by polychaetes (13.07%) and Decapods (2.73%). The rest of the fauna were constituted by oligochaetes, alphieds, amphipods and balanus. Molluscs were represented by gastropod sp. 4229 specimens), *Dentalium* sp. (167 specimens), Bivalve sp. (1042 specimens) and *Paphia papilliens* (189 specimens). Gastropod sp. were present at stations 23 24, 26 and 28 and *Dentalium* sp. at stn. 23 only. *Paphia papilliens* and bivalve sp. were present at stns. 23 and 24.

The polychaetes showed a total number of 899 and maximum was obtained at stn. 22 (336/m^2) followed by stn. 28 (333/m^2). Polychaetes were absent at stn. 23 but stns. 24 and 25 recorded low densities. *Perinereis cavifrons* (family – Nereidae), *Nephthys dibranchis* (family – Nephthydidae), *Lumbrinereis simplex* (family – Eunicidae), *Glycera alba* (family – Glyceridae), *Prionospio pinnata* (family – Spionidae), *Cossura coasta* (family – Cossuridae), *Heteromastides bifidus and Scyphoproctus djiboutiensis* (family – Capitellidae) *and Pista indica* (family – Terebellidae) were the 9 species encountered during the study. Out of these *Lumbrinereis simplex* was the dominant species (458 specimens) followed by *Prionospio pinnata* (147 specimens) and *Scyphoproctus djiboutiensis* (126 specimens). The least dominant species were *Nephthys dibranchis, Glycera alba, Cossura coasta* and *Heteromastides bifidus* constituting 21 specimens each. *Lumbrinereis simplex* was obtained from stations 25, 26 and 28 and *Prionospio pinnata* at stations 22, 24 and 28.

Decapod sp. was obtained from stns. 22 (146/m^2) and station 24 (42/m^2). *Oligochaete* sp. was present at stn. 22 only (84/m^2). This group was followed by *Alphied* sp. (42/m^2), *Balanus* sp. (21/m^2) both at station 22 and *Eriopisa chilkensis* at stn. 24 (21/m^2).

Area 5

Four faunal groups were encountered in this area. The faunal composition indicated dominance of molluscs, followed by polychaetes. The rest of the faunal groups were oligochaetes and mysids.

Molluscs formed 52.56% of the benthic community with a total number of 854 specimens. This group was represented by Gastropod sp. and bivalve sp. contributing 833/m^2 (stn. 30) and 21/m^2 (stn. 29) respectively.

Polychaetes numbering 730 specimens formed 44.86% of the benthic fauna and were represented by six species viz. *Ancistrosyllis constricta* (21 specimens), *Nephthys dibranchis* (105 specimens), *Lumbrinereis simplex* (354 specimens), Prionospio *pinnata* (21 specimens), *Cossura coasta* (208 specimens) and *Pista indica* (921 specimens). *Nephthys dibranchis* and *Cossura coasta* were obtained from stns. 30 and 31. *Lumbrinereis simplex* from stns. 29 and 31, *Ancistrosyllis constricta* and *Pista indica* from stn. 30 and *Prionospio pinnata* from stn. 31.

Oligochaetes and mysids were obtained from stns. 29 and 31 respectively contributing 21/m^2 each.

Area 6

The faunal composition in this area showed the occurrence of 4 groups of benthos viz. Polychaetes (24.45%), Decapods (0.85%), Molluscs (73.85%) and juvenile fishes (0.85%).

Gastropod sp. and Bivalve sp. represented the group molluscs with a total number of 1813 and 21 respectively. Gastropod sp. were present at stn. 32 (188/m^2), stn. 33 (1250/m^2) and stn. 34 (375/m^2) and Bivalve sp. at stn. 33 only (21/m^2).

Polychaetes were the second dominant group with a total of 607 specimens. This group was constituted by the species *Ancistrosyllis constricta* (family – Hesionidae), *Lumbrinereis simplex* (family-Eunicidae), *Goniada emerita* (family - Glyceridae), *Cossura coasta* (family – Cossuridae) and Scyphoproctus *djiboutiensis* (family-Capitellidae). *Lumbrinereis simplex* (314 specimens) was the dominant species followed by *Cossura coasta* (126 specimens) and *Scyphoproctus djiboutiensis* (104 specimens). *Ancistrosyllis constricta* and *Goniada emerita* showed a total number of 42 and 21 respectively. *Lumbrinereis simplex* and *Cossura* *oasta* were present in all the three stations in this area. The remaining 3 species occurred only at one station each.

Decapods (21/m^2) and juvenile fishes (21/m^2) were the least dominant groups occurring at stn. 33 and 34 respectively.

Area 7

Polychaetes (27.18%), molluscs (71.61%) and fishes (1.21%) were the 3 groups encountered during the study in this region.

Molluscs (2474 specimens) were the dominant group constituting *gastropod* sp. (2369 specimens), Dentalium sp. (63 specimens), Bivalve sp. (21 specimens) and *Cavolina* sp. (21 specimens). Gastropod sp. was present at stations 35 to 38, and the maximum was at stn. 35 (1333/m^2) and minimum at stn. 37 (220/m^2). The other species were present only in one station each.

Polychaetes were the next group in abundance (939 specimens) and were represented by *Nephthys dibranchis* (230 specimens), *Lumbrinereis simplex* (500 specimens) and *Cossura coasta* (209 specimens). All the three species were present at stations 35, 36 and 38. Station 35 showed the maximum abundance of the above 3 species and the corresponding numbers were 167/m^2, 395/m^2 and 104/m^2. At stn. 36 all the species showed a density of 21/m^2 and at stn. 38 the density of *Nephthys dibranchis* was 42/m^2 and *Lumbrinereis simplex* and *Cossura coasta* showed a density of 84//m^2 each.

Juvenile fishes were the least dominant group and were present at stn. 38 only (42/m^2).

Monsoon

Standing stock (Density – No/m^2 and Biomass – g/m^2) - Figure 5.4 and Table 5.4

In area 1, a total of 21373 specimens were collected and the density of different stations varied from 42 (stn. 9) to 7524/m^2 (stn. 3). The biomass varied between 0.09 (stn. 9) and 43.64 g/m^2 (stn. 3) with a total biomass of 81.51 g.

The total density and biomass were 4682 and 34.77g respectively in area 2. The ranges for different stations were from 292 (stn. 13) to 1283/m^2 (stn. 14) and 1.88 (stn. 11) and 10.64/gm^2 (stn. 12) respectively.

The faunal standing stock in terms of population and biomass varied from 84 (stn.19) to 4073/m^2 (stn. 21) and 0.59 (stn. 19) to 6.05 g/m^2 (stn. 17) respectively. The total number and biomass were 5442 and 12.63 g in area 3.

Area 4 showed the total number of 2959 and biomass of 215.97g. The density of different stations ranged between 42 (stn. 26) and 1458/m^2 (stn. 27) and biomass from 0.21 (stn. 26) and 110.73 g/m^2 (stn. 27).

In area 5 the faunal potential in terms of population density and biomass varied from 42 (stn. 31) to 3312/m^2 (stn. 29) and 0.67 (stn .31) to 25.58 g/m^2 (st.29) respectively. The total number and biomass were 3501 and 37.78g respectively.

In area 6, the total number and biomass were 6063 and 20.99g respectively. The density varied from 63 (stn. 32) to 5083/m^2 (stn. 34) and biomass from 0.58 (stn. 32) to 17.80 g/m^2 (stn. 34).

Area 7 recorded a total number of 2502 and biomass of 12.96g and the corresponding ranges were from 344 (stn. 38) to 1469/m^2 (stn. 36) and from 4.25 (stn. 35) to 4.41 g/m^2 (stn. 36).

In general, between the areas the total density varied from 2502 (Area 7) to 21373 (Area 1) and the biomass from 12.63 (Area 3) to 215.97 g (Area 4).

Community structure (Fig. 5.6 & Table 5.6)

Area 1

In this area 10 groups viz. polychaetes, oligochaetes, amphipods, tanaidaceans, isopods, decapods, sergestids, molluscs, juvenile fishes and nematodes were encountered during the study. Amphipods were the dominant group forming

62.74% of the benthic fauna followed by polychaetes (20.81%), isopods (6.72%) and molluscs (5.32%).

Amphipods were represented by the species *Grandidierella bonneri, G. gilesi, Quadrivisio bengalensis, Eriopisa chilkensis* and *Corophium triaenonyx. Corophium triaenonyx* was the dominant species with a total number of 8845 and was present at stns. 1 to 5, 7 and 10. The maximum density was at stn. 3 ($5625/m^2$) and minimum at stns. 5, 7 and 10 ($21.m^2$). *Quadrivisio bengalensis* (4312 specimens) was the next dominant species and distributed at stns. 2 to 5. Maximum ($2770/m^2$) and minimum ($21/m^2$) densities were recorded at stations 4 and 5 respectively. *Eriopisa chilkensis* and *Grandidierella bonneri* were present only at stns. 2 and 4 each with a density of $21/m^2$. *G. gilesi* was present at stn. 2 ($21/m^2$), stn. 3 ($105/m^2$) and stn. 4 ($84/m^2$).

Polychaetes were the second dominant group (4447 specimens) constituted by *Ancistrosyllis constricta* (family – Hesionidae), *Lycastis indica* and Perinereis cavifrons *(family – Nereidae),* Nephthys dibranchis *(family – Nephthydidae), Diopatra neapolitana* and *Lumbrinereis simplex* (family – Eunicidae), *Glycera convoluta* (family – Glyceridae), *Prionospio pinnata* (family – Spionidae), *Heteromastus similis, Heteromastides bifidus, Paraheteromastus tenuis* and *Scyphoproctus djiboutiensis* (family – Capitellidae), *Maldanella capensis* (family – Maldanidae), *Owenia fusiformis* (family – Oweniidae), *Pista indica* (family – Terebellidea) and Sabellid sp. (family – Sabellidae). *Prionospio pinnata* was the most common and abundant species (1909 specimens) occurring at all stations with a maximum density of $854/m^2$ at stn. 7. *Paraheteromastus tenuis* was present at stns. 1 to 7 with a total number of 231. *Ancistrosyllis constricta* (617 specimens) and *Perinereis cavifrons* (345 specimens) were present at 6 stations each. *Owenia fusiformis* (21 specimens), *Glycera convoluta* (42 specimens) and *Lumbrinereis simplex* (21 specimens) were the least dominant species.

Isopods numbering 1436 was the next dominant group and were present at stns. 1 to 4 and density ranged between 21 (stn. 3) and $1092/m^2$ (stn. 4).

Molluscs comprising Nudibranchs (21 specimens), Gastropod sp. (928 specimens), Bivalve sp. (63 specimens), *Cavolina* sp. (21 specimens), *Modiolus striatulus* (84 specimens) and *Paphia papilliens* (21 specimens) were the fourth in abundance. Gastropod sp. occurred at stn. 1, 2, 4, 6, 7 & 8 and the others at one or two stations only.

Tanaidaceans were represented by *Apseudes gymnophobium* (397 specimens) and *A. chilkensis* (21 specimens). The former species was present at stns. 1 to 4 and latter at stn. 2 only.

Juvenile fishes were present at stns. 2 to 4 with a total number of 84 specimens.

Oligochaetes and Decapods showed the numerical abundance of 126 and 105 respectively. The former was present at stations 2 & 4 to 7, with a maximum density of $42/m^2$ at stn. 5 and a density of $21/m^2$ at other stations. Decapod and crabs were present at stations 3 & 4 and 2 & 4 respectively with a total number of 63 specimens each.

Sergestids were present at stns. 2 ($42/m^2$) and 4 ($63/m^2$) and Nematodes at stn. 1 ($21/m^2$).

Area – 2

In this area the 7 groups encountered were polychaetes, amphipods, tanaidaceans, isopods, decapods, cumaceans and sergestids. Polychaetes were the major group with a destiny of 4053 forming 86.57%. Amphipods formed 6.28% and isopods 4.02% and a rare occurrence of decapods (0.90%), sergestids (0.44%) and cumaceans (0.44%) were observed.

12 species of polychaetes were encountered during the study. *Heteromastides bifidus* was the most dominant (2197 specimens) followed by *Scyphoproctus djiboutiensis* (705 specimens) and *Nephthys dibranchis* (377 specimens). The other species obtained were *Ancistrosyllis constricta* (84

specimens), *Lycastis indica* (425 specimens), Lumbrinereis *simplex* (21 specimens), *Glycera alba* (42 specimens), *Glycera convoluta* (42 specimens), *Prionospio pinnata* (282 specimens), P. *polybranchiata* (42 specimens), *Heteromastus similis* (21 specimens) and *Paraheteromastus tenuis* (198 specimens).

Amphipods were represented by *Grandidierella gilesi* (147 specimens), *Quadrivisio bengalensis* (21 specimens) and *Corophium triaenonyx* (126 specimens). The *Grandidierella gilesi* was obtained from stations 12, 14 and 16, the *Quadrivisio bengalensis* from stn. 11 and *Corophium triaenonyx* from 13 and 14.

Isopods were represented by the *Cirrolina fluviatilis* (167/m^2) and the family Anthuridae (21/m^2) and were present at stn. 14 only.

Apseudes chilkensis was the only representative of the tanaidaceans and was present at stn. 11 (42/m^2) and stn. 16 (21/m^2).

Cumaceans and sergestids were present at stns. 16 and 11 respectively each with a density of 21/m^2.

Area – 3

Polychaetes, oligochaetes, amphipods, tanaidaceans, mysids, molluscs and juvenile fishes were the 7 groups obtained from this area. Molluscs contributed 74.08% to the benthic fauna followed by polychaetes (21.29%) and tanaidaceans (1.94%).

The dominant group constituted by gastropod sp. (4110 specimens) and *Modiolus striatulus* (21 specimens) were present only at stn. 21 and 18 respectively.

Polychaetes (1159 specimens) were represented by 8 species and out of these *Prionospio polybranchiata* (323 specimens) and *Paraheteromastus tenuis* (198 specimens) were presented at 3 stations each. *Ancistrosyllis constricta, Nephthys dibranchis, Heteromastides bifidus* and *Scyphoproctus djiboutiensis* were recorded from 2 stations each and the rest of the species at 1 station each.

Tanaidaceans showed the numerical abundance of 105 specimens and were constituted by *Apseudes gymnophobium* (84 specimens) and *A. chilkensis* (21 specimens). The former species was obtained from stns. 18 & 20 and later from stn. 18.

Oligochaetes and Amphipods were the next groups in abundance. Oligochaetes occurred at stn. 19 ($42/m^2$) only. *Quadrivisio bengalensis* ($42/m^2$) and *Corophium triaenonyx* ($21/m^2$) represented the amphipods and both occurred at stn. 18 only.

Juvenile fishes numbering 42 occurred at stns.17 and 18. Mysids were present at stn. 18 ($21/m^2$) only.

Area – 4

Polychaetes, mysids, sergestids, molluscs and foraminifera were the 5 groups encountered during the study. The dominant group was polychaetes (45.08%) followed by molluscs (43.63%) and foraminifera (8.45%).

Ancistrosyllis constricta numbering 1166. *Perinereis cavifrons* with 42 specimens, *Prionospio pinnata* with 84 specimens and *Scyphoproctus djiboutiensis* with 42 specimens were the 4 species of polychaetes encountered and these species come under the families Hesionidae, Nereidae, Spionidae and Capitellidae respectively. The first 2 species were present at stns. 24 and 27, third species at stn. 24 to 28 and fourth at stns. 27 and 28.

Molluscs were constituted by Gastropod sp. (1165 specimens), Dentalium sp. (42 specimens), *Cardium* sp. (42 specimens) and *Paphia papilliens* (42 specimens). Gastropod sp. was present at stns. 24, 27 and 28 and the rest of the species at 24 and 27.

Foraminifera (250 specimens), mysids (42 specimens) and Sergestids (42 specimens) were the rest of the species in dominance. Foraminifera and mysids were present at stn. 24 and 27 ad sergestids at stns. 26 and 27.

Area – 5

Polychaetes (99.40%) and Decapods (0.60%) were the 2 groups encountered during the study.

Perinereis cavifrons (family – Nereidae), *Lumbrinereis simplex* and *L. notocirrata* (family – Eunicidae), *Glycera alba* (family – Glyceridae), *Prionospio pinnata* and *P. polybranchiata* (family – Spionidae), *Maldanella capensis* (family – Maldanidae) and *Sternaspis scutata* (family – Sternaspidae) were the 8 species encountered during the study. Out of these *Prionospio pinnata* and *P. polybranchiata* were the most abundant species and the total numbers were 1437 and 1395 respectively. *Lumbrinereis notocirrata* and *Maldanella capensis* were the 2 least dominant species with a density of $21/m^2$ each at station 29 followed by *Glycera alba* with 42 specimens (stns. 29 and 31) and *Sternaspis scutata* with 21 specimens (stn. 30).

Decapods ($21/m^2$) were obtained from stn. 29 only.

Area – 6

Polychaetes (99.65%) and molluscs (0.35%) were the 2 groups encountered from this area. *Perinereis cavifrons* (21 specimens), *Lumbrinereis notocirrata* (1104 specimens), *Prionospio pinnata* (4875 specimens), *Cossura coasta* (21 specimens) and *Heteromastides bifidus* (21 specimens) were the 5 species of polychaetes encountered from this area. These species come under the families Nereidae, Eunicidae, Spionidae, Cossuridae and Capitellidae respectively. *Lumbrinereis notocirrata* and *Prionospio pinnata* were present at stns. 32 to 34, *Perinereis cavifrons* and *Cossura coasta* at stn. 34 and *Heteromastides bifidus* at stn. 33.

Gastropod sp. ($21/m^2$) was the sole representative of molluscs and was present only at stn. 34.

Area – 7

Of the 5 groups encountered from this area the most abundant group was polychaetes (94.96%) followed by molluscs (2.52%). The rest of the benthic fauna was represented by decapods, sergestids and amphioxus each contributing 0.84%.

Lycastis indica and *Perinereis cavifrons* (family – Nereidae), *Lumbrinereis simplex* (family – Eunicidae), *Prionospio pinnata* (family – Spionidae) and *Cossura coasta* (family – Cossuridae) were the representatives of the polychaetes.

Prionospio pinnata, the dominant species accounted 2124 numbers followed by *Lumbrinereis simplex* and *Cossura coasta* with 105 specimens each and *Perinereis cavifrons* and *Lycastis indica* with 21 specimens each. *Prionospio pinnata* was present at stns. 35 (563/m^2), 36 (1322/m^2) and 38 (239/m^2).

Gastropod sp. numbering 42 and bivalve sp. numbering 21 were the representatives of molluscs. The former was present at stns. 35 and 36 and later at stn. 36 only.

Decapods, sergestids and amphioxus were the least noticed groups in this area and the numbers recorded were 21 each. Decapods and sergestids were present at stn. 38 and amphioxus at stn. 36.

The standing stock in terms of total biomass of the different areas varied from 37.47 (Area 6) to 297.30g (Area 4) during pre-monsoon and 12.63 (Area 3) to 215.97g (Area 4) during monsoon. The high biomass values noticed at certain stations were attributed to the presence of large gastropods and bivalves.

The distribution of different faunal groups indicated that maximum numbers of groups as well as specimens were encountered in area 1 during both seasons. Area 2 and 3 also exhibited a relatively good benthic population. A remarkable reduction in the faunal groups and species diversity was noticed in the dredging and disposal areas. Polychaetes were the dominant and common group during both seasons and the percentage composition varied from 11.89 to 66.11 during pre-monsoon and 19.71 to 99.65 during monsoon.

A total of 24 species of polychaetes were encountered during the study period. Twenty one species were recorded during monsoon and 19 species were noticed during pre-monsoon. Sixteen species were common to both seasons where as 5 species were found only during monsoon period (*Lumbrinereis notocirrata, Glycera convoluta, Maldanella capensis, Owenia fusiformis* and *Sternaspis scutata*) and 3 species were noticed only during pre-monsoon period (*Dendronereis aestuarina, Goniada emerita,* and *Capitella capitata*).

Oligochaetes occurred during monsoon (Areas 1 & 3) and pre-monsoon (Areas 1, 2, 4 & 5). The amphipod species *Corophium triaenonyx* and *Quadrivisio bengalensis* were collected in large numbers during both the seasons in the areas 1, 2 & 3 and were absent in the dredging and disposal site, where only polychaetes, decapods, mysids, sergestids, gastropod, bivalves and juvenile fishes were present.

5.3.4 Statistical inferences (Figs. 5.17 – 5.10 & Table 5.7 – 5.14)

Community Structure

Species richness was higher in areas 1 and 2 compared to other areas during pre-monsoon. About 60% of the stations, species richness was > 4.05 in area 1 and 83.33% of the stations, species richness > 4.62 in area 2. In all other areas the richness ranged between 0.92 (station. 26) and 4.36 (station. 32) except station 22 (7.40) where it was considerably high. Average species richness was highest (5.41) in area 2 and least (1.36) in area 3. The absolute variation for species richness was least (0.23) in area 5 and highest (2.18) in area 4. Absolute richness was most variable (106.42%) in area 3 and least variable (6.97%) in area 5.

Species concentration factor was highest at stations of areas 1 (0.42 to 0.85) and 2 (0.37 to 0.84) than at stations of other areas. A decreasing trend was observed for species concentration from area 1 to area 7. More uniformity was observed towards the higher side for species concentration in areas 1 and 2 while towards the lower side in the other areas. This pattern of the distribution of species concentration was clearly seen in the coefficient of variation values in the study area where it ranged between 20.78% (area 1) to 41.95% (area 4) except area 3 (84.35%).

Species diversity measured by Shannon weaver index (statistically the best measure of diversity which uses the relative abundance of each species than its absolute abundance) showed the values between 1.00 & 2.96 in area 1, 1.00 & 2.88 in area 2, 1.26 & 3.00 in area 3 and 0.94 to 3.53 in other areas. The highest (2.14) average diversity was in area 2 with lesser variability (26.43%) and least (0.78) average diversity was in area 3 with maximum variation (90.69%). In Area 5 species diversity was distributed uniformly (17.86%) indicating least fluctuation in the existing environmental conditions.

Species dominance index measured by Pielou's measure of diversity, ranged between 0.62 (station. 10) to 1.83 (station. 5) in area 1, 0.31 (station. 13) to 1.90 (station. 16) in area 2 and between 0.24 (station. 28) and 1.58 (station. 22) in area 3 except station 20 (2.03) where it was slightly more. Based on the average distribution, species dominance was highest (1.64) in area 5 followed by area 2 (1.37) and area 1 (1.15). Least dominance (0.43) was obtained in area 4 followed by areas 3, 7 and 6. Species dominance was highly variable (90.70%) in area 3 followed by area 4 (58.95%).

Species evenness in the distribution as measured by Heip's index, a function of Shannon index showed higher evenness at station 5 (2.06), Station 6 (2.28) of area 1 and station. 22 (2.13) of area 4. In general higher diversity was followed by lower level of evenness or equitability in the distribution. Average spatial distribution showed high evenness at area 1 (1.38) followed by area 4 (1.15) with least variation for evenness (28.03%) at area 5 and maximum (83.32%) in area 3. This disparity in the community structure observed might be attributed to the dredging effect in particular to the areas, which are highly disturbed due to the dumping of the dredged material.

During monsoon, not much variation in the richness of species was observed in the study area. Compared to pre-monsoon except for the fact that peak values were observed for the stations with higher richness in the latter and that the disparity between richer stations and perishing stations was increased. The highest richness was obtained at station. 4 (12.82) of area 1, station 11 (8.23) of area 2, station.18 (9.40) of area 3, station. 27 (7.27) of area 4, station. 29 (4.58) of area 5 and station. 36 (4.37) of area 7. The least values were obtained at station. 10 (2.79) of area 1, station. 15 (1.75) of area 2, station 19 - 21 (1.23) of area 3, station 26 (1.54) of area 4 and station 31, 32 & 33 (1.45) of areas 5, 6 & 7. Based on the spatial distribution of richness index, a steady decrease was observed from area 1 (6.97) to area 6 (1.80) with a higher values (4.44) at area 4 and in area 7 (3.18). The variability in the richness distribution also followed a similar pattern with maximum variation at area 3 (89.34%) and decreasing steadily from area 4 to 7.

Species concentration showed a pattern of distribution similar to that of pre-monsoon period with a further marginal upward increase in areas 1 and 2 and a significant increase in the other areas. Seasonal variation was not felt much in this aspect. Higher average concentrations were obtained in area 1 (0.54), area 2 (0.58), area 4 (0.57) and area 5 (0.56) with least value (0.23) for the concentration factor at area 6. Highest variation (63.76%) was obtained in area 3 and least variation (18.09%) in area 5.

Diversity measured by Shannon Weaver index showed decreasing trend from area 1 to area 7, with maximum values at station 2 (3.40) and station 6 (3.20) of area 1 and least values (<0.96) at sts.31, 36 and stations 7, 20 and 21. Average distribution showed a steady decrease from area 1 (1.82) to area 6 (0.57). Highest variation (74.51%) for the diversity index was obtained in area 3 and least (22.69%) in area 7. This showed that higher diversity was maintained at moderate uniform manner in areas 1 and 2 while lower diversity was maintained at a more uniform manner in area 7.

Species dominance index was much less in areas 1 to 3, but with not much significant difference at areas 4 to 7during monsoon compared to pre-monsoon. Maximum dominance index was 0.94 (stn. 5), in area 1, 0.72 (stn. 13) in area 2, 0.82 (stn. 18) in area 3, 1.14 (stn. 26) in area 4, 1.76 (stn. 30) of area 5, 2.76 (stn. 34) of area 6 and 1.18 (stn. 36) of area 7 while minimum dominance index was 0.26 (stn. 8), 0.28 (stn. 16), 0.21 (stn. 20), 0.49 (stn. 28), 0.64 (stn. 29), 1.00 (stn. 32) and 0.66 (stn. 35) of areas 1 to 7. The range of distribution of species dominance showed that highest dominance was in area 6 and least in areas 1. The average distribution of dominance index was high in areas 5 (1.25) and 6 (1.66) and low in areas 3 (0.49) and 1 (0.53). The variation in the dominance distribution over space was maximum in area 3 (74.57%) followed by areas 1 (57.36%) and 6 (48.08%) and in the remaining areas it was between 22.65% (area 7) and 35.17% (area 5).

Not much significant difference could be observed in species evenness in monsoon season. This evenness coefficient ranged from 0.20 (station 7) to 2.3 (stn. 6) in area 1, 0.60 (stn. 16) to 1.61 (stn. 11) in area 2, 0.07 (stn. 21) to 1.77 (stn. 20) in area 3, 0.67 (stn. 24) to 1.79 (stn. 28) in area 4, 0.89 (stn. 30) to 1.87 (stn. 31) in area 5, 0.10 (stn. 33) to 1.03 (stn. 32) of area 6, and 0.15 (stn. 36) to 0.69 (stn. 38) in area 7. The average distribution showed that Heip's evenness index was very low in area 6 (0.48) and area 7 (0.46) and ranged between 0.91 (area 1) to 1.29 (area 5) with a steady increase from area 1 to area 5. Evenness index varied maximum in area 1 (C.V. = 88.73%) and area 6 (82.01%) and in other areas it ranged between 36.75% (area 5) and 55.54% (area 3).

Species niche breadth

During pre-monsoon season of the 28 species encountered from area 1, *Prionospio pinnata* ($\overline{X}$ = 123/m2) showed high niche breadth with low variation (C.V. 114%), Corophium *triaenonyx* with average spatial abundance 838/m^2 and high variation 242.74% controlled by silt content (r = 0.54) Sabellid sp. ($\overline{X} = 2252/m^2$) C.V. = 286.34% with average abundance ranging between 6 and 50 had > 3.10 as niche breadth. All other species had niche breadth < 2.0.

In area 2 it ranged between 1.07 *Corophium triaenonyx* ($\overline{X} = 410/m^2$) with high dependence on sand content (r = 0.56) and 5.19 *Nephthys dibranchis* with ($\overline{X} = 18/m^2$). Nearly 37% of the species had low value for niche breadth ranging between 1.07 (*Corophium triaenonyx* with and 1.75 *Heteromastides bifidus* with

($\bar{X} = 24/m^2$) and low variation, 187.68%). The species with maximum niche breadth was highly correlated with none of the parameters while that with low niche breadth was controlled by sediment characteristics (sand) ($r = 0.56$).

In area 3 out of the 9 species, (*Nephthys dibranchis* and *Prionospio polybranchiata,* $\bar{X} = 13/m^2$) both with lowest variation (C.V. 133.33%) had the maximum niche breadth value of 2.32. For the other species it ranged between 1.08 (*Scyphoproctus djiboutiensis* $\bar{X} = 67/m^2$ C.V. = 200%) and moderately correlated with silt ($r = 0.24$) and 1.94 (*Ancistrosyllis constricta,* $\bar{X} = 4/m^2$ C.V. = 200%) and showed no affinity for the sediment characteristics. (*Lumbrinereis simplex* $\bar{X} = 17/m^2$, C.V. = 200% controlled by sand ($r = 0.51$) had 1.83 as niche breadth In this area no well defined relation could be obtained between abundance, variability and niche breadth.

In area 4, out of the 18 species, maximum niche breadth was 2.88 (P*rionospio pinnata* $\bar{X} = 25/m^2$ C.V.125%) with moderate dependence on organic matter ($r = 0.22$) and for the rest of the species, niche breadth ranged between 1.20 (*Dentalium* sp. $\bar{X} = 28/m^2$ C.V. 223.6%) and 2.31.was (*Lumbrinereis simplex* $\bar{X} = 76/m^2$ C.V. 142.99%) and was highly correlated with sand ($r = 0.68$). This indicated that sediment characteristic to a moderate extent can control the niche breadth.

In area 5, with 10 species the range of niche breadth was further narrowed between 1.08 (Gastropod sp. $\bar{X} = 278/m^2$ C.V. 141.42%) and 2.05 (*Cossura coasta* $\bar{X} = 69/m^2$ C.V. 70.71%). Gastropod sp. was dependent on organic matter ($r = 0.42$) and *Cossura coasta* was also highly correlated with organic matter ($r = 1.00$) (*Nephthys dibranchis* $\bar{X} = 35/m^2$ C.V. 110%) with organic matter ($r = 0.63$) and (*Lumbrinereis simplex* $\bar{X} = 118/m^2$ C.V. 79.34%) depend on sand content ($r = 0.69$) had a niche breadth of approximately 1.85.

In area 6 with almost the same number of species as in area 5. The niche breadth varied between 1.11 (*Scyphoproctus djiboutiensis* $\bar{X} = 35/m^2$ 141.42%) and 2.75 (*Cossura coasta* $X = 42/m^2$ C.V. 40.82%) and (*Lyca... indica*

$\overline{X}$ = 104/m^2 C.V. 42.90%) *Scyphoproctus djiboutiensis* was highly correlated with sand (r = 1.00) where as *Cossura coasta* and Lycastis *indica* were highly controlled by silt (r = 0.95) and clay (r = 0.96). In this area also niche breadth was controlled by sediment characteristics.

In area 7, with the lowest number of species, 8 had highest niche breadth (3.16) for (Gastropod sp. $\overline{X}$ = 592/m^2 C.V. 73.38%) and it was highly correlated with sand (r = -0.76) and organic matter (r = -0.95). For the rest of the species the range for niche breadth was 1.26 (*Dentalium* sp. $\overline{X}$ = 16/m^2 C.V. = 173.21%) and its abundance was highly controlled by sand (r = 0.67), clay (r= - 0.88) and organic matter (r = 0.61) to 2.64 (*Cossura coasta* $\overline{X}$ = 52/m^2 C.V. 82.28%) and its occurrence was to a great extent dependent on clay (r = 0.84) and organic matter (r = - 0.93). During this season, it was concluded that species having a wide range spatial distribution with high variation have low niche breadth and species, which were more or less uniformly distributed, had high niche breadth.

During monsoon in area 1 with 36 species, high values of niche breadth (6.34) were for (*Paraheteromastus tenuis* $\overline{X}$ = 21.40/m^2), C.V. 94.90%, moderate correlation with sand (r = 0.39), Apseudes *gymnophobium* 7.88-niche breadth ($\overline{X}$ =1/m^2 C.V. 300%,) maximum variation and it was highly correlated with silt (r = 0.22). For the remaining 34 species the range for niche breadth was 1.22 (Sabellid sp., $\overline{X}$ = 30/m^2 C.V. 300%) and high relation with organic matter (r = -0.41) to 5.96. (*Glycera convoluta,* $\overline{X}$ = 2/m^2) C.V. 213.44%) high correlation with silt (r = 0.26) and (*Owenia fusiformis,* $\overline{X}$ = 1/m^2 C.V. 300%) and depend moderately on silt (r = 0.28) and (Nudibranchs and Nematodes $\overline{X}$ = 1/m^2 C.V. 300%) and was controlled by organic matter (r = 0.83) for Nudibranchs and by clay (r = 0.49 and organic matter (r = 0.51) for Nematodes.

In area 2, of the 21 species, (*Scyphoproctus djiboutiensis* $\overline{X}$ = 121/m^2 C.V. 69.48 %) and high correlation with clay (r= 0.59) has maximum niche breadth (4.52) and for the remaining 20 species it varied between 1.95 (Isopod sp. $\overline{X}$ = 28/m^2 C.V. 223.61%) and high correlation with sand (r = 0.84) and 4.18 (*Heteromastides bifidus*

$\overline{X}$ = 368/m^2 C.V. 75.85%) and highly correlated with sand (r = 0.72). This indicated that higher the abundance, lower the spatial variation and higher the niche breadth and vice versa.

In area 3 with 17 species the niche breadth distribution was more consistent with lower values ranging between 1.01 (Gastropod sp. $\overline{X}$ = 802/m^2 C.V. 200%) and not correlated with any (sediment characteristic) and 3.11 (*Ancistrosyllis constricta* $\overline{X}$ = 4/m^2 C.V. 122.5%) and highly dependent on silt (r = 0.70) and clay (r = 0.80). This indicated that silt and clay play a vital role in increasing the niche breadth.

In area 4, with 11 species the maximum niche breadth 3.57 was for (*Prionospio pinnata* $\overline{X}$ = 8/m^2 C.V. 48.59%) and highly controlled by organic matter (r = 0.58) and minimum niche breath was 1.57 for (Gastropod sp $\overline{X}$ = 166/m^2 C.V. 145.35%) and highest correlation was with clay (r = 0.35). *Ancistrosyllis constricta* the most abundant ($\overline{X}$ = 292/m^2) C.V. 100% and dependent on sand. (r = 0.57) had a niche breadth of 2.03. In this area it was observed that lower the abundance, lower the variation and higher the niche breadth and vice versa.

In area 5, (9 species) area 6 (6 species) and area 7 (10 species) the highest niche breadth (2.73) was for (*Lumbrinereis simplex* $\overline{X}$ = 49/m^2 C.V. 40.21%) and high correlation with sand (r = 0.49), for *Perinereis cavifrons* and *Heteromastides bifidus* (niche breadth 1.76) $\overline{X}$ = 3/m^2, C.V. 141%. with high dependence on organic matter. (r = > 0.70) and for *Prionospio pinnata* (niche breadth 12.44) ($\overline{X}$ = 708/m^2) .C.V. 64.11% and highly controlled by sand (r = -0.95) and organic matter (r = 0.59). In these areas also the relation between niche breadth, abundance and spatial variation was the same in the other areas and observed same as that during pre-monsoon season except in area 6 where the most abundant species *Prionospio pinnata* had higher niche breadth and this was correlated with high organic matter content.

redictive regression model

Relation between total benthic density and sediment characteristics studied uring pre-monsoon showed that the log transformed standardised values of sand, lt, clay and organic matter content (without their first order interaction effects) ould predict the log standardised values of benthic density from the regression iodel

$Y = -1.2930 \times 10^{-8} - 0.2522\ X$ where X = organic matter and Y = total enthic density with only 3.4337% explained variability ($F (1, 32) = 2.1734$) ($P <$ .05). This model suggested that organic matter along with some other related actors could predict the benthic density with higher prediction efficiency.

Relation between total benthic density and sediment characteristic during nonsoon showed that the sediment characteristics were not enough to predict the enthic density in the dredging area during this season. The log transformed tandardised values of the total benthic density could be predicted from the log ansformed standardised values of sediment characteristic with only 7.23%

Parameters	Relative Importance	Standard Error	Statistic 't'	95% confidence interval LCL	UCL
$X_4 \cdot X_7$	4.2004	0.4285	9.8017	(3.2605	5.0404)
$X_4 \cdot X_9$	-2.4921	0.3763	-6.6236	(-3.2296	-1.7547)
$X_2 \cdot X_4$	2.1086	0.1009	20.8975	(1.9108	2.3064)
$X_1 \cdot X_2$	-1.8696	0.1878	-9.9568	(-2.2376	-1.5016)
$X_2 \cdot X_5$	-1.5651	0.1370	-11.4217	(-1.8337	-1.2965)
$X_4 \cdot X_8$	-1.3920	0.4607	-3.0218	(-2.2949	-0.4891)
X_6	1.0571	0.0947	0.1674	(0.8716	1.2426)
$X_1 \cdot X_7$	0.9441	0.1506	6.2686	(0.6489	1.2393)
X_4	0.9131	0.2774	3.2924	(0.3695	1.4568)
$X_1 \cdot X_5$	0.7127	0.3059	2.3300	(0.1132	1.3122)
$X_1 \cdot X_9$	0.6842	0.2046	-3.3440	(-1.0852	-0.2831)
$X_4 \cdot X_6$	0.5325	0.7730	-0.6888	(-2.0476	0.9826)
$X_3 \cdot X_5$	0.4952	0.2982	-1.6606	(-1.0797	0.0893)

ırameters	Relative Importance	Standard Error	Statistic 't'	95% confidence interval	
				LCL	UCL
$X_3 \cdot X_8$	0.46.09	0.2926	1.5753	(-0.1126	1.0345)
X_2	-0.3442	0.1495	-2.3020	(-0.6373	-0.0511)
X7	0.3119	0.1831	-1.7037	(-0.6707	0.0469)
$X_6 \cdot X_8$	-0.3075	0.9763	-0.3149	(-2.2210	1.6061)
X_8	-.02699	0.1333	-2.0244	(-0.5312	-0.0086)
X_1	0.2608	0.1573	1.6584	(-0.0474	0.5691)
$X_1 \cdot X_3$	-0.2421	0.4491	-0.5390	(-1.1222	0.6381)
$X_5 \cdot X_7$	-0.2396	0.3782	-0.6336	(-0.9810	0.5017)
$X_5 \cdot X_6$	-0.2072	0.4147	-0.4996	(-1.0199	0.6056)
$X_5 \cdot X_8$	-0.2020	0.8327	-0.2426	(-1.8342	1.4.301)
$X_3 \cdot X_4$	-0.1989	0.4371	-0.4552	(-1.0558	0.6578)
X_5	-0.1984	0.0846	-2.3446	(-0.3642	-0.0325)
$X_2 \cdot X_9$	-0.1862	0.1785	-1.0433	(-0.5361	0.1636)
$X_7 \cdot X_8$	0.1760	1.1037	0.1595	(-1.9873	2.3393)
X_9	0.1734	0.1418	1.2226	(-0.1046	0.4514)
$X_2 \cdot X_7$	-0.1658	0.3117	-0.5320	(-0.7767	0.4450)
$X_6 \cdot X_7$	0.1632	0.6682	0.2442	(-1.1464	1.4728)
$X_4 \cdot X_5$	0.1421	0.4658	0.3052	(-0.7708	1.0551)
X_3	0.1317	0.2880	-0.4572	(-0.6961	0.4348)
$X_6 \cdot X_9$	-0.1121	0.8165	-0.1373	(-1.7124	1.882)
$X_2 \cdot X_8$	0.1083	0.2374	0.4561	(-0.3570	0.5735)
$X_3 \cdot X_9$	0.0997	0.2753	0.3632	(-0.4396	0.6395)
$X_1 \cdot X_6$	0.0989	0.4561	-0.2169	(-0.9928	0.7949)
$X_3 \cdot X_6$	0.1917	0.4568	0.2022	(-0.7977	0.9813)
$X_3 \cdot X_7$	0.0618	0.4020	9.1538	(-0.7260	0.8497)
$X_7 \cdot X_9$	0.0540	1.6202	0.0334	(-3.1228	3.2309)
$X_2 \cdot X_3$	-0.0459	0.2017	-0.2279	(-0.4413	0.3494)
$X_1 \cdot X_4$	-0.0441	0.1422	-0.3098	(-0.3228	0.2347)
$X_8 \cdot X_9$	-0.0253	-	-	-	-
$X_1 \cdot X_8$	0.0114	0.1737	0.0659	(-0.3291	0.3520)
$X_5 \cdot X_9$	0.0027	0.5273	0.0052	(-1.0308	1.0363)
$X_2 \cdot X_6$	-0.0011	0.2999	-0.0036	(-0.5889	0.5868)

explained variability $F (1, 32) = 3.5740$) ($P < 0.05$). The regression equation is $Y = 2.1006 \times 10^{-7} + 0.3169 X$ where X = sand, Y = total benthic density (33.5%) = $1.8905 < 2.021$). Hence this equation is not precise enough to predict benthic density, silt, clay, organic matter content and their first order interactions were also not statistically significant to predict the density.

Similarity between stations in the 7 areas.

Similarity between stations during pre-monsoon was obtained using parametric as well as non-parametric methods. In the parametric method, Bray Curtis Coefficient of similarity based on actual counts of this species in the stations was used. In the non-parametric method community coefficient, which depends only on presence and absence of the species, was used.

In area 1 during pre-monsoon more than 90% similarity was observed between stations 1 to 3 and 8 to 10. In this area the stations 5 and 6 were comparatively less similar to other stations (Bray Curtis index is less than 90%). But similarity based on presence and absence was very low between stations indicating the less common occurrence. Different species occupy the stations indicating different sediment characteristics. In monsoon season more or less the same pattern of similarity was obtained between stations based Bray Curtis index where as in the case of community coefficient, 65% commonness was observed between stations 2 and 4 and stations 5 and 7. On the whole a marginal increase in the commonness of species during this season was observed.

In area 2 during pre-monsoon season highest similarity was observed between station 13 and other stations. But stations 11 and 12 showed less than 50% similarity with stations 15 and 16. This indicated that migration tendency was not very crucial. Using community coefficient it was observed that common number of species was less between stations 13 and other stations. During monsoon season a slight reshuffling was observed in the number of common species, with station 13 keeping a lower level similarity with the rest of the stations even though the trend remained almost same. Regarding the presence/ absence/ of species not much significant difference could be observed for the pattern of station wise similarity during the 2 seasons indicating that the change whatever has been observed was only indicative of sampling fluctuations but not ecologically attributed.

In area 3 the five stations studied did not present much difference in the station wise similarity based on the abundance of species during the 2 seasons while the presence of common species was more during monsoon than during pre-monsoon except station 18 and 19.

In area 4 the abundance of species showed almost the same pattern in both season except stations 23, 28 Bray Curtis similarity (< 60%) and stations 26, 28 (< 70%). Pre-monsoon showed less occurrence of common species than monsoon season particularly station 24 with other stations. In area 5 and 6 higher similarity was observed between stations during monsoon and pre-monsoon where as in area 7 it was in reverse order.

Factor analysis

The Q-mode analysis applied to dredging areas 1, 3 and 4 during pre-monsoon showed that 4, 3 and 3 significant factor groups (>1) containing the stations 2, 3, 5 and 7 in factor group 1, stations 4 and 9 in factor group 2, and station 6 in factor group 3, and station 8 in factor group 4, in area 1 together explained about 168% of the spatial variation in the benthic faunal distribution. In area 2, 3 factor groups were ecologically significant with respect to benthic distribution containing stations 12 and 16 in factor group 1, stations 11 and 15 in factor group 2, stations 13 and 14 in factor groups 3 and 4 explained about 77.06% of the spatial variation in this area. In area 4, 3 significant factor groups delineated could explain about 80.48% of the spatial variation in benthic faunal distribution. In this area, stations 23, 26 and 27 were grouped together while stations 22 and 25 were separated into 2 distinct factor groups. For all factor groups the factor loadings were numerically high indicating that there was unique difference between the stations included in the different factor groups and between groups difference were more significant than within group difference since the stations included in each factor group have high factor loadings of the same sign. In these areas, the first two factor groups were differential factor groups explaining more than 50% of the spatial variations in the benthic faunal distribution in these three areas.

During monsoon season, Q-mode factor analyses have been carried out only for areas 1, 2 & 3. In area 1, only 3 statistically significant groups of stations were obtained, containing stations 7 and 9, in factor group 1, stations 1 and 3 in factor group 2 and station 6 in factor group 3. These three groups have factor loadings and explain about 51.79% of the variability in the spatial benthic faunal distribution in this area. The information gathered from the distribution of benthos in the other stations did not add significantly to the information gathered from the stations of factor groups 1 - 3 and these 3 factor groups were differential factor groups with stations (7, 9) and 1 & 3 were equally important. In area 2, the first two factor groups were important with both having high negative factor loadings and the first factor group formed the differential factor group. The stations 12, 13, 14 and 16 provided the maximum information about the benthic faunal distribution in this area and explained about 2.5 times information gathered from station 15 of area 2. In area 3, all the 4 factor groups were ecologically important in the sense that they explain almost the same amount of variability in the benthic distribution and first 3 form the differential factor groups. Groups 1 and 2 had positive factor loading while groups 3 and 4 showed negative loadings.

5.4 DISCUSSION

5.4.1 Water quality

Information on hand showed that the indicator parameters of water quality were in general within acceptable limits as per Indian and U.S. standards for harbour and coastal waters. The environment in and around Cochin harbour which has been under varying degrees of stress due to dredging over the last 5 decades has not shown any sign of serious environmental impairment as can be seen from the present study and documented data.

Though the concentrations of some of the nutrients like inorganic phosphate are high (>2 μmol/l) especially during the low water brought in by the river discharge is reflected in river mouth as well as in very nearshore waters. But due to dilution and mixing the concentration are near normal about 10 km off the coast.

The present data and the data collected earlier indicate that there is build up of various nutrients in the harbour region and close to the coast. A comparison of the data collected over the years indicate that since 1965 there has been more than two fold increase in the general levels of inorganic phosphate of the river mouth (1.23 to 3.3 μmol/l). Similarly, the average nitrate values have also increased from 7.72 to 19.7 μmol/l in the backwater system. This is due to the effect of the effluents discharged from the fertilizer factory in the upstream. Earlier studies (NIO, 1993) from this region have shown the release of nutrients and metals to the overlying water during dredging. But these nutrients come to normal levels within 20 minutes after dredging. So the long-term impact to the environment due to dredging is negligible.

Thresiamma Joseph *et al.* (1998) observed that immediately after the hauling of the dredging head, the sediment cloud patch was uniformly spread over the water column and all the nutrients in the water column increased substantially. After 2 hours of dredging, the sediment plume completely mixed with the surrounding waters. Nitrite and Phosphate had reverted to their pre-dredging levels. They also stated that the disturbance due to dredging was confined to a short period and to a limited area and was unlikely to cause any intense environmental damages to the entire system.

Dissolved oxygen saturation in the surface and bottom waters varied in general, from 60 to 80 % and BOD_5 was within in the permissible limits. Particulate matter and sediments also did not indicate high levels. So long term impact to the environment due to dredging is negligible.

5.4.2 Sediment characteristics

The silty clay and sandy clay substratum predominated the study area except for one or two stations. Compared to monsoon organic matter was low during pre-monsoon, the average organic matter in the areas 1, 2 and 3 ranged from 4.07 to

5.27% during monsoon and 3.71 to 4.27% during pre-monsoon. In the dredging channel the value were 3.40% during pre-monsoon and 3.51% during monsoon. In the disposal area the average organic matter content is 4.51 and 4.00% during pre-monsoon and monsoon periods respectively. On either side of the dredging channel the organic matter content values varied from 3.83 to 4.53 % and 3.61 to 4.34% during monsoon and pre-monsoon respectivey.

High organic matter content in the region can be ascribed to high productivity of the overlying waters (Devassy, 1983). Sewage and municipal discharge and clayey nature of the sediment may also be responsible for high organic matter (Shirodkar and Sengupta, 1985). More over land derived organic matter finally deposit in the river channel. Strong tidal currents in the region continuously drain out available suspended organic matter in the sea without allowing sufficient limit for the deposition during the out flow of water.

The pre-monsoon season showed the presence of minor portions of sand. The silt portion marginally reduced giving way to deposition of clay material at the dredging site. These observations lead to the conclusion that more finer material than silt is either sedimented or translocated on the seaward side of the dredged site. This factor also excludes the possibility of river borne material to reach the dredged area under diminished low river discharge rate during pre-monsoon season.

The sediment characteristics and bottom topographic features will be restored after a period of intermittent dredging. The tidal flushing characteristics and river discharge plus material inputs helps the dredged site to return to its initial status (Rasheed, 1997).

The energy content varied from 723.60 (Area 2) to 974.16 (Area 7) during pre-monsoon and 758.16 (Area 4) to 1138.32 (Area 1) during monsoon which is lower than the reported values (224.0 to 7949.40 J/g) for the retting yards of Cochin backwater by Remani *et al.*, (1981), the values (699.78 to 5134.30 J/g) of the retting zones of Ashtamudi estuary (Bijoy Nandan and Abdul Aziz, 1996) and the values

(12.26 to 2286.79 J/g) of the polluted environment and mangrove environment (270.00 to 1535.80 J/g) of the present study.

5.4.3 Standing stock and community structure

The quantitative and qualitative study of benthos in the area showed a wide variation in their distribution, abundance and composition. This may be probably due to various biological and physico-chemical environmental factors. Wide fluctuations in salinity and nature of substratum and organic enrichment in the sediment are the important factors restricting the abundance of benthos. A sufficient quantity of sediment will be removed as a result of dredging. The fauna will be exposed to a new substratum.

The dredging operations usually affect the ecosystem mainly in 2 ways. It disturbs the bottom and increases the turbidity level in the water column. The perturbation may affect the benthic communities for spawning, shelter and feeding. The addition of particulate matter to the ambient load will increase the turbidity. This may cause discoloration of the water column with possible adverse effects on living communities. Light penetration also gets reduced, which affects efficient photosynthetic activity even in the presence of sufficient nutrients and congenial conditions. Finer portions of suspended particles may clog the gill surface of fishes and some invertebrates. The settlement of large amount of suspended particles may smoother the bottom fauna.

The perturbation in the environment as a result of dredging and dredge spoil dumping disturbs the bottom due to the turbidity developed. The expected changes in the benthic organisms are species replacement and an increase in the abundance of certain particular organism. A perusal of the data collected from the nearshore waters and the Cochin harbour area in the last two decades clearly indicated that there is no change either in the benthic biomass or in the faunal composition over the years (NIO, 1993).

Survival of the benthic species depends on the thickness and other characteristics of the deposited material. Studies conducted elsewhere indicated that deposition of sediments upto 10cm did not affect the benthic population provided that there were no differences between the originally present and deposited sediments. Detailed analysis of the sediment samples collected from the dumping sites and the harbour area covering an area of 130km showed that the sediment characteristics are comparable. Hence the damage to the bottom community caused by dumping the spoil is minimal and is reflected in the data also. Therefore it can be concluded that an increase in the quantum of dredge material and the disposal at selected site is unlikely to cause any serious damage to the bottom community. The impacts observed if any were relatively short term. The behaviour of organisms in the reference area was very similar to that in the disposal area and no definite impact could finally be established. It was not perceptible since the species composition of benthos was observed to be identical with that in the neighbouring areas over the years. The absence of accumulation of dead shells in this area in the present study suggests that there was no indication of mortality due to impact of dredging and dredges spoil disposal (NIO, 1993). Comparison of substrate and benthic community structure near the dredging and disposal site showed that benthic communities were resilient and was able to cope with the stress of anticipated additional loading.

A study by the Swedish scientist Rosenberg (1977) indicated that the reduction in number and the diversity of organisms are the aftermath of the deleterious effects. The larval development in the vicinity of the dredged area is often strongly affected. Several studies concerning the effects of dredge material deposition on benthic macro-invertebrates have been carried out (Harrison, 1967; Flint, 1979; Van Dolah *et.al.*, 1984; Wildish and Thomas, 1985; Rees *et.al.*, 1992). Since different types of effects were identified in these studies, it is impossible to draw a general conclusion about the impact of dredge material deposition on the benthic community structure. For instance, Harrison (1967) reported a 71% reduction in the average number of benthic animals at a disposal site in the upper Chesapeake Bay at one month after dredging and disposal activities ceased. However within 18 months, the number of individuals and species diversity at the disposal site were same as in surrounding areas.

The study of the benthic community at the Botany Bay showed that the benthic fauna at the dredged area is different from the nearby non-dredged areas with respect to species composition and richness, both of which are closely related to the sediment type (Jones & Candy, 1981). They also conclude that the macrobenthic faunal variations in the Botany Bay are an indirect impact of dredging. A very recent report narrates the outcome of dredging on benthic recovery in Galveston Bay, Texas (Ray and Clarke, 1995). Van Dolah *et.al.* (1984), who studied the effect of dredging and open-water disposal on benthic macro-invertebrates in a South Carolina estuary, showed that detrimental effects on benthic macrofauna in the area of open-water disposal were minimal. On the other hand, Flint (1979) in freshwater and Rees et.al. (1992) in the marine environment, showed important increases in the total number of individuals in newly deposited sediment caused by rapid recolonization by opportunistic species, the species that can quickly respond to open or unexploited habitats by either a high reproduction rate or a high dispersal ability (Grassle and Grassle, 1974). According to Flint (1979), more than a year was required for the affected areas to re-establish a benthic community structure similar to unaffected areas of Lake Erie. The different results obtained in various regions show that the potential environmental effects of each dredging project must be evaluated on a case-by-case basis. According to Micheal Harvey et.al. (1998) the surface sediment composition and the benthic community structure were changed drastically, shortly after the open sea deposition of dredge materials. The faunal response may be characterized as a decrease in the density of the less opportunistic families with the most opportunistic life style. Both direct burial by dredged sediment discharged in large quantities within a short time interval and an enhanced food supply are the two factors that may explain the changes in density in various families. More than two years are required for the disturbed areas to re-establish a sediment composition and a macro-benthic community structure similar to undisturbed areas of the Ance a Beaufils sea bottom.

The studies by Rosenberg (1977) and Jones and Candy (1981) suggested that the benthic fauna of dredged areas differs from that of nondredged areas with respect to species composition and diversity. Jones and Candy (1981) also narrated the variation of sediment texture during dredging. Long term studies on dredging conducted by May (1973) had indicated that it may cause a variety of environmental changes depending on the area and the extent of dredging.

The dredged site showed a slight increase in number of organisms especially in polychaetes, which indicates the onset of colonisation in this area. Most tropical estuaries exemplify a characteristic food web commonly involving benthic organisms. Any process which is likely to institute originative changes on the bottom life system of an estuary will particularly have long standing impacts on the ecosystem as a whole (Kurian *et al.*, 1975; Mc Cauley *et al.*, 1976; Flint, 1984 and Amson, 1988). In establishing the geographical boundaries of an estuary, the bottom bed is invariably one such rigid but ecosensitive plane where benthic fauna has established a way of propagation. Within a seasonal cycle of reasonable duration many environmental factors have been delineated for their extent of influence on the survival and propagation of benthos (Langton and Robinson, 1990). Another fact is that for a given set of environmental characteristics a process such as dredging would bring about an outcome wherein the process triggers a rapid growth and propagation of bottom fauna (Mc Call, 1977 and Jones and Candy, 1981). The result of the present study showed low representation of certain species in dredged area and their tendency for recolonisation on suspension of operations. Kalpan *et al.* (1975) and Met Calfe *et al.* (1976) have commended on the factors affecting the recolonisation of a dredged channel in the context of input assessments. Higher species density were noted at the nondredged location compared to dredged area and under favourable conditions, the recolonization is possible in this dynamic environment.

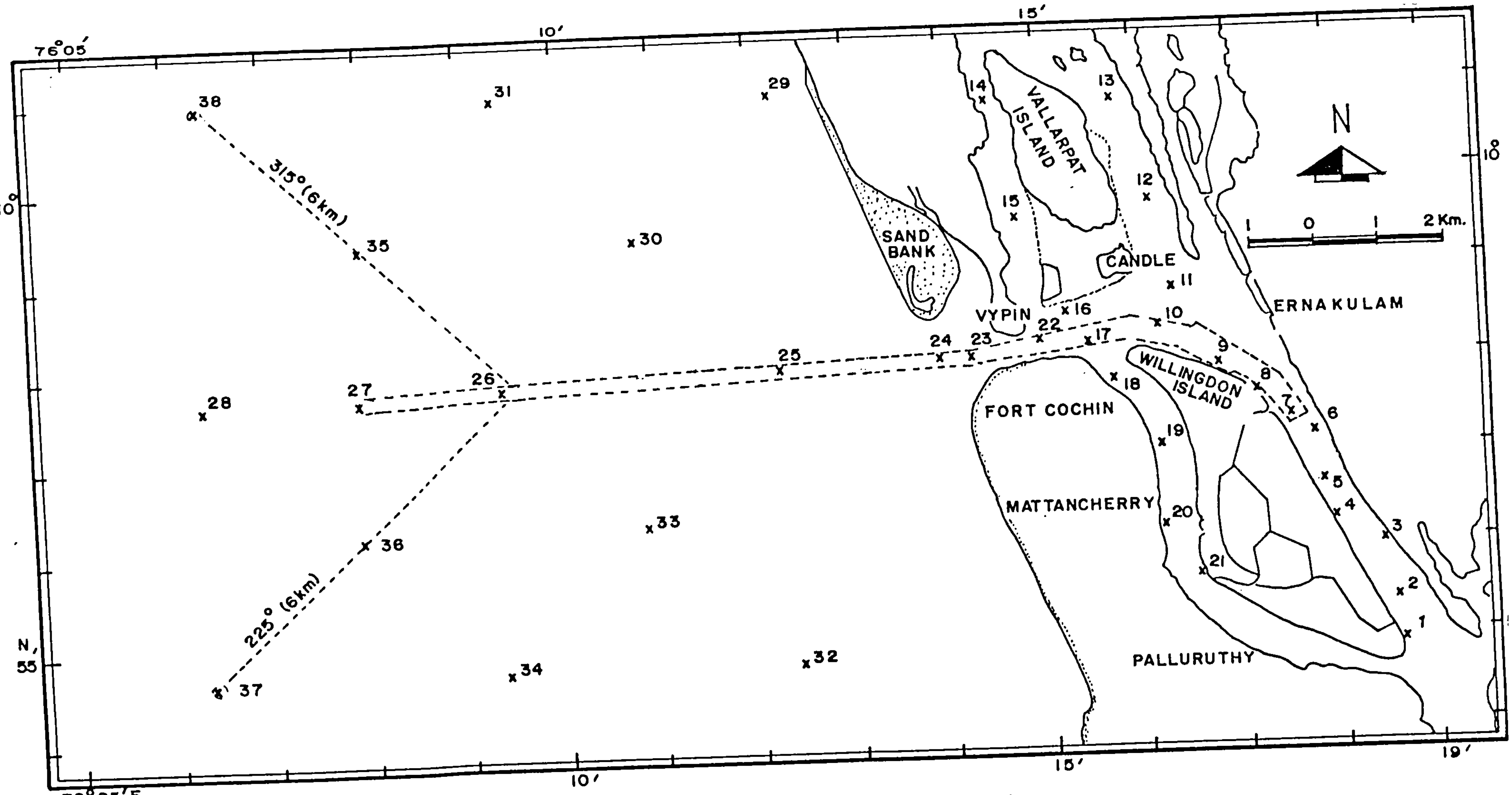


Fig.5.1. Location of sampling stations

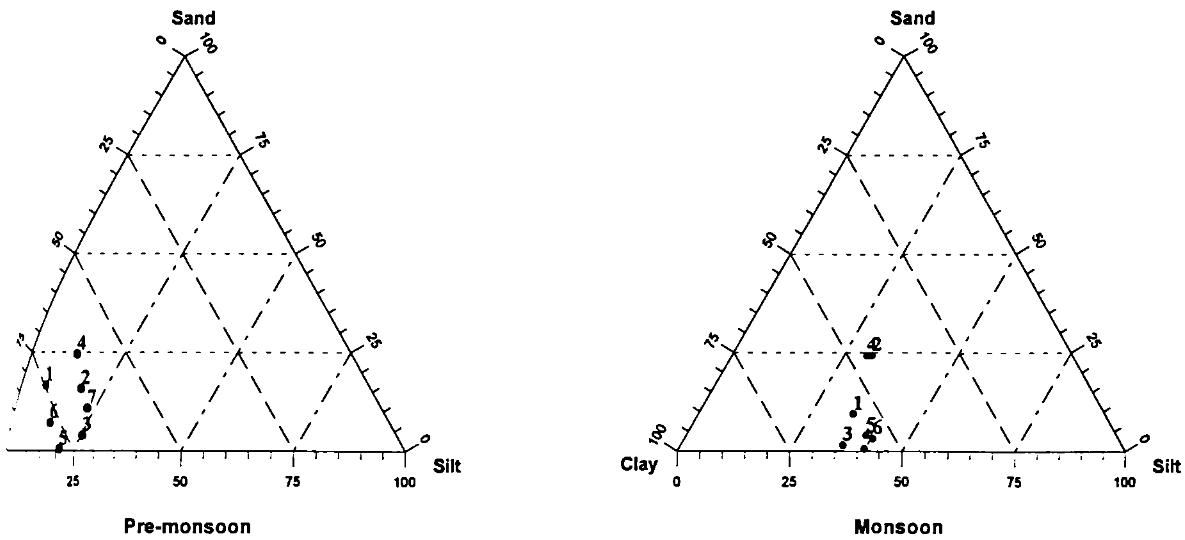


Fig. 5.2. **Grain size distribution at different stations during pre-monsoon and monsoon.**

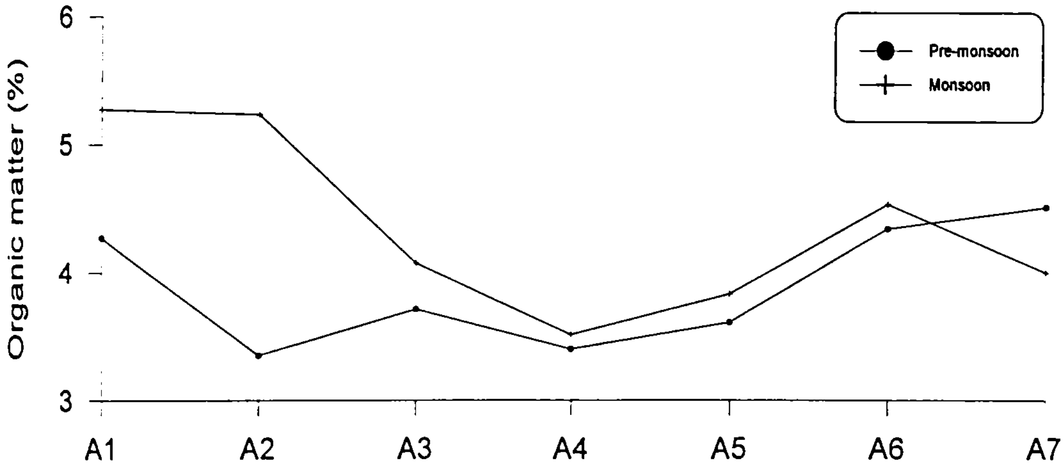


Fig. 5.3. **Distribution of organic matter in different seasons at A1 to A7**

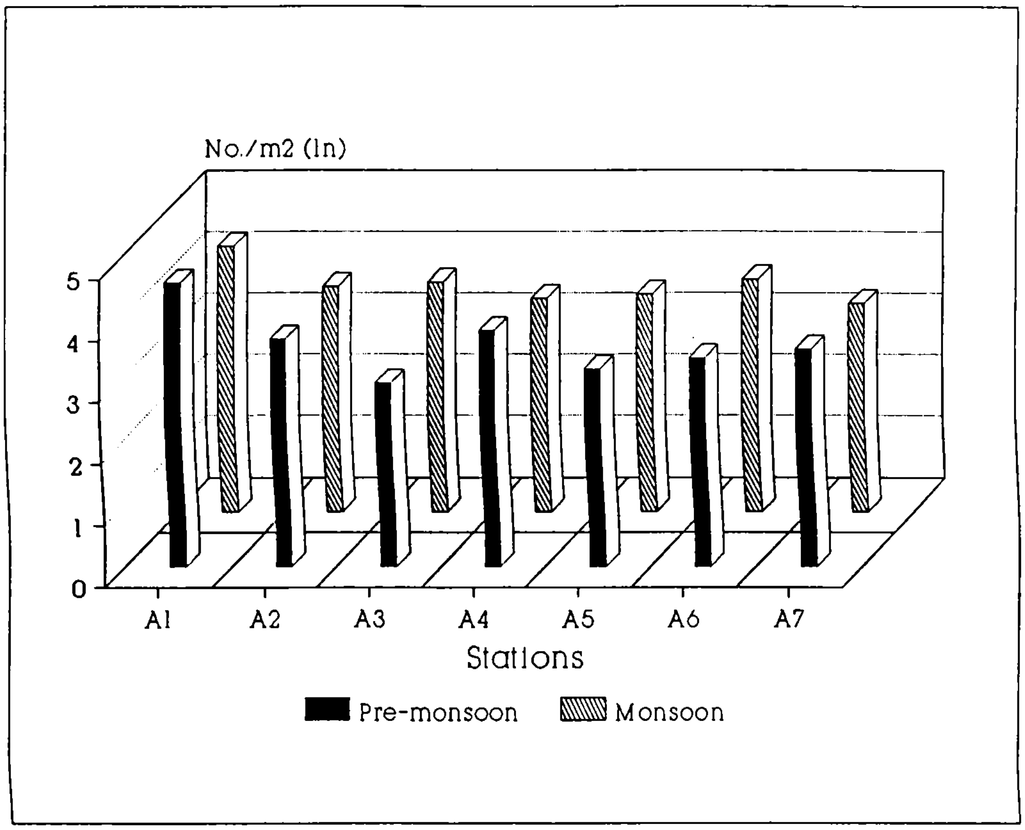


Fig. 5.4. Total benthic density (no./m^2) at A1 to A7 in different seasons

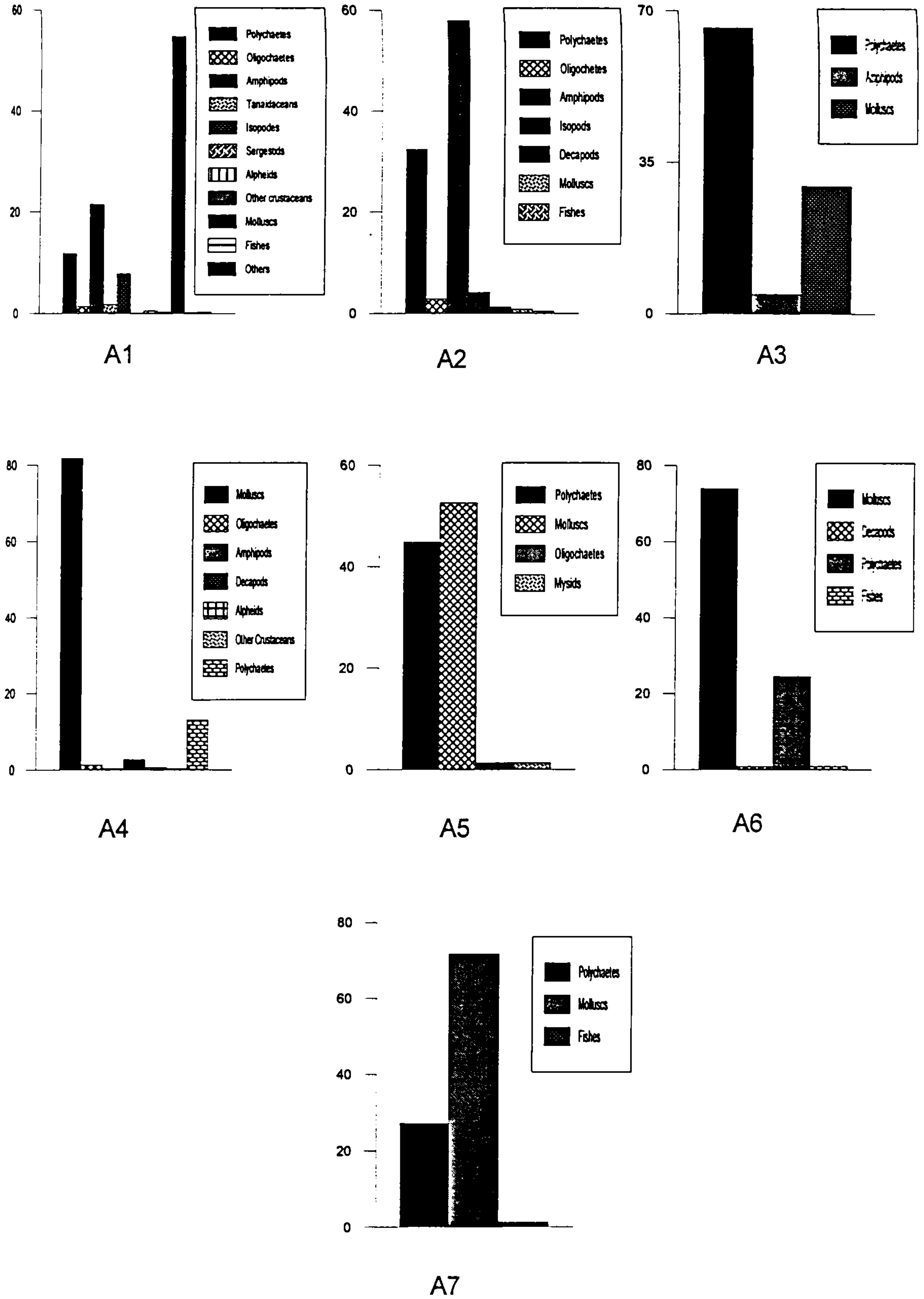


Fig. 5.5. **Percentage distribution of major groups of benthos at A1 to A7 during pre-monsoon**

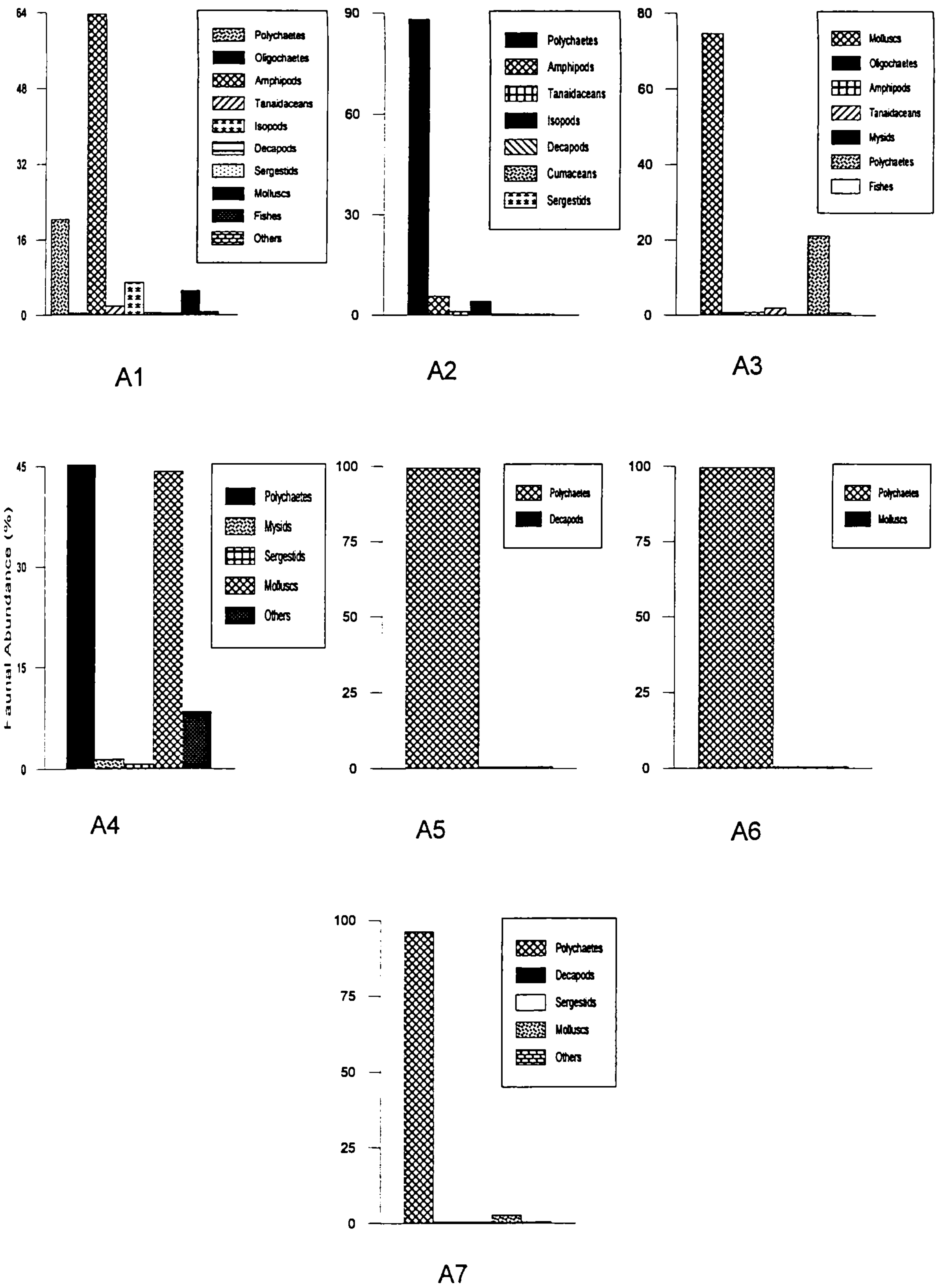


Fig. 5.6. **Percentage distribution of major groups of benthos at A1 to A7 during monsoon**

A1

Stns	1	2	3	4	5	6	7	8	9	10
1	–	●	●	◑	●	●	●	●	●	●
2	98	–	⊛	●	◔	●	⊛	●	●	●
3	98	42	–	●	◑	●	⊛	●	●	●
4	76	99	99	–	●	●	●	●	●	●
5	98	60	79	99	–	◕	◑	◑	●	◔
6	97	94	96	98	85	–	◕	●	◕	◑
7	98	46	33	99	73	88	–	●	●	●
8	100	93	100	99	79	100	100	–	●	●
9	97	93	100	99	100	84	100	100	–	●
10	100	90	91	100	69	73	94	100	100	–

A2

Stns	11	12	13	14	15	16
11	–	◷	●	◑	⊛	⊛
12	52	–	●	◔	◑	⊛
13	99	96	–	●	●	●
14	71	97	97	–	◕	◑
15	34	74	99	88	–	◑
16	49	42	99	73	76	–

A3

Stns	17	18	19	20	
17	–	●	●	◕	●
18	100	–	⊛	●	●
19	100	33	–	●	●
20	86	100	100	–	◕
21	100	100	100	82	–

20-30	⦶
30-40	⊕
40-50	⊛
50-50	◷
60-70	◔
70-80	◑
80-90	◕
90-100	●

A4

Stns.	22	23	24	25	26	28
22	–	●	●	●	●	●
23	100	–	◕	●	●	◔
24	90	88	–	●	●	●
25	100	100	100	–	◕	●
26	100	91	97	88	–	◔
28	98	54	97	97	64	–

A5

Stns	29	30	31
29	–	●	◷
30	100	–	◕
31	56	83	–

A6

Stns	32	33	34
32	–	◑	⊛
33	71	–	◷
34	44	53	–

A7

Stns	35	36	37	38
35	–	◔	◕	◷
36	61	–	⊛	◑
37	81	44	–	◷
38	55	19	54	–

Fig.5.7. Bray Curtis similarity coefficient (%) between stations in the areas A1 to A7 during pre-monsoon.

A1

Stns	1	2	3	4	5	6	7	8	9	10
1	–									
2	8	–								
3	9	40	–							
4	39	11	6	–						
5	13	33	22	26	–					
6	29	8	9	39	13	–				
7	7	22	25	5	25	23	–			
8	0	14	0	18	20	0	0	–		
9	27	13	0	17	0	17	0	0	–	
10	10	20	25	13	25	22	13	0	0	–

A2

Stns	11	12	13	14	15	16
11	–					
12	33	–				
13	7	30	–			
14	31	25	20	–		
15	44	38	8	23	–	
16	37	30	7	20	27	–

A3

Stns	17	18	19	20	21
17	–				
18	0	–			
19	0	100	–		
20	17	0	0	–	
21	0	0	0	14	–

0-10
10-20
20-30
30-40
40-50
50-60
60-70
80-90
90-100

A4

Stns	22	23	24	25	26	27
22	–					
23	0	–				
24	14	43	–			
25	0	0	0	–		
26	0	20	14	33	–	
27	8	14	25	20	50	–

A5

Stns	29	30	31
29	–		
30	0	–	
31	14	25	–

A6

Stns	32	33	34
32	–		
33	38	–	
34	43	50	–

A7

Stns	35	36	37	38
35	–			
36	80	–		
37	14	17	–	
38	67	80	14	–

Fig.5.8. Community coefficient (%) between stations in the areas A1 to A7 during pre-monsoon.

A1

Stns	1	2	3	4	5	6	7	8	9	10
1	–	◕	◷	◑	●	●	●	●	●	●
2	85	–	●	◕	●	◕	◔	◑	●	◕
3	55	93	–	◔	●	●	●	●	●	●
4	72	80	62	–	●	●	●	●	●	●
5	96	90	98	96	–	◔	◕	●	◑	◑
6	94	87	98	96	68	–	◕	●	◑	◕
7	94	63	98	95	84	83	–	◔	●	◕
8	95	77	99	96	94	91	67	–	●	◕
9	99	96	99	99	70	74	92	93	–	◑
10	97	87	98	93	78	86	82	85	76	–

A2

Stns	11	12	13	14	15	16
11	–	◔	◑	◑	⊛	◔
12	67	–	◔	⊗	◕	⊗
13	72	64	–	◑	●	◔
14	77	31	72	–	◕	⊛
15	46	83	97	81	–	◑
16	61	36	63	44	77	–

A3

Stns	17	18	19	20	21
17	–	◕	●	●	●
18	85	–	●	●	●
19	100	91	–	●	●
20	100	94	100	–	●
21	100	99	100	98	–

20-30 ⊕
30-40 ⊗
40-50 ⊛
50-60 ◷
60-70 ◔
70-80 ◑
80-90 ◕
90-100 ●

A4

Stns	24	26	27	28
24	–	●	⊕	●
26	98	–	●	◑
27	24	96	–	●
28	94	75	93	–

A5

Stns	29	30	31
29	–	●	●
30	92	–	◑
31	98	79	–

A6

Stns	32	33	34
32	–	◕	●
33	89	–	◑
34	98	70	–

A7

Stns	35	36	38
35	–	⊛	⊛
36	41	–	◑
38	45	73	–

ig.5.9. Bray Curtis similarity coefficient (%) between stations in the areas A1 to A7 during monsoon.

A1

	1	2	3	4	5	6	7	8	9	10
1	–	⊕	⊛	⊗	⊕	⊕	⊗	⦶	○	⦶
2	27	–	⊗	◔	⊗	⊕	⊗	⊕	○	⦶
3	44	35	–	⊗	⊕	⊕	⊕	○	○	⊕
4	31	65	38	–	⊗	⦶	⊗	⦶	○	⦶
5	25	32	29	36	–	⊕	◔	⦶	⦶	⊗
6	28	23	25	18	27	–	⊗	⊕	○	○
7	33	32	22	30	60	36	–	⊗	⦶	⊗
8	13	24	6	17	18	23	30	–	⊕	⊕
9	8	4	7	5	13	9	13	20	–	⊕
10	14	19	20	18	33	7	33	29	25	–

A2

Stns	11	12	13	14	15	16
11	–	⊕	⊕	⊕	⊕	⊛
12	29	–	⊕	⊕	⦶	⊕
13	23	20	–	⦶	⦶	⦶
14	20	27	20	–	⊕	⊕
15	27	11	14	25	–	⦶
16	47	29	14	20	17	–

A3

Stns	17	18	19	20	21
17	–	⊗	○	○	○
18	33	–	○	⦶	⦶
19	0	7	–	○	⊕
20	0	15	0	–	⊕
21	0	14	25	25	–

0-10	○
10-20	⦶
20-30	⊕
30-40	⊗
40-50	⊛
60-70	◔
80-90	◕

A4

Stns	24	26	27	28
24	–	○	◕	⦶
26	10	–	⦶	⊕
27	82	18	–	⊕
28	20	25	27	–

A5

Stns	29	30	31
29	–	⊕	⊕
30	22	–	⊕
31	25	25	–

A6

Stns	32	33	34
32	–	◔	⊛
33	67	–	⊗
34	40	33	–

A7

Stns	35	36	38
35	–	⊗	⊗
36	38	–	○
38	33	10	–

Fig.5.10. Community coefficient (%) between stations in the areas A1 to A7 during monsoon.

Table 5.1 **Distribution of chemical properties during the final stages of the dredging**

DEPTH M	SALINITY psu	PHOSPHATE -P µmol/l	NITRITE-N µmol/l	AMMONIA-N µmol/l	SILICATE-Si µmol/l
Pre-dredging					
S	16.10	0.50	0.54	0.41	55.70
M	22.42	0.67	0.28	0.00	44.41
B	31.91	0.71	0.24	0.00	14.39
Immediately after dredging					
S	19.31	1.89	0.65	0.21	48.06
M	24.62	3.35	0.75	5.03	39.36
B	33.52	3.02	0.58	4.25	10.92
20 minutes after dredging					
S	17.77	0.55	0.52	0.00	50.38
M	31.90	0.75	0.28	0.00	15.31
B	33.26	1.22	0.22	3.49	11.24
Two hours after dredging					
S	15.74	0.67	0.60	0.00	55.19
M	18.90	0.75	0.54	0.00	46.63
B	19.80	0.71	0.52	0.00	45.20

S - surface, M – mid layer, B - bottom

Table 5.2 **Distribution on energy content (J/g dry weight) at different station in the areas A1 to A7 during pre-monsoon and monsoon seasons.**

Areas	Stations	Pre-monsoon	Average	Monsoon	Average
A1	1	591.84	922.32	1337.04	1138.32
	2	965.52		976.32	
	3	1090.80		1105.92	
	4	1090.82		1207.44	
	5	900.72		1125.36	
	6	771.12		1002.24	
	7	216.00		1162.08	
	8	991.44		991.44	
	9	1645.92		1373.76	
	10	96.12		1090.80	
A2	11	1071.36	723.60	1300.32	1129.68
	12	1028.16		1594.08	
	13	436.32		1706.40	
	14	680.40		926.64	
	15	572.40		488.16	
	16	602.64		762.48	
A3	17	1028.16	801.36	680.40	879.12
	18	1017.36		1183.68	
	19	581.04		822.96	
	20	1157.76		1121.04	
	21	220.32		591.84	
A4	22	719.28	734.40		758.16
	23	51.84			
	24	956.88		114.48	
	25	704.16			
	26	1004.40		924.48	
	27			1028.16	
	28	965.52		961.20	
A5	29	643.68	779.76	976.32	827.28
	30	838.08		643.68	
	31	859.68		859.68	
A6	32	576.72	937.44	1002.24	978.48
	33	1099.44		613.44	
	34	1136.16		1321.92	
A7	35	488.16	974.16	488.16	864.00
	36	1168.56		1168.56	
	37	1300.32			
	38	937.44		937.44	

'able 5.3 Sediment characteristics during pre-monsoon and monsoon

AREA	STATIONS	PRE-MONSOON				MONSOON			
		SAND (%)	SILT (%)	CLAY (%)	ORGANIC MATTER (%)	SAND (%)	SILT (%)	CLAY (%)	ORGANIC MATTER (%)
A1	1	0.24	21.11	78.65	2.74	3.70	27.00	69.30	6.19
	2	0.46	14.04	85.50	4.47	14.62	34.63	50.75	4.52
	3	23.27	8.13	68.60	5.05	23.33	31.91	44.76	5.12
	4	15.50	4.45	80.05	5.05	1.59	40.06	58.35	5.59
	5	5.63	2.77	91.60	4.17	0.47	33.98	65.55	5.21
	6	20.07	8.53	71.40	3.57	37.42	19.33	43.25	4.64
	7	30.44	0.91	68.65	1.00	0.45	40.20	59.35	5.38
	8	19.31	5.94	74.75	4.59	8.96	43.14	47.90	4.59
	9	23.05	20.20	56.75	7.62	0.28	32.32	67.40	6.36
	10	27.93	1.97	70.10	4.45	3.59	41.46	54.95	5.05
A2	11	1.33	10.32	88.35	4.71	8.51	37.68	53.81	6.02
	12	7.49	14.81	77.70	4.76	14.88	35.52	49.60	7.38
	13	30.40	18.40	51.20	2.02	8.35	44.55	47.10	7.90
	14	28.00	22.00	50.00	3.15	62.05	15.60	22.35	4.29
	15	23.04	21.21	55.75	2.65	11.45	25.85	62.70	2.26
	16	4.17	27.08	68.75	2.79	40.55	27.80	31.65	3.53
A3	17	10.72	24.38	64.90	4.76	4.09	34.56	61.35	3.15
	18	1.41	35.69	62.90	4.71	0.27	52.63	47.10	5.48
	19	2.21	13.64	84.15	2.69	0.44	27.61	71.95	3.81
	20	4.69	24.06	71.25	5.36	2.35	30.20	67.45	5.19
	21	0.39	28.66	70.95	1.02	0.59	35.36	64.05	2.74
A4	22	23.39	4.86	71.75	3.33	--	--	--	--
	23	64.62	12.68	22.70	0.24	--	--	--	--
	24	50.69	6.41	42.90	4.43	94.20	0.50	5.30	0.53
	25	6.30	19.95	73.75	3.26	--	--	--	--
	26	1.47	15.58	82.95	4.65	1.00	44.45	54.55	4.28
	27	--	--	--	--	0.50	36.20	63.30	4.76
	28	0.54	21.76	77.70	4.47	1.20	39.30	59.50	4.45
A5	29	0.13	12.22	87.65	2.98	11.43	39.62	48.95	4.52
	30	0.31	22.99	76.70	3.88	0.36	39.59	60.05	2.98
	31	0.86	27.34	71.80	3.98	0.18	41.07	58.75	3.98
A6	32	20.16	7.49	72.35	2.67	6.10	46.80	47.10	4.64
	33	0.17	25.70	74.13	5.09	0.10	39.20	60.70	2.84
	34	0.85	11.40	87.75	5.26	3.50	39.80	56.70	6.12
A7	35	2.25	29.35	68.40	2.26	0.58	49.67	49.75	2.26
	36	4.99	29.56	65.45	5.41	0.20	41.20	58.60	5.41
	37	19.26	22.60	58.14	6.02	--	--	--	--
	38	16.64	10.66	72.70	4.34	1.10	33.20	65.70	4.34

le 5.4 Benthic density (No/m^2) and biomass (g/m^2) during pre-monsoon and monsoon

		PRE-MONSOON				MONSOON			
EA	STATIONS	Density	Total Density	Biomass	Total Biomass	Density	Total Density	Biomass	Total Biomass
A1	1	9941	41414	164.52	231.34	2815	21373	2.97	81.51
	2	398		8.37		2148		9.26	
	3	750		0.72		7524		43.64	
	4	28672		22.24		5921		3.54	
	5	231		10.83		189		5.41	
	6	335		9.39		294		4.69	
	7	689		10.68		1001		0.89	
	8	168		0.91		1136		1.86	
	9	188		3.58		42		0.09	
	10	42		0.10		303		9.16	
A2	11	377	5027	18.33	38.17	680	4682	1.88	34.77
	12	230		3.36		1038		10.64	
	13	3104		4.41		292		4.51	
	14	794		2.98		1283		6.85	
	15	250		8.29		418		6.02	
	16	272		0.80		971		4.87	
A3	17	84	953	0.59	31.75	231	5442	6.05	12.63
	18	21		0.10		898		2.31	
	19	42		0.10		84		0.59	
	20	218		2.46		156		2.68	
	21	588		28.50		4073		1.00	
A4	22	629	6882	31.74	297.3		2959		215.97
	23	3355		203.09					
	24	1106		44.65		1396		102.65	
	25	42		1.13					
	26	313		2.89		42		0.21	
	27					1458		110.73	
	28	1437		13.80		63		2.38	
A5	29	167	1625	1.18	61.36	3312	3501	25.58	37.78
	30	1062		47.42		147		11.53	
	31	396		12.76		42		0.67	
A6	32	439	2483	2.06	37.47	63	6063	0.58	20.99
	33	1439		21.16		917		2.61	
	34	605		14.25		5083		17.80	
A7	35	2020	3455	40.72	175.51	689	2502	4.25	12.96
	36	483		17.80		1469		4.41	
	37	304		90.99					
	38	648		26.00		344		4.30	

Table 5.5 Total No. of specimens, numerical abundance and percentage contribution of different groups of benthic fauna at stations A1 to A7 during pre-monsoon season

Areas	No. of specimens	Poly-chaetes	Oligo-chaetes	Amphi-pods	Tanaid-aceans	Isopods	Decapods	Mysids	Sergestids	Alpheids	Other Crustaceans	Molluscs	Fishes	Misc. Groups
A1	41414	4928 (11.90)	562 (1.36)	8919 (21.54)	731 (1.76)	3270 (7.90)	--	--	21 (0.05)	21 (0.05)	105 (0.25)	22689 (54.79)	42 (0.10)	126 (0.30)
A2	5027	1630 (32.42)	147 (2.92)	2916 (58.01)	--	208 (4.14)	63 (1.25)	--	--	--	--	42 (0.84)	21 (0.42)	--
A3	953	630 (66.11)	--	42 (4.41)	--	--	--	--	--	--	--	281 (29.48)	--	--
A4	6882	899 (13.07)	84 (1.22)	21 (0.30)	--	--	188 (2.73)	--	--	42 (0.62)	21 (0.30)	5627 (81.76)	--	--
A5	1626	730 (44.86)	21 (1.29)	--	--	--	--	21 (1.29)	--	--	--	854 (52.56)	--	--
A6	2483	607 (24.45)	--	--	--	--	21 (0.85)	--	--	--	--	1834 (73.85)	21 (0.85)	--
A7	3455	939 (27.18)	--	--	--	--	--	--	--	--		2474 (71.61)	42 (1.21)	--

(Values in the brackets indicates the %)

Table 5.6 Total No. of specimens, numerical abundance and percentage contribution of different groups of benthic fauna at stations A1 to A7 during monsoon season

Area	No. of speci-mens	Poly-chaetes	Oligo-chaetes	Amphipods	Tanaid-aceans	Isopods	Decapods	Mysids	Cumaceans	Sergestids	Molluscs	Fishes	Misc. Groups
A1	21373	4447 (20.81)	126 (0..59)	13409 (62.74)	418 (1.96)	1436 (6.72)	126 (0.90)	--	--	105 (0.49)	1138 (5.32)	147 (0.69)	21 (0.09)
A2	4682	4053 (86.57)	--	294 (6.28)	63 (1.35)	188 (4.02)	42 (0.90)	--	21 (0.44)	21 (0.44)	--	--	--
A3	5442	1159 (21.29)	42 (0.77)	42 (0.77)	105 (1.94)	--	--	21 (0.38)	--	--	4031 (74.08)	42 (0.77)	--
A4	2959	1334 (45.08)	--	--	--	--	--	42 (1.42)	--	42 (1.42)	1291 (43.63)	--	250 (8.45)
A5	3501	3480 (99.40)	--	--	--	--	21 (0.60)	--	--	--	--	--	--
A6	6063	6042 (99.65)	--	--	--	--	--	--	--	--	21 (0.35)	--	--
A7	2502	2376 (94.96)	--	--	--	--	21 (0.84)	--	--	21 (0.84)	63 (2.52)	--	21 (0.84)

(Values in the brackets indicates the %)

Table 5.7a **Average ($\overline{X}$) and Coefficient of Variation (C.V. (%)) of total benthic density and sediment characteristics in the areas A1 to A7 during pre-monsoon season**

AREA	Benthic density		Sand		Silt		Clay		Organic matter	
	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)
A1	4140.70	209.25	16.59	62.50	8.81	78.84	74.60	12.53	4.27	37.86
A2	837.83	123.13	15.74	74.65	18.98	28.22	65.29	21.85	3.35	30.98
A3	190.60	110.28	3.88	95.33	25.09	27.48	70.83	10.48	3.71	43.66
A4	1147.00	94.15	24.50	101.80	13.54	46.68	61.96	35.04	3.40	44.61
A5	541.67	70.08	0.43	71.66	20.85	30.48	78.72	8.42	3.61	12.45
A6	827.67	52.87	7.06	131.26	14.86	52.66	78.08	8.81	4.34	27.26
A7	866.25	78.82	10.78	67.59	23.04	33.32	66.42	8.46	4.51	31.73

Table 5.7b **Average ($\overline{X}$) and Coefficient of Variation (C.V.(%)) of total benthic density and sediment characteristics in the areas A1 to A7 during monsoon season**

AREA	Benthic density		Sand		Silt		Clay		Organic matter	
	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)
A1	2112.20	116.97	9.44	124.29	34.40	20.23	56.16	15.90	5.27	11.47
A2	757.00	46.98	24.30	83.11	31.17	29.94	44.54	30.49	5.23	39.01
A3	1082.20	140.54	1.55	95.31	36.07	24.26	62.38	13.50	4.07	26.72
A4	740.50	94.60	24.22	166.77	30.11	57.61	45.66	51.48	3.51	49.25
A5	1168.33	129.53	3.99	131.86	40.09	1.72	55.92	8.86	3.83	16.67
A6	2006.00	109.39	3.23	75.98	41.93	8.23	54.83	10.41	4.53	29.58
A7	839.67	53.29	0.63	58.87	41.36	16.26	58.02	11.25	4.00	32.67

Table 5.8a Average ($\bar{X}$ (No/m^2)) and Coefficient of Variation (C.V. (%)) of species in Areas A1 to A7 based on species distribution during pre- monsoon season

SPECIES	PRE-MONSOON													
	AREA 1		AREA 2		AREA 3		AREA 4		AREA 5		AREA 6		AREA 7	
	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)
POLYCHAETES														
Ancistrosyllis constricta	23.10	169.83	10.50	152.75	4.20	200.00	--	--	8.00	115.92	14.00	141.42	--	--
Lycastis indica	--	--	10.50	152.75	--	--	--	--	--	--	--	--	--	--
Dendronereis aestuarina	--	--	3.50	223.61	--	--	--	--	--	--	--	--	--	--
Perinereis cavifrons	141.60	280.55	7.00	141.42	--	--	7.00	223.61	--	--	--	--	--	--
Nephthys dibranchis	6.30	213.44	17.50	44.72	12.60	133.33	3.50	223.61	34.67	101.64	--	--	57.50	112.94
Diopatra neapolitana	49.90	249.53	3.50	223.61	--	--	--	--	--	--	--	--	--	--
Lumbrinereis simplex	18.90	152.75	7.00	223.61	16.80	200.00	76.33	142.99	118.00	79.34	104.67	42.90	125.00	127.14
L. notocirrata	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gonida emerita	--	--	--	--	--	--	--	--	--	--	7.00	141.42	--	--
Glycera alba	6.30	213.44	--	--	--	--	3.50	223.61	--	--	--	--	--	--
G.convoluta	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Prionospio pinnata	123.10	114.05	94.17	73.58	8.40	200.00	24.50	125.36	7.00	141.42	--	--	--	--
P. polybranchiata	--	--	--	--	12.60	133.33	--	--	--	--	--	--	--	--
Cossura coasta	--	--	3.50	223.61	4.20	200.00	3.50	223.61	69.33	70.71	42.00	40.82	52.25	82.28
Capitella capitata	8.40	229.13	7.00	223.61	--	--	--	--	--	--	--	--	--	--
Heteromastus similis	8.40	300.00	24.17	223.61	--	--	--	--	--	--	--	--	--	--
Heteromastides bifidus	--	--	24.33	187.68	--	--	3.50	223.61	--	--	--	--	--	--
Paraheteromastus tenuis	--	--	10.50	152.75	--	--	--	--	--	--	--	--	--	--
Scyphoproctus djiboutiensis	--	--	48.50	141.42	67.20	200.00	21.00	223.61	--	--	34.67	141.42	--	--
Maldanella capensis	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Owenia fusiformis	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sternaspis scutata	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pista indica	93.90	178.64	--	--	--	--	7.00	223.61	7.00	141.42	--	--	--	--
Sabellid sp.	12.60	300.00	--	--	--	--	--	--	--	--	--	--	--	--
OLIGOCHAETES														
Oligochaete sp.	56.20	153.62	24.50	31.94	--	--	14.00	223.61	7.00	141.42	--	--	--	--

Table 5.8a contd…

SPECIES	PRE-MONSOON													
	AREA 1		AREA 2		AREA 3		AREA 4		AREA 5		AREA 6		AREA 7	
	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	$\bar{X}$	C.V. (%)	($\bar{X}$)	C.V. (%)
AMPHIPODS														
Grandidierella bonneri	--	--	--	--	--	--	--	--	--	--	--	--	--	--
G. gilesi	8.40	300.00	55.50	223.61	--	--	--	--	--	--	--	--	--	--
Melita zeylanica	8.30	300.00	--	--	--	--	--	--	--	--	--	--	--	--
Quadrivisio bengalensis	37.60	264.87	20.83	223.61	--	--	--	--	--	--	--	--	--	--
Eriopisa chilkensis	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Corophium triaenonyx	837.57	242.74	409.67	221.32	8.40	200.00	--	--	--	--	--	--	--	--
TANAIDACEANS														
Apseudes chilkensis	54.20	274.60	--	--	--	--	--	--	--	--	--	--	--	--
A. gymnophobium	18.80	175.22	--	--	--	--	3.50	223.61	--	--	--	--	--	--
ISOPODS														
Isopod sp.	327.00	198.48	34.61	223.61	--	--	--	--	--	--	--	--	--	--
Anthuridae	--	--	--	--	--	--	--	--	--	--	--	--	--	--
DECAPODS														
Decapod sp.	--	--	7.00	223.61	--	--	31.33	170.82	--	--	7.00	141.42	--	--
Crab	--	--	3.50	223.61	--	--	--	--	--	--	--	--	--	--
MYSIDS														
Mysid sp.	--	--	--	--	--	--	--	--	7.00	141.42	--	--	--	--
CUMACEANS														
Cumacea sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SERGESTIDS														
Sergestid sp.	2.10	300.00	--	--	--	--	--	--	--	--	--	--	--	--
ALPHEIDS														
Alpheid sp.	2.10	300.00	--	--	--	--	7.00	223.61	--	--	--	--	--	--
OTHER CRUSTACEANS														
Barnacles	10.40	240.35	--	--	--	--	--	--	--	--	--	--	--	--
Balanus	--	--	--	--	--	--	2.50	223.61	--	--	--	--	--	--

Table 5.8a contd...

SPECIES	PRE-MONSOON													
	AREA 1		AREA 2		AREA 3		AREA 4		AREA 5		AREA 6		AREA 7	
	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)
MOLLUSCS														
Nudibranchs	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gastropod sp.	8.40	300.00	3.50	223.61	56.20	145.32	704.83	152.06	277.67	141.42	604.33	76.60	592.25	73.38
Dentalium sp.	--	--	--	--	--	--	27.83	223.61	--	--	--	--	15.75	173.21
Bivalve sp.	--	--	--	--	--	--	173.67	183.98	7.00	141.42	7.00	141.42	5.25	173.21
Cavolina sp.	--	--	--	--	--	--	--	--	--	--	--	--	5.25	173.21
Cardium sp.	--	--	--	--	--	--	--	--	--	--	--	--		
Modiolus striatulus	2252.10	286.34	--	--	--	--	--	--	--	--	--	--	--	--
Paphia papilliens	--	--	--	--	--	--	31.50	142.72	--	--	--	--	--	--
Donax sp.	8.30	300.00	3.50	223.61	--	--	--	--	--	--	--	--	--	--
FISHES														
Juvenile fish	4.20	200.00	3.50	223.61	--	--	--	--	--	--	7.00	141.42	10.50	173.21
MISCELLANEOUS GROUPS														
Amphioxus	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Foraminifera	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sea anemone	2.10	300.00	--	--	--	--	--	--	--	--	--	--	--	--
Nematodes	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Echinoderms	10.50	240.83	--	--	--	--	--	--	--	--	--	--	--	--

Table 5.8b Average ($\overline{X}$ (No./m^2)) and Coefficient of Variation (C.V.(%)) of species in Areas A1 to A7 based on species distribution during monsoon season

SPECIES	MONSOON													
	AREA 1		AREA 2		AREA 3		AREA 4		AREA 5		AREA 6		AREA 7	
	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)	$\overline{X}$	C.V. (%)
POLYCHAETES														
Ancistrosyllis constricta	61.40	171.49	11.83	124.43	4.00	122.47	291.50	100.00	--	--	--	--	3.33	141.42
Lycastis indica	3.10	300.00	6.67	223.61	--	--	--	--	--	--	--	--	--	--
Dendronereis aestuarina	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Perinereis cavifrons	29.40	156.69			4.20	200.00	15.50	100.00	132.00	141.42	3.33	141.42	7.00	141.42
Nephthys dibranchis	3.70	179.30	62.33	108.99	29.20	152.56	--	--	--	--	--	--	--	--
Diopatra neapolitana	14.60	221.40	--	--	--	--	--	--	--	--	--	--	--	--
Lumbrinereis simplex	2.10	300.00	1.67	223.61	--	--	--	--	48.67	40.21	--	--	38.67	77.48
L. notocirrata	--	--	--	--	--	--	--	--	6.67	141.42	360.67	137.50	--	--
Gonida emerita	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Glycera alba	--	--	3.33	141.42	--	--	--	--	10.00	81.65	--	--	--	--
G.convoluta	1.50	213.44	6.67	223.61	--	--	--	--	--	--	--	--	--	--
Prionospio pinnata	192.80	134.56	43.67	129.93	6.20	200.00	18.00	48.59	482.00	131.00	1625.00	103.65	708.00	64.11
P. polybranchiata	--	--	8.67	223.61	62.40	160.25	--	--	465.00	141.42	--	--	--	--
Cossura coasta	--	--	--	--	--	--	--	--	--	--	3.33	141.42	35.00	74.83
Capitella capitata	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Heteromastus similis	3.10	300.00	1.67	223.61	--	--	--	--	--	--	--	--	--	--
Heteromastides bifidus	13.40	195.66	367.83	75.85	45.80	189.27	--	--	--	--	3.33	141.42	--	--
Paraheteromastus tenuis	21.40	94.90	32.50	148.03	39.40	130.74	--	--	--	--	--	--	--	--
Scyphoproctus djiboutiensis	6.20	250.89	120.83	69.48	37.60	173.43	10.00	100.00	--	--	--	--	--	--
Maldanella capensis	9.40	266.43	--	--	--	--	--	--	6.67	141.42	--	--	--	--
Owenia fusiformis	1.00	300.00	--	--	--	--	--	--	--	--	--	--	--	--
Sternaspis scutata	--	--	--	--	--	--	--	--	10.67	141.42	--	--	--	--
Pista indica	36.40	224.17	--	--	--	--	--	--	--	--	--	--	--	--
Sabellid sp.	29.70	300.00	--	--	--	--	--	--	--	--	--	--	--	--
OLIGOCHAETES														
Oligochaete sp.	9.80	156.41	--	--	8.40	200.00	--	--	--	--	--	--	--	--

Table 5.8b contd…

SPECIES	MONSOON													
	AREA 1		AREA 2		AREA 3		AREA 4		AREA 5		AREA 6		AREA 7	
	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)
AMPHIPODS														
Grandidierella bonneri	3.10	300.00	--	--	--	--	--	--	--	--	--	--	--	--
G. gilesi	22.90	171.19	22.00	135.86	--	--	--	--	--	--	--	--	--	--
Melita zeylanica	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quadrivisio bengalensis	432.10	206.18	1.67	223.61	6.20	200.00	--	--	--	--	--	--	--	--
Eriopisa chilkensis	2.10	300.00	--	--	--	--	--	--	--	--	--	--	--	--
Corophium triaenonyx	884.30	193.69	19.00	200.99	2.00	200.00	--	--	--	--	--	--	--	--
TANAIDACEANS														
Apseudes chilkensis	39.30	219.01	--	--	2.00	200.00	--	--	--	--	--	--	--	--
A. gymnophobium	0.50	300.00	8.67	177.09	18.60	150.06	--	--	--	--	--	--	--	--
ISOPODS														
Isopod sp.	145.60	221.72	27.83	223.61	--	--	--	--	--	--	--	--	--	--
Anthuridae	--	--	3.50	223.61	--	--	--	--	--	--	--	--	--	--
DECAPODS														
Decapod sp.	2.50	204.94	3.33	141.42	--	--	--	--	6.67	141.42	--	--	3.33	141.42
Crab	7.30	202.82	--	--	--	--	--	--	--	--	--	--	--	--
MYSIDS														
Mysid sp.	--	--	--	--	2.00	200.00	10.50	100.00	--	--	--	--	--	--
CUMACEANS														
Cumacea sp.	--	--	1.67	223.61	--	--	--	--	--	--	--	--	--	--
SERGESTIDS														
Sergestid sp	8.20	207.30	1.67	223.61	--	--	5.00	100.00	--	--	--	--	--	--
ALPHEIDS														
Alpheid sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--
OTHER CRUSTACEANS														
Barnacles	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Balanus	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 5.8b contd…

SPECIES	MONSOON													
	AREA 1		AREA 2		AREA 3		AREA 4		AREA 5		AREA 6		AREA 7	
	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)	$\bar{X}$	C.V. (%)
MOLLUSCS														
Nudibranchs	1.00	300.00	--	--	--	--	--	--	--	--	--	--	--	--
Gastropod sp.	92.50	241.94	--	--	802.00	200.00	166.00	145.31	--	--	10.33	141.42	14.00	70.71
Dentalium sp.	--	--	--	--	--	--	10.50	100.00	--	--	--	--	--	--
Bivalve sp.	5.20	242.77	--	--	--	--	--	--	--	--	--	--	7.00	141.42
Cavolina sp.	1.00	300.00	--	--	--	--	--	--	--	--	--	--	--	--
Cardium sp.	--	--	--	--	--	--	10.50	100.00	--	--	--	--	--	--
Modiolus striatulus	7.30	257.60	--	--	6.00	200.00	--	--	--	--	--	--	--	--
Paphia papilliens	2.10	300.00	--	--	--	--	15.50	100.00	--	--	--	--	--	--
Donax sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--
FISHES														
Juvenile fish	15.20	138.46	--	--	6.20	134.71	--	--	--	--	--	--	--	--
MISCELLANEOUS GROUPS														
Amphioxus	--	--	--	--	--	--	--	--	--	--	--	--	3.33	141.42
Foraminifera	--	--	--	--	--	--	62.50	100.00	--	--	--	--	--	--
Sea anemone														
Nematodes	1.00	300.00	--	--	--	--	--	--	--	--	--	--	--	--
Echinoderms	--	--	--	--	--	--	--	--	--	--	--	--	--	--

5.9 **Average ($\bar{X}$ (No./m^2)) and Coefficient of Variation (C.V. (%)) for each stations in Areas A1 to A7 based on species distribution during pre- monsoon and monsoon seasons**

AREA	STATIONS	PRE-MONSOON		MONSOON	
		($\bar{X}$)	C.V. (%)	($\bar{X}$)	C.V. (%)
A1	1	354.86	112.94	77.19	141.42
	2	14.21	305.11	56.81	190.34
	3	26.79	82.28	208.83	77.48
	4	1023.96	73.38	163.94	64.11
	5	8.21	173.21	4.53	74.83
	6	11.96	173.21	7.78	141.42
	7	24.61	173.21	27.17	141.42
	8	6.00	173.21	30.92	70.71
	9	6.71	67.59	1.17	141.42
	10	1.50	33.32	8.39	141.42
A2	11	15.71	112.94	29.81	141.42
	12	9.58	273.67	48.86	289.68
	13	129.33	83.28	12.29	77.48
	14	33.08	73.38	61.52	64.11
	15	10.42	173.21	20.29	74.83
	16	11.33	173.21	43.52	141.42
A3	17	9.33	112.94	13.47	141.42
	18	2.33	282.84	52.18	155.41
	19	4.67	82.28	4.94	77.48
	20	24.22	73.38	9.18	64.11
	21	65.33	173.21	239.53	74.83
A4	22	34.94	112.94	--	--
	23	186.39	359.09	--	--
	24	61.44	82.28	82.27	141.42
	25	2.33	73.38	--	--
	26	17.39	173.21	2.82	227.87
	27	--	--	134.18	77.48
	28	79.83	173.21	4.55	64.11
A5	29	17.00	112.94	367.44	141.42
	30	106.20	230.59	18.56	151.14
	31	39.60	82.28	3.44	77.48
A6	32	48.78	112.94	8.67	141.42
	33	159.89	241.56	149.17	217.63
	34	67.22	82.28	845.17	77.48
A7	35	252.50	112.94	69.00	141.42
	36	60.38	225.71	144.70	271.34
	37	38.00	82.28	--	--
	38	81.00	73.38	33.20	77.48

Table 5.10a Correlation coefficient (r) of total benthic density with sediment characteristics during pre-monsoon in the areas A1 to A7

Parameters	A1	A2	A3	A4	A5	A6	A7
Sand (%)	-0.21	0.64	-0.37	0.74	-0.04	-0.65	-0.69
Silt (%)	-0.01	-0.03	0.21	-0.08	0.47	1.00	0.37
Clay (%)	0.24	-0.52	0.01	-0.82	-0.45	-0.26	0.37
Organic matter (%)	0.04	-0.59	-0.68	-0.76	0.63	0.58	-0.97

Table 5.10b Correlation coefficient (r) of total benthic density with sediment characteristics during monsoon in the areas A1 to A7

Parameters	A1	A2	A3	A4	A5	A6	A7
Sand (%)	0.16	0.80	-0.39	0.54	1.00	-0.08	-0.95
Silt (%)	0.04	-0.68	0.14	-0.65	-0.52	-0.57	0.27
Clay (%)	-0.25	-0.73	-0.08	-0.45	-0.99	0.38	-0.22
Organic matter (%)	0.07	-0.15	-0.52	-0.47	0.74	0.74	0.55

Table 5. 11 **Species richness (Margalef's) index (*M*), Concentration (Simpson's) index (*SI*), Diversity (Shannon Weaver's) index (*H*), Dominance (Pielou's) index (*D*) and Evenness (Heip's) index (*E*) for benthic community structure in the areas A1 to A7 during pre-monsoon and monsoon**

AREA	STATIONS	PRE-MONSOON					MONSOON				
		M	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
A1	1	4.61	0.50	1.55	1.28	0.47	7.35	0.38	1.38	0.36	0.27
	2	2.66	0.63	1.62	0.96	1.35	13.91	0.87	3.40	0.41	1.45
	3	1.60	0.57	1.35	0.97	1.44	7.72	0.40	1.19	0.75	0.18
	4	7.75	0.42	1.57	1.70	0.25	12.82	0.72	2.55	0.80	0.56
	5	6.83	0.81	2.78	1.83	2.06	7.29	0.82	2.71	0.94	2.01
	6	7.30	0.85	2.96	1.29	2.28	9.41	0.88	3.20	0.35	2.33
	7	4.87	0.68	2.09	1.12	1.18	5.39	0.23	0.89	0.33	0.20
	8	3.10	0.69	1.81	1.166	1.71	3.02	0.45	1.12	0.26	0.51
	9	4.05	0.64	1.89	0.84	1.40	--	--	--	0.52	--
	10	1.42	0.49	1.00	0.62	1.72	2.79	0.68	1.77	0.26	1.62
A2	11	5.36	0.75	2.32	1.54	0.56	8.23	0.83	2.84	0.39	1.61
	12	3.90	0.64	1.87	1.38	0.81	4.59	0.55	1.78	0.63	0.83
	13	4.62	0.37	1.16	0.31	1.24	3.82	0.34	1.08	0.72	0.49
	14	7.15	0.84	2.89	1.88	0.84	4.44	0.66	2.05	0.46	1.13
	15	4.80	0.63	1.96	1.22	1.14	1.75	0.53	1.31	0.69	1.35
	16	6.62	0.79	2.66	1.90	0.50	7.78	0.61	1.95	0.38	0.60
A3	17	1.20	0.49	1.00	1.00	--	5.85	0.70	2.23	0.43	1.39
	18	--	--	--	--	--	9.40	0.80	2.73	0.82	1.20
	19	--	--	--	--	--	1.20	0.50	1.00	0.37	1.72
	20	3.94	0.72	2.03	2.03	1.66	1.05	0.23	0.57	0.21	0.77
	21	1.66	0.54	1.26	1.26	1.27	1.28	0.03	0.12	0.05	0.07
A4	22	7.40	0.85	3.00	1.58	2.13	--	--	--	--	--
	23	1.96	0.23	0.73	0.39	0.36	--	--	--	--	--
	24	3.78	0.37	1.17	0.33	0.44	6.23	0.56	1.85	0.85	0.67
	25	1.42	0.49	1.00	0.33	1.72	--	--	--	--	--
	26	0.92	0.50	1.00	0.31	1.71	1.54	0.42	0.91	1.14	1.48
	27	--	--	--	--	--	7.27	0.68	2.11	0.82	0.72
	28	2.19	0.37	0.94	0.24	0.52	2.71	0.63	1.52	0.49	1.79
A5	29	3.10	0.43	1.17	0.98	0.75	4.58	0.63	1.70	0.64	1.53
	30	3.04	0.37	1.11	1.39	0.51	2.07	0.63	1.51	1.76	0.89
	31	3.55	0.59	1.64	2.52	1.04	1.54	0.42	0.91	1.48	1.87
A6	32	4.36	0.72	3.53	0.94	1.44	1.34	0.30	0.71	1.00	1.03
	33	2.92	0.24	1.32	0.65	0.32	1.57	0.04	0.18	1.18	0.10
	34	2.49	0.53	2.14	1.26	0.99	2.49	0.35	0.838	2.76	0.32
A7	35	2.79	0.52	1.44	0.53	0.81	2.43	0.32	0.96	0.66	0.542
	36	2.58	0.24	0.77	0.75	0.39	4.37	0.16	0.63	1.18	0.15
	37	1.86	0.43	1.07	1.184	0.970	--	--	--	--	--
	38	3.27	0.59	1.71	0.530	1.13	2.74	0.43	1.13	0.68	0.69

Table 5.12 **Station wise average ($\overline{X}$) and Coefficient of Variation (C.V. (%)) for species richness, concentration, diversity, dominance and evenness indices in the areas A1 to A7 during pre-monsoon and monsoon season**

AREA		PRE-MONSOON					MONSOON				
		M	*SI*	*H*	*D*	*E*	*M*	*SI*	*H*	*D*	*E*
A1	$\overline{X}$	4.42	0.63	1.86	1.15	1.38	6.97	0.54	1.82	0.54	0.91
	σ	2.17	0.13	0.57	0.35	0.60	4.16	0.28	1.05	0.31	0.81
	C.V. (%)	49.23	20.78	30.75	30.76	43.63	59.73	51.69	57.55	57.36	88.73
A2	$\overline{X}$	5.41	0.67	2.14	1.37	0.92	5.10	0.58	1.84	0.65	1.00
	σ	1.14	0.15	0.57	0.53	0.24	2.26	0.15	0.56	0.20	0.40
	C.V..(%)	21.04	23.09	26.43	26.42	38.92	44.22	25.19	30.76	30.76	40.00
A3	$\overline{X}$	1.36	0.35	0.86	0.86	0.93	3.76	0.45	1.33	0.49	1.03
	σ	1.45	0.30	0.78	0.78	0.78	3.36	0.29	0.10	0.36	0.57
	C.V. (%)	106.42	84.35	90.69	90.70	83.32	89.34	63.76	74.51	74.51	55.54
A4	$\overline{X}$	2.95	0.47	1.31	0.43	1.15	4.44	0.57	1.60	0.86	1.17
	σ	2.18	0.20	0.77	0.26	0.72	2.38	0.10	0.45	0.24	0.48
	C.V. (%)	73.69	41.95	58.94	58.95	62.90	53.53	17.27	28.11	28.10	41.37
A5	$\overline{X}$	3.23	0.46	1.31	1.64	0.76	2.73	0.56	1.37	1.25	1.30
	σ	0.23	0.09	0.23	0.64	0.21	1.32	0.10	0.34	0.44	0.48
	C.V. (%)	6.97	20.19	17.86	39.25	28.03	48.48	18.09	24.70	35.17	36.76
A6	$\overline{X}$	3.25	0.50	1.43	0.97	0.91	1.80	0.23	0.57	1.65	0.48
	σ	0.80	0.20	0.53	0.25	0.45	0.50	0.13	0.28	0.79	0.40
	C.V. (%)	24.60	39.52	37.02	25.62	49.63	27.61	58.14	49.67	48.08	82.01
A7	$\overline{X}$	2.62	0.44	1.25	0.8653	0.82	3.18	0.30	0.91	0.95	0.46
	σ	0.51	0.13	0.36	0.25	0.28	0.85	0.11	0.214	0.21	0.23
	C.V. (%)	19.49	29.62	28.74	28.73	38.84	16.86	35.97	22.69	22.65	50.12

Table 5.13a Niche breadth for benthic species in the areas A1 to A7 during pre-monsoon season

SPECIES	PRE-MONSOON						
	A1	A2	A3	A4	A5	A6	A7
POLYCHAETES							
Ancistrosyllis constricta	3.51	2.48	1.94	--	1.70	1.24	--
Lycastis indica	--	2.48	--	--	--	2.75	--
Dendronereis aestuarina	--	2.22	--	--	--		--
Perinereis cavifrons	1.35	2.86	--	1.67	--	--	--
Nephthys dibranchis	3.16	5.20	2.32	2.22	1.74	--	2.19
Diopatra neapolitana	1.75	2.22	--	--	--	--	--
Lumbrinereis simplex	3.94	1.67	1.28	2.31	1.95	--	1.88
L. notocirrata	--	--	--	--	--	--	--
Gonida emerita	--	--	--	--	--	1.43	--
Glycera alba	3.16	--	--	2.22	--	--	--
G.convoluta	--	--	--	--	--	--	--
Prionospio pinnata	5.44	4.30	1.52	2.88	1.43	--	--
P. polybranchiata	--		2.32	--	--	--	--
Cossura coasta	--	2.22	1.94	2.22	2.05	2.75	2.64
Capitella capitata	2.69	1.67	--	--	--	--	--
Heteromastus similis	1.70	1.22	--	--	--	--	--
Heteromastides bifidus	--	1.75	--	2.22	--	--	--
Paraheteromastus tenuis	--	2.48	--		--	--	--
Scyphoproctus djiboutiensis	--	2.17	1.08	1.25	--	1.11	--
Maldanella capensis	--	--	--	--	--	--	--
Owenia fusiformis	--	--	--	--	--	--	--
Sternaspis scutata	--	--	--	--	--	--	--
Pista indica	2.847	--	--	1.67	1.43	--	--
Sabellid sp.	1.48	--	--	--	--	--	--
OLIGOCHAETES							
Oligochaete sp.	3.47	5.74	--	1.36	1.43	--	--
AMPHIPODS							
Grandidierella bonneri	--	--	--	--	--	--	--
G. gilesi	1.70	1.11	--	--	--	--	--
Melita zeylanica	1.71	--	--	--	--	--	--
Quadrivisio bengalensis	1.63	1.25	--	--	--	--	--
Eriopisa chilkensis	--	--	--	--	--	--	--
Corophium triaenonyx	1.67	1.07	1.52	--	--	--	--

Table 5.13a contd...

SPECIES	PRE-MONSOON						
	A1	A2	A3	A4	A5	A6	A7
TANAIDACEANs							
Apseudes chilkensis	1.51						
A. gymnophobium	3.18			2.22			
ISOPODS							
Isopod sp.	2.11	1.16					
Anthuridae							
DECAPODS							
Decapod sp.		1.67		1.92		1.43	
Crab		2.22					
MYSIDS							
Mysid sp.					1.43		
CUMACEANS							
Cumacea sp.							
SERGESTIDS							
Sergestid sp	3.56						
ALPHEIDS							
Alpheid sp.	3.56			1.67			
OTHER CRUSTACEANS							
Barnacles	2.39						
Balanus				2.22			
MOLLUSCS							
Nudibranchs							
Gastropod sp.	1.70	2.22	1.88	2.14	1.08	2.46	3.16
Dentalium sp.				1.20			1.26
Bivalve sp.				1.60	1.42	1.43	1.67
Cavolina sp.							1.67
Cardium sp.							
Modiolus striatulus	1.21						
Paphia papilliens				2.23			
Donax sp.	1.71	2.22					
FISHES							
Juvenile fish	3.88	2.22				1.43	1.37
MISCELLANEOUS GROUPS							
Amphioxus							
Foraminifera							
Sea anemone	3.56						
Nematodes							
Echinoderms	2.38						

Table 5.13b Niche breadth for benthic species in the areas A1 to A7 during monsoon season

SPECIES	MONSOON						
	A 1	A 2	A 3	A 4	A 5	A 6	A 7
POLYCHAETES							
Ancistrosyllis constricta	3.65	3.11	3.11	2.03	--	--	--
Lycastis indica	2.79	1.69	--	--	--	--	1.76
Dendronereis aestuarina	--	--	--	--	--	--	
Perinereis cavifrons	3.90	--	1.94	2.29	1.04	1.76	1.43
Nephthys dibranchis	4.78	3.17	1.87	--	--	--	--
Diopatra neapolitana	2.41	--	--	--	--	--	--
Lumbrinereis simplex	3.56	3.23	--	--	2.73	--	2.02
L. notocirrata	--	--	--	--	1.44	1.11	--
Gonida emerita	--	--	--	--	--	--	--
Glycera alba	--	3.52	--	--	2.14	--	--
G.convoluta	5.96	1.69	--	--	--	--	--
Prionospio pinnata	4.91	2.69	1.67	3.56	1.23	1.68	12.44
P. polybranchiata	--	1.55	1.77	--	1.01	--	--
Cossura coasta	--	--	--	--	--	1.76	2.05
Capitella capitata	--	--	--	--	--	--	--
Heteromastus similis	2.79	3.23	--	--	--	--	--
Heteromastides bifidus	3.02	4.18	1.30	--	--	1.76	--
Paraheteromastus tenuis	6.30	2.45	2.26	--	--	--	--
Scyphoproctus djiboutiensis	2.68	4.52	1.58	2.42	--	--	--
Maldanella capensis	2.12	--	--	--	1.44	--	--
Owenia fusiformis	5.65	--	--	--	--	--	--
Sternaspis scutata	--	--	--	--	1.30	--	--
Pista indica	2.17	--	--	--	--	--	--
Sabellid sp.	1.22	--	--	--	--	--	--
OLIGOCHAETES							
Oligochaete sp.	4.51	--	1.52	--	--	--	--
AMPHIPODS							
Grandidierella bonneri	2.79	--	--	--	--	--	--
G. gilesi	3.18	2.65	--	--	--	--	--
Melita zeylanica	--	--	--	--	--	--	--
Quadrivisio bengalensis	2.13	3.23	1.67	--	--	--	--
Eriopisa chilkensis	3.56	--	--	--	--	--	--
Corophium triaenonyx	2.61	1.62	2.70	--	--	--	--

Table 5.13b contd...

SPECIES	MONSOON						
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
TANAIDACEANS							
Apseudes chilkensis	2.47	--	2.70	--	--	--	--
A. gymnophobium	7.88	2.25	2.00	--	--	--	--
ISOPODS							
Isopod sp.	2.26	1.20	--	--	--	--	--
Anthuridae	--	2.22	--	--	--	--	--
DECAPODS							
Decapod sp.	4.80	3.52	--	--	1.44	--	1.76
Crab	3.13	--	--	--	--	--	--
MYSIDS							
Mysid sp.	--	--	2.70	2.41	--	--	--
CUMACEANS							
Cumacea sp.	--	3.23	--	--	--	--	--
SERGESTIDS							
Sergestid sp	2.97	3.23	--	2.71	--	--	1.76
ALPHEIDS							
Alpheid sp.	--	--	--	--	--	--	--
OTHER CRUSTACEANS							
Barnacles	--	--	--	--	--	--	--
Balanus	--	--	--	--	--	--	--
MOLLUSCS							
Nudibranchs	5.65	--	--	--	--	--	--
Gastropod sp.	2.10	--	1.01	1.57	--	1.31	2.20
Dentalium sp.	--	--	--	2.41	--	--	--
Bivalve sp.	2.99	--	--	--	--	--	1.43
Cavolina sp.	5.65	--	--	--	--	--	
Cardium sp.	--	--	--	2.41	--	--	--
Modiolus striatulus	2.43	--	1.69	--	--	--	--
Paphia papilliens	3.56	--	--	2.30	--	--	--
Donax sp.	--	--	--	--	--	--	--
FISHES							
Juvenile fish	4.42	--	2.63	--	--	--	--
MISCELLANEOUS GROUPS							
Amphioxus	--	--	--	--	--	--	1.76
Foraminifera	--	--	--	2.09	--	--	--
Sea anemone	--	--	--	--	--	--	--
Nematodes	5.65	--	--	--	--	--	--
Echinoderms	--	--	--	--	--	--	--

able 5.14a **Q-Mode factor analysis for grouping the stations in the areas A1 to A7 during pre-monsoon season**

REA	FACTOR	STATIONS	RANGE OF FACTOR LOADING	EIGEN VALUE	CLOSENESS RATIO	VARIANCE VALUE	VARIANCE %
A1	1	2, 3, 5, 7	-0.80 to -0.98	4.15	41.46	3.65	36.48
	2	4, 9	0.98 to 0.98	2.01	61.56	1.94	19.38
	3	6	-0.97	1.17	73.28	1.07	10.70
	4	8	100	1.06	83.86	1.06	10.62
A2	1	2, 6	0.73 to 0.95	2.99	49.87	1.69	28.12
	2	1, 5	-0.88 to -0.99	1.31	71.75	1.81	30.24
	3	3	1.0	1.03	88.47	1.00	16.70
	4	4	0.93	0.46	96.07	1.09	18.20
A4	1	2, 5, 6	-0.85 to -0.994	2.82	47.01	2.69	44.82
	2	4	-1.00	1.08	64.99	1.15	19.1578
	3	1	1.00	1.03	82.18	1.00	16.67
	4	3	-1.00	0.95	98.03	1.00	16.71

Table 5.14b **Q-Mode factor analysis for grouping the stations in the areas A1 to A7 during monsoon season**

AREA	FACTOR	STATIONS	RANGE OF FACTOR LOADING	EIGEN VALUE	CLOSENESS RATIO	VARIANCE VALUE	VARIANCE %
A1	1	7, 9	-0.93 to -0.94	3.81	38.08	2.15	21.52
	2	1,3	0.96 to 0.99	2.22	60.33	2.00	20.03
	3	6	0.93	0.97	70.01	1.02	10.22
	4	8	'-0.97	0.83	78.33	1.02	10.16
	5	4	0.96	0.74	85.74	1.02	10.16
	6	10	-0.94	0.61	91.79	0.98	9.78
A2	1	2, 3, 4, 6	-0.93 to -0.98	4.17	69.41	3.77	62.87
	2	5	-0.99	1.45	93.61	1.47	24.46
	3	1	0.69	0.22	97.26	0.59	9.78
A3	1	2,3	0.83 to 0.88	1.51	30.27	1.47	29.383
	2	4	1.00	1.01	50.52	1.00	20.06
	3	1	-0.98	1.00	70.52	1.04	20.83
	4	5	-1.00	0.99	90.27	1.00	20.00

CHAPTER 6

BENTHIC PRODUCTION AND FISHERY POTENTIAL

6.1 INTRODUCTION

The brackish water as biotic niche is highly dynamic and productive and is characterised by rich, varied and distinct biological entities, which can tolerate the extremely fluctuating physico-chemical features of this environment. Thus a characteristic type of fish population has developed in each brackish water system on which the commercial fisheries are based. Demand for protein rich food sources is rising exponentially with the rapid and accelerating increase in human population. Brackish water fishery resources can contribute a lot to this requirement.

Benthic organisms form an important link in the food chain at different trophic levels. Between the primary production and the fish production, the role of benthic organisms first as a feeder of detritus and plant material and in turn forming food of some predators like crabs and fishes is now well recognized. This concept of bottom communities received little attention until last five decades. The investigations of Belegvad (1930), Jones (1950, 1951, and 1956) and Mulicki (1957) have thrown new light on the importance of benthic communities. Belegvad (1930) for the first time showed a direct connection between the variations in the quantity of benthic biomass and pelagic fishery. A detailed knowledge of the food and feeding habits of fishes of any water body is highly desirable to define the fishery potential. However, distinguishing selective and generalized feeding habits pose problems (Graham, 1956) and benthic food resources available to bottom feeders can on occasions be accessible to pelagic stock also (Prasad, 1966). Qasim (1977) has given the estimated fish yield for the Indian Ocean (between lat. 26°N to 4°S and long. 30°E to 125°E) to be 15-17 million tonnes with India's share to be around 46% or 7.36 million tonnes. He has estimated 14% or 1.03 million tonnes out of the total 7.36 million tonnes to come from the demersal sources. Parulekar *et al.* (1982) estimated the potential demersal fish and crustacean resources of the Indian continental shelf based on the benthic productivity to be 1.2 million tonnes as against the exploited value of 0.45 million tonnes/yr. The marine fish production in

India during 1999 has been provisionally estimated to be 2.42million tones. The pelagic group formed 52.9% of the total landings and demersal finfish, crustaceans and molluscs together contributed 47.1% (Kurup *et al.*, 2000).

Madhusoodhanakurup (1982) has given the faunestic list of demersal fishes in Vembanad lake which includes *Dasyatis uarnak* and *D. sephen* (rays), *Anquilla bicolor, Thyrsoidea macrurus, Muraenesox bagio and Pisoodonophis boro* (eels), *Tachysurus maculatus, T. subrostratus, Saurida undosquamis, Austrobatrachus dussumieri, Platycephalus indicus, P.crocodilus, Epinephelus tauvina, Therapon iarbua, Lutianus johni, L. argentimasculatus, Etroplus suratensis, E. maculatus, Valamugil speicleri, Liza macrolepis,Eleotris fusca, Pseudorhombus arsius, Solea ovata, Synaptura commersoniana, Tetraodon fluviatilis and T. leopardus*. The author has highlighted the importance of bottom fauna as a main food source for various species of fishes in the Vembanad Lake. The analysis of the gut content of *Daysciaena albida* and *G. filamentosus* showed the presence of filamentous algae and diatoms, benthic organisms like crabs, amphipods, isopods, bivalves, polychaetes and juveniles of bottom dwelling fishes like *Trypauchen* sp. and *Cynoglossus* sp. He further stated that the size of the food consumed by the fish increases with an increase in size of the fish. This can be confirmed by noting the fact that smaller planktonic food items were found in appreciable quantities in the gut of juvenile fishes. In addition to amphipods and isopods, polychaetes were also found to be consumed in high amounts by the adult fishes. Moreover, juvenile crabs, bivalves, molluscs and detritus were also encountered in appreciable percentage.

For past two decades a number of reports on the benthos of Indian Ocean have appeared. Most of them pertains to the regional studies on macrobenthos and quite a year (Kurian, 1971; Savich, 1972; Damodaran, 1973 and Harkantra *et al*, 1980) have attempted to correlate the benthic standing crop as an indication of the potential resources of demersal fish and prawns. A number of estimates about the tertiary potential including demersal resources from the Indian Ocean are available (Prasad *et al*, 1970; Jones and Banerji, 1973; Qasim, 1977; Desai *et al*, 1990 and Krishnamoorthy *et al*, 1999). All these workers have estimated the fishery potential based on primary productivity and secondary production or on the exploratory fish survey data and calculated tertiary production either as 0.1% of primary production or 10% of secondary production (Cushing, 1971 & 1973). As far as demersal resources are concerned the benthic biomass as rightly pointed out by Moiseev (1971) is the more valid parameter for projecting the potential demersal fish (including the crustacean and molluscs). Madhupratap *et al* (1977 & 1993) have calculated the tertiary production from secondary production for the Kerala backwaters from Azhikode to Alleppey. Parulekar *et al* (1980) have given an account of benthic production and the trophic relations of Goa estuaries. Parulekar et al., 1982, carried out the assessment of demersal fishery resources of the Indian seas based on benthic standing stock. Madhusoodhanakurup *et al.* (1993) have given an account of the exploited fishery resources of the Vembanad Lake. The present study tries to focus on the demersal fish resources based on benthic production.

6.2 MATERIALS AND METHODS

Quantitative study on benthos and its possible relationship with the demersal living resources in the Cochin backwaters are examined. The data on biomass and carbon production obtained during the course of the present study are analysed for quantifying the potential fishery resources. Organic carbon equivalent for the benthic biomass was determined by the procedure of Lie (1968) and productivity estimates were made as per the methodology of Sanders (1956) and Crisp (1979). Annual biomass production is calculated as twice the standing stock (Harkantra and Parulekar, 1994) The potential yield is taken as the 10% of the benthic standing stock (Parulekar *et al.*, 1982). (See chapter 2 for details).

6.3 RESULTS (Tables 6.1 - 6.4)

In the southern limb the maximum production in terms of carbon and biomass production was noticed at station 3 and the values were 5854.06 $gC/m^2/y$ and 77128.52 $g/m^2/y$ respectively followed by station 4 and the corresponding values were 84.04 $gC/m^2/y$ and 1107.18 $g/m^2/y$ (Table 6.1). Station 1 and 2 showed negligible biomass and hence these stations showed the annual carbon production ($gC/m^2/y$) and biomass production ($g/m^2/y$) of <1. At station 5 the production in terms of carbon was 1.06 $gC/m^2/y$ and biomass production was 14.04 $g/m^2/y$. In the area towards southern limb the annual benthic production in terms of carbon and biomass production were 994.78 $gC/m^2/y$ and 13106.50 $g/m^2/y$ respectively (Table 6.4).

In the northern limb area, which is 25 km upstream towards north from barmouth, the maximum production occurred at station 8 and here an annual carbon production of 2.58 $gC/m^2/y$ was noticed and the annual biomass production was 33.94 $g/m^2/y$. Stations 6 & 7 showed the annual carbon productions of 0.74 $gC/m^2/y$ and 0.90 $gC/m^2/y$ respectively and the corresponding biomass productions were 10.00 $g/m^2/y$ and 11.80 $g/m^2/y$. At stations 9 to 13 the annual carbon productions were 0.78, 0.18, 0.24, 1.06 and 0.54 $gC/m^2/y$ respectively and the corresponding biomass productions were 10.38, 2.38, 3.28, 14.08 and 7.06 $g/m^2/y$ (Table 6.1). In this area an annual carbon production of 4.06 $gC/m^2/y$ and a biomass production of 53.46 $g/m^2/y$ were observed (Table 6.4).

In the barmouth (stn. 14) the annual carbon production was 29.46 $gC/m^2/y$ and the biomass production was 388.28 $g/m^2/y$ (Table 6.1). The biomass of stn. 14 is incorporated with both northern and southern limb areas for calculating the annual production in terms of carbon and biomass production and in turn for the calculation of fishery potential.

For the mangrove area the maximum production was observed at station 5 followed by P6 and P3. The production in terms of carbon at station P1 to P6 was 2.08, 2.04, 3.60, 1.54, 3.90 and 3.66 $gC/m^2/y$ and the corresponding biomass production was 27.28, 27.02, 47.46, 20.22, 51.48 and 48.06 $g/m^2/y$ respectively (Table 6.2). In this area the annual carbon production and biomass production was 2.80 $gC/m^2/y$ and 36.92 $g/m^2/y$ respectively (Table 6.4).

In the area of dredging and disposal site (130 km^2) the maximum carbon production and biomass production were in the area A4 followed by A7 (Table 6.3). The annual carbon production in the area A1 to A7 was 4.76, 1.84, 1.34, 15.72, 5.02, 2.96 and 7.32 $gC/m^2/y$ respectively and the corresponding biomass production was

62.56, 24.32, 17.76, 207.08, 66.08, 38.98 and 96.40 g/m^2/y respectively. In this area a mean biomass of 36.66 g/m^2 was noticed and the annual carbon production and biomass production were 5.56 gC/m^2/y and 73.32 g/m^2/y (Table 6.4).

Considering all these values and taking the potential yield as 10% of the benthic standing crop the potential yield is calculated as 1310650 kg/km^2 in the southern limb area from barmouth, 5350 kg/km^2 in the northern limb area from the barmouth, 3690 kg/km^2 from the Puduvypin area and 7330 kg/km^2 from the dredging and disposal site.

6.4 DISCUSSION

The maximum benthic production and potential were observed in the southern limb and this may be due to the high biomass obtained at station 3 and 4. At station 3 a large number of small gastropods were obtained and these were considered to be consumed by higher forms and a potential contributor to the next trophic level. At station 4, the high biomass obtained was due to the presence of the bivalve sp., *Villorita cyprinoides* (with maximum size of 2.1 - 3.7 long, 1.8 - 3.3 broad and with a height of 1.2 - 2.3 cm) obtained throughout the observation period, which are considered to be subsistence fishery resource.

In the northern limb the high values obtained at station 8 were due to the presence of tube dwelling polychaetes and at station 12 it was due to the occurrence of polychaetes in large numbers. At the barmouth also the gastropods obtained for which only the viable components, which are transferred to the next trophic levels, are considered.

The mangrove area also supports a good potential for fishery resources. The maximum potential was obtained in the dredging and disposal site and this may be due to fresh recruits from adjacent area leading to recolonisation of a rich / healthy benthic community.

The fishery potential estimated based on the benthic productivity was compared with the earlier data (Saraladevi, 1986) to evaluate the change in the production potential over the years. The estimated fishery potential in the barmouth for the previous and present investigation is comparable probably due to limited build up of pollutants due to effective flushing and dilution. However, along the industrially polluted northern limb, the fishery potential reduced by a factor of 2.

The primary sources of food for the benthos in shallow waters are the algae plant and terrigenous organic detritus. In most areas, grazed or unutilized surplus of plankton in overlying water is the chief source of nutrition and high benthic productivity depends upon their presence. Detritus and bacteria also form important food resources as they can be carried to greater distances by water currents. Sponges, pelecypods and brachiopods feed mainly on detritus. Polychaetes on the other hand are mainly deposit feeders. They are common in mud and muddy sands, where as the suspension feeders are more common in sandy gravel.

Primary producers occupy the base of the ecological pyramids, which produce organic matter with the help of nutrients and sunlight. They form the food of herbivorous planktonic forms, which in active stage are fed upon by carnivorous planktonic forms and as detritus by benthic organisms. The macrobenthic infauna is dominated by polychaete-bivalve combination, which are filter feeders and therefore mainly subsist on the particulate matter in the water column. Productivity of benthos is presumably related to the primary productivity of the overlying water column (Lie, 1968). The herbivorous and carnivorous planktonic and some of the benthic forms together occupy the second stage in the ecological pyramid. They in turn form the food of the higher carnivores including fishes, which are the tertiary producers. Thus, it is evident that benthos is a very important link in the food chain and any reduction in benthic productivity may adversely affect the demersal fishery.

Direct relevance of benthic standing crop and production to the exploited demersal fishes and crustacean resources is by now, a well-established fact (Kurian, 1971; Savich, 1972; Damodaran, 1973 and Harkantra *et al.*, 1980).

For Mandovi, Cumbarjuna canal and Zuari estuaries, the observed macrobenthic standing stock was 4.08 $gC/m^2/y$ and hence the estimated annual production was 8.16 $gC/m^2/y$ (Parulekar *et al.*, 1982). The annual yield of fishes and crustaceans from Vembanad lake was estimated as 7202.1 tonnes and the average yield / ha as 342.14kg (Madhusoodhanakurup *et al.*, 1993).

The fish seed recruitment details and related aspects of the mangrove ecosystem of Puduvypin have been already been described (Purushan, 1989). Thus there is an abundance of fish seed resources at Puduvypin. Needless to say that immense scope lies for taking up farming of *Chanos chanos* and mullets in large areas exclusively depending upon their natural seed availability. *Tilapia* seems to be having great potential because of its better conversion ratio quickly reaching appreciable size within a short period at this brackish water habitat.

Despite availability of seed resources of potential, brackish water fish farming still has not attained the required momentum in the area. However farmers transport the seed during season to long distances for culture purposes elsewhere and obtain higher yields. Identification of core areas of occurrence of benthic forms preferentially fed upon like tanaidaceans and soft-shelled forms can be of potential value in this regard. Dredging of the areas near prawn bed is suggested to have seriously affected the food sources and disappearances of prawn from the normal habitat may be the result of this action, apart from other causes if any (Desai, 1973).

Table 6.1 Benthic biomass and annual production at stations 1 to 14.

Stations	Mean biomass Wet wt. (g/m^2)	Mean biomass Dry wt. (g/m^2)	Carbon content (gC/m^2)	Annual carbon production, Mean (gC/m^2/y)	Annual biomass production (g/m^2/y)
1	0.15	0.03	0.01	0.02	0.30
2	0.34	0.07	0.03	0.06	0.68
3	38564.26	8484.14	2927.03	5854.06	77128.52
4	553.59	121.79	42.02	84.04	1107.18
5	7.02	1.54	0.53	1.06	14.04
6	5.00	1.10	0.37	0.74	10.00
7	5.94	1.31	0.45	0.90	11.88
8	16.97	3.73	1.29	2.58	33.94
9	5.09	1.12	0.39	0.78	10.18
10	1.19	0.26	0.09	0.18	2.38
11	1.64	0.36	0.12	0.24	3.28
12	7.04	1.55	0.53	1.06	14.08
13	3.53	0.78	0.27	0.54	7.06
14	194.14	42.71	14.73	29.46	388.28

Table 6.2 Benthic biomass and annual production at stations P1 to P6

Stations	Mean biomass Wet wt. (g/m^2)	Mean biomass Dry wt. (g/m^2)	Carbon content (gC/m^2)	Annual carbon production, Mean (gC/m^2/y)	Annual biomass production (g/m^2/y)
P1	13.64	3.00	1.04	2.08	27.28
P2	13.51	2.97	1.02	2.04	27.02
P3	23.73	5.22	1.80	3.60	47.46
P4	10.11	2.22	0.77	1.54	20.22
P5	25.74	5.66	1.95	3.90	51.48
P6	24.03	5.29	1.83	3.66	48.06

Table 6.3 Benthic biomass and annual production in the areas A1 to A7.

Stations	Mean biomass Wet wt. (g/m^2)	Mean biomass Dry wt. (g/m^2)	Carbon content (gC/m^2)	Annual carbon production, Mean (gC/m^2/y)	Annual biomass production (g/m^2/y)
A1	31.28	6.88	2.38	4.76	62.56
A2	12.16	2.68	0.92	1.84	24.32
A3	8.88	1.95	0.67	1.34	17.76
A4	103.54	22.78	7.86	15.72	207.08
A5	33.04	7.27	2.51	5.02	66.08
A6	19.47	4.29	1.48	2.96	38.98
A7	48.20	10.60	3.66	7.32	96.40

'able 6.4 **Benthic biomass, annual production and potential yield from 4 different areas**

Areas	Mean biomass Wet wt. (g/m^2)	Mean biomass Dry wt. (g/m^2)	Carbon content (gC/m^2)	Annual carbon production, Mean ($gC/m^2/y$)	Annual biomass production ($g/m^2/y$)	Potential Yield (Kg/km^2)
Southern limb (including barmouth) (5 km^2)	6553.25	1441.72	497.39	994.78	13106.50	1310650
Northern limb (including barmouth) (5 km^2)	26.73	5.88	2.03	4.06	53.46	5350
Mangroves (0.025 km^2)	18.46	4.06	1.40	2.80	36.92	3690
Dredging and disposal site (130 km^2)	36.66	8.07	2.78	5.56	73.32	7330

CHAPTER 7

SUMMARY

Benthic productivity is of importance in assessing the biological production potential of any aquatic environment. It is well recognized that the distribution and abundance of benthic animals of a region are directly linked to the fishery of that particular area. Benthos, being an important source of food for demersal fishes, can serve as a reliable index of the fish stocks. Benthic population is also considered as an essential tool for pollution monitoring, since benthic fauna reflect the integrated effect of stress more effectively due to their sedentary habits. Because of the relative abundance of food and the shallowness of the estuaries benthic production in estuaries is quite high compared to other aquatic habitats.

For traditional fishing and aquaculture in the coastal areas, maintenance of water quality is very important. A proper understanding of the environmental parameters and their effects on biota is hence a pre-requisite for the management of any ecosystem. Benthic fauna has a direct relationship with the type of the bottom and the physical nature of the substratum, which also acts as a controlling factor to a considerable extent. Benthos, therefore, may be treated as sensitive indicators of pollution and shows the extent of accumulation of organic matter in sediments.

Considering the importance of benthos, an attempt has been made to study the composition, distribution, abundance and diversity of the components in relation to the environmental parameters in three different environments. Before this only one attempt has been made to study the overall effects of industrial pollution on benthos and water quality. That study aforesaid was undertaken in 1981 and covered the northern limb of Cochin backwaters, which forms a part of the present area. The data obtained during 1996 – 1997 is examined against the backdrop of this available information and applied to evaluate the changes over a period of 15 years on benthic communities in a system subjected to ongoing stress from industrial effluents. The environments selected were (1) the industrial and sewage effluent discharge sites of Cochin backwaters, (2) the mangrove ecosystem of Puduvypin and (3) the dredging and disposal site of Cochin Port Trust area. The data generated will be helpful in

assessing the present status of benthic productivity of this vital ecosystem and can be utilized for ecological monitoring and future evaluations.

The thesis is presented in 7 chapters. The first chapter gives a general introduction to the topic and describes the different types of benthos, their adaptations, food and feeding, benthic productivity, economic importance, pollution stress and also highlights the scope and purpose of the present study.

The second chapter is on the materials and methods, which covers the methodology adopted for the collection and analysis of benthic fauna, water and sediment samples from the three different environments and also the methods for statistical interpretation.

The third chapter comprises of the study of these environments in the Cochin backwaters for a period of one year (June 1996 to May 1997). Fourteen stations along the northern and southern limbs of Cochin backwaters upto a distance of 25km upstream were selected. The stations 1, 2, 11 and 13 are located near the discharge sites of industrial effluents in the southern and northern limbs respectively and stations 6 and 7 are at the sewage discharge site. Barmouth (station 14) is treated as a reference station.

The results of the physico-chemical parameters highlight the effects of pollution. The physico-chemical aspects deal with the spatial and temporal variations of the 16 environmental parameters studied (Temperature, Salinity, pH, dissolved oxygen, BOD_5, nitrite, nitrate, ammonia, phosphate, chlorophyll `a', particulate organic carbon, suspended load, attenuation coefficient, sediment characteristics, organic carbon and energy content). The results of the study indicated the changes due to the large-scale movements of the estuarine water under the influence of tide, monsoon and land runoff coupled with its heterogenous nature owing to the effluent discharge from the industries.

The vertical gradient in temperature and salinity was very less for the entire area and this is due to the shallow-nature of the estuary as also reported by earlier workers. The general drop in salinity to near freshwater conditions observed during monsoon is due to the dilution by large amount of freshwater influx while the differences in the surface and bottom salinity is caused by the tidal influence creating a two-layered flow. Variations in the pH due to chemical and other industrial discharges render a stream unsuitable not only for recreational purposes but also for the rearing of fish and other aquatic life. The observed wide variation in pH in the northern and southern limbs can be attributed to the intermittent discharge of effluents from the chemical factories. The fairly steady pH values at stations 5 to 7 and 14 are governed by the influence of seawater intrusion.

In general high dissolved oxygen values were noticed during the study and the results are comparable with the results reported earlier for the estuarine and coastal waters. The low BOD_5 values noted in the area may be due to the efficient breakdown of organic matter in presence of high oxygen content, tidal dilution and significant contribution from inorganic sources to the total waste load discharged.

The high values of nitrite are to be seen against higher values of ammonia at the effluent discharge sites of the southern limb and the phytoplankton abundance during the preceding months. Nitrate concentration with abnormally high value indicates the external addition of some effluents rich in nitrogenous compounds into the estuary, by the agricultural runoff and municipal sewage. The maximum concentration of ammonia (167.56 µmol/l) at station 1 was observed in the southern limb. which decreased towards downstream. The northern limb registered a maximum (116.06µmol/l) at station 12. In the sewage discharge site and barmouth, the values were <25µmol/l. The high concentration of ammonia at stations located near the effluent discharge point may be due to the oxidation of ammonia. which is reported to be slow in relatively polluted waters. Phosphate concentration was high in the southern limb (1.36 to 150.70µmol/l) compared to other stations. The low values noticed during monsoon period can be explained by the combined effect of dilution of estuarine water by riverine freshwater containing low phosphate and removal by adsorption caused by the influx of silt laden freshwater. The high values in the southern limb may be attributed by the influence of industrial effluents from the plants producing phosphate fertilizers. High concentration of phosphate was followed by an abundance of phytoplankton and the subsequent decrease in the concentration of phosphate may presumably be due to its utilization by phytoplankton.

Stations in the southern limb showed high chlorophyll `a' values compared to other areas. Maximum value of 151.83 mg/m^3 was noticed at station 2. The phytoplankton abundance noticed in the southern limb may be due to the effect of nitrogenous effluents discharged near the area. No definite pattern was observed in the temporal and spatial distribution of particulate organic carbon and the values were comparatively high in the southern limb.

The increased turbulence during monsoon and high particulate matter associated with the land run off results in the substantial increase in the suspended load and the values exceeding 200mg/l were commonly observed. Generally high attenuation coefficient (`K' value) was noticed in the monsoon months (1.5 to 15.0 in July) and rest of the months showed values <5. High `K' values were noticed during the study compared to earlier reports and this may be due to the ongoing changes in the system.

The substratum of the study area exhibited a varied textural type with a mixture of sand, silt and clay combinations. The concentration of organic matter at different stations depended upon the sediment texture and the values increased with proportion of finer fractions. The observed peak value in the monsoon month could be attributed to the influx of land run off containing considerable amounts of terrigenous matter and the deposits of planktonic matter, which sink to the bottom. Energy content of the study area varied from 12.96 to 2286.79 J/g, which is lower than the reported values for retting yards of Cochin backwaters and Ashtamudi estuary, receiving high organic loads.

In general water quality of the study area revealed fluctuating values for all the parameters possibly due to the intermittent release of the effluents from the industries located upstream in both limbs of Cochin backwater and the prevailing natural flow of dilution water throughout the investigation period.

The distribution pattern of bottom fauna exhibited considerable variations both quantitatively and qualitatively at different stations of the study area. The results revealed a progressive reduction in number of taxa/species from the mouth of the estuary to upstream stations. The difference in biomass and density in estuaries is often attributed to seasonal variations, migration, food availability, reproduction, recruitment etc. The existence of "alternative pathways for utilization of excess basic food material available in Cochin backwaters" propounded and quoted in previous studies by various authors is valid in the present context also.

Benthic productivity in terms of density and biomass was very low in the upstream stations, located near the industrial complex. Maximum number of 1020064 specimens with a biomass of 462771.17g was collected from station 3 during the investigation. This was contributed by a single species of gastropod. Second peak in density (831558) was observed at barmouth with a variety of faunal groups.

No definite pattern of variation was observed between seasons at the different stations. Seasonal averages showed high values during pre-monsoon at stns. 3 & 4. Stations 5 to 9 recorded high numbers during monsoon and stns. 12 and 14 showed high numbers during post-monsoon. Organisms were absent at station 1 during monsoon, Stn. 2 during pre-monsoon and post-monsoon, stn. 10 during post-monsoon, station 11 during pre-monsoon and monsoon and station 13 during pre-monsoon.

A total of 14 groups were encountered during the study and the number of groups at different stations varied from 1 (station 1) to 11 (stations 9 & 4). The number of groups encountered at other stations were 2 groups at stations 2, 11,12 and 13; 4 groups at station 10; 6 groups at stations 3. 8 groups at stations 6 & 8; 9 groups at stations 5 & 7 and 10 groups at station 4.

A total of 91 species / genus / families belonging to 14 groups were encountered during the study. Polychaetes formed the dominant and common group constituted by 54 species from 19 families. Second dominant group amphipods contributed 7 species. Only 2 species, each were noticed under tanaidaceans and isopods. Three species were recorded under decapods, one species under mysids and one species under cumaceans. Gastropods and bivalves were represented by 5 and 8 species and insects were represented by 4 species. Rare occurrence of juvenile fishes and flat worms were also noticed.

Polychaetes dominated at all stations except at stns. 3 & 14, where gastropods and amphipods dominated respectively. Station 6 recorded maximum number (29) of polychaete species followed by station 7 and 8 (27). Stations 5, 4 and 9 showed 20 to 23 species, barmouth registered 18 species and 9 species were recorded from stn.13. In rest of the stations the number of species was less varying from 1 to 6.

Low diversity and higher population density of a few organisms denote stress condition, which practically eliminate many species but promote survival of a few. Contrary to this high diversity and lesser relative dominance of individual species characterise areas of relative environmental stability. Low diversity and lower number of fauna at the upstream stations during the study indicate stress conditions and the effect were reduced slowly towards downstream because of dilution and hence the increased diversity was observed.

The faunal composition exhibited a different picture in the sewage discharge area in having high benthic faunal density and diversity. The increasing dominance of polychaetes in this region suggests that the environment is receiving higher organic load by sewage discharge. Of the nine groups encountered from this area, polychaetes, represented by 29 species, dominated and contributed to more than 75% of the bottom fauna. A total of 53 species belonging to different groups were recorded from the sewage area.

The presence of large numbers of gastropod sp. at station 3 and the commercially important bivalve species, *Villorita cyprinoides* at station 4 contributed to the high biomass noticed at these stations. The spatial distribution of bivalves suggests that an increase in salinity is more conducive than the substratum.

Temporal and spatial variations in the different environmental parameters noticed here are thus reflected in the qualitative and quantitative distribution of the bottom fauna.

In general the study revealed stress and localised impact of industrial waste on the biota, predominance of stress tolerant species and low diversity in the vicinity of the effluent discharge point. These studies on impact of environmental parameters on the distribution of macrobenthos thus indicate the quantum of endurance warranted by the infauna to tide over the wide range of environmental stress. Low diversity and lower number of benthic fauna near discharge site can be attributed to the stress caused by cumulative toxic effects of effluents.

Species diversity was least at station 1 showing the presence of a single species. At station 2 only 3 species occurred showing low richness of 2.39. In the other stations the index varied from 0.67 (station 4) to 12.47 (station 7). The seasonal average richness of the 14 stations varied from 1.65 (station 3) to 7.60 (station 6). At station 4 to 9, the range for richness index was between 5.19 (station 5) and 7.60 (station 9). Species concentration factor measured by Simpson's index was very low at station 3. In other stations it varied from 0.16 (station 4) to 0.89 (station 6). The average distribution of the concentration factor was least (0.61) at station 4 and highest (0.80) at station 6. Species diversity index was < 1 at stations 3 and 14. In other stations it ranged between 0.50 (station 8) and 4.85 (station 7). The temporal distributional variability of diversity was higher at stations 4 to 9. Seasonal average of species diversity was least (2.04) at station 4 and maximum (2.85) at station 6. Species dominance index recorded a wide range (0.06 to 5.48) at stations 1 to 14. The temporal average distribution of species dominance in the effluent discharge area varied between 0.67 (station 5) and 0.88 (station 6). Species dominance index was distributed with high values at station 4 and station 6 and reduced with a small gradient from stations 6 to 9. On comparing the various seasons for species evenness index high values were observed at stations 5, 6, 8 and 14. At station 8, high venness in distribution was observed in early post-monsoon. The statistical distribution of Heip's equitability coefficient showed a steady increase from station 3 (0.07) to station 6 (1.92), thereafter decreased to 1.06 at station 7. At station 14 there was a clear-cut change in the environmental conditions as indicated by low uniformity during June to October and nearly 4 times uniformity during November to May.

At station 1, *Capitella capitata* has moderate correlation with sand (r = 0.40) with a niche breadth of 3.54. At station 2, this species showed very low niche breadth and high correlation with organic matter and moderate correlation with clay. *Branchiocapitella singularis* and *Littorina littorea* have a niche breadth of 1.91 and 1.16. and were controlled by the same parameters. Station 3 with 14 species had maximum niche breath (6.32) for *Lycastis indica* and was moderately controlled by suspended load and for *Prionospio polybranchiata* the niche breadth was 6.16 having high correlation with salinity and temperature had only low niche breadth (3.83). *Villorita cyprinoides* having very low correlation with ammonia and niche breadth of 2.64 indicated that at this station higher niche breadth was followed by lower abundance and low variability. Of the 40 species at station 4 the niche breadth varied between 1.18 (*Nucula* sp.) and 7.33 (*Villorita cyprinoides*) and these species were highly correlated with dissolved oxygen, nutrients, suspended load and silt.

Of the 37 species at station 5, 4 were moderately abundant and showed a niche breadth between 1.41 (*Diopatra neapolitana*) and 8.05 (*Ancistrosyllis constricta)* and was highly correlated with nitrate dissolved oxygen and organic matter. Station 6, with 44 species. the niche breadth ranged between 1.52 (*Scolelepis indica)* and 8.04 (*Ancistrosyllis constricta*) and they were moderately related to most of the parameters.

Of the 40 species recorded from station 7, the niche breadth ranged between 1.69 (Oligochaete sp.) and 6.98 (*Ancistrosyllis constricta)* and they were controlled by salinity, temperature, nitrite, suspended load, sand and silt. The niche breadth of the 44 species at station 8 ranged between 1.34 (*Prionospio cirrobranchiata)* and 6.55 *(Prionospio polybranchiata)* and was highly correlated with nutrients, temperature, sand, and particulate organic carbon. Among the 40 species at station 9, *Prionospio polybranchiata, Pendora flexosa Quadrivisio bengalensis, Dendronereis aestuarina Notomastus aberans and Heteromastides bifidus) were* abundant and their niche breadth were 4.05, 2.06. 2.22, 8.09, 1.26 and 6.34 respectively and were highly correlated with ammonia and sand, with nitrite, with salinity, with ammonia and clay, with nitrite and suspended load and silt respectively.

At station 11 with 4 species, all rare had low niche breadth for *Dendronereis aestuarina* and *Prionospio polybranchiata* both having high correlation with salinity and organic matter. Station 14, showed 37 species of which the *Grandidierella gilesi, Quadrivisio bengalensis* and *Eriopisa chilkensis* were controlled by clay and Corophium triaenonyx, Apseudes gymnophobium and Cirrolinia fluviatilis were controlled by suspended load. In this station niche breadth varied between 1.09 (Mysid sp) and 5.62 (*Diopatra neapolitana*). All abundant species have very low niche breadth indicating an inverse relation between species abundance and niche breadth.

In the effluent discharge area the 14 stations were classified into 6 groups depending on the distance from the discharge sites on both limbs. The 6 groups were (1) stations 1, 2 and 3 (2) stations 4 and 5 (3) stations 6 and 7 (4) stations 8 and 9 (5) stations 10, 11, 12 and 13 and (6) station 14.

At stations 1, 2, and 3 the most important parameter combinations were nitrite, phosphate, silt and clay. Eight parameters viz., temperature, nitrite, ammonia, phosphate, organic matter, sand, silt and clay; predict the benthic density of these stations with 69.01% explained variability. All the model parameters, particularly the first three were highly significant (P = < 0.05) and the last one was statistically insignificant and hence need not be considered in the future prediction for benthic density in this area. At stations 4 and 5, the best set of parameters obtained was salinity, phosphate, ammonia, organic matter, sand and suspended load. The model parameters were ranked according to the relative importance. For predicting the benthic density at stations 6 and 7, the parameters temperature, nitrite, ammonia, organic matter particulate organic carbon, sand and clay were selected depending on the comparatively high correlation of these parameters with total benthic density. This model could explain about 93.4% of the spatial as well as temporal variation in the benthic density distribution and all the parameters are significant ($P<0.05$) in predicting the benthic production. At stations 8 and 9 depending on the linear correlation between total density and parameters, like temperature salinity, phosphate, nitrate, organic matter, silt and clay were selected for the model and explained 94.44% of the spatial and temporal variations in the benthic density. At stations 10 to 13 depending on the benthic density and parameter correlation, the factors – temperature, salinity, dissolved oxygen, nitrite, nitrate, ammonia, organic matter, particulate organic carbon, and clay were selected for the model. The parameters considered at this station were nitrite, ammonia, sand and clay for the best prediction model using standardised values of the total benthic density. The individual effects and their first order interaction effects could predict the density using this model. At station 3, > 90% similarity was observed between June and other months and also between February and other months. Based on presence/ absence of species June to November showed < 50% similarity.

At station 4 high similarities was obtained between months August to December and January to May (70 to 90%). Depending on the presence/ absence of species, only April and February showed about 63% similarity. At station 5 high similarity was observed between the months, June to December and March to May (> 70%). Maximum similarity was observed between May and June to December (> 90%). Station 6 high similarity was observed between months (> 90%) between March and April (54%) and March and May (51%). Based on the presence/ absence of common species January and February showed the least similarity with other months of the study period (< 10%).

At station 7, based on abundance of species, with May and April having highest similarity with other months of the year (> 70%). The highly dissimilar periods were September and January (< 60%). But based on the presence/ absence of species it showed a similarity < 40% between months except that of August with September (64%). Station 8 showed high season wise similarity (> 75%) between months except that between September and December (< 62%). But the chance for common occurrence of species was very poor during September and October with other months (< 24%). Station 9 showed high similarity for abundance of common species between January and other months, from June to December (> 95%). But December showed less similarity with from February to May (< 68%). But the presence of common species was very low (< 10%) between January and other months of the year.

The highly abundant species at station 10 *Dendronereis aestuarina* and *Pendora flexosa* showed high variation and were highly correlated with nitrite, nitrate, temperature and salinity whereas at station 11 this species was controlled by salinity, temperature, organic matter and silt content. The species *Capitella capitata* which were abundant at stations 12 and 13 were highly correlated with clay at station 12 and controlled by nitrate and particulate organic carbon at station 13. Except station 12 high similarity (> 98%) was observed between all the months.

Station 14 showed high seasonal similarity (> 98%) based on abundance of common species except June and July (< 20%) and April and May (< 60%). Based on presence/ absence of common species a value (< 30%) was obtained except that between August and September (~ 69%) and October and November (59%).

Q-mode factor analysis was applied only to stations 3, 5, 6, 7, 8, 9, 12 and 14 because in other stations either low number of species were observed or species were obtained only in few months.

In station 3, the months except August and November were grouped in factor 1 which had high even value and formed the differential factor groups explaining 53.41% of the variation in the seasonal variation in benthic density. In station 5, 4 factor groups, containing the months, January, March, May in the factor 1, November and December in the factor 2, July to September in the factor 3 and June in the factor 4, explaining about 74.88% of the seasonal variation in the benthic density. High positive loading was obtained for factors 1 and 2 while high negative loading for factor 3. In station 6, four-factor groups having all positive loadings except the first one, which had wider range with negative loadings were obtained

At station 7, four factor groups obtained with high negative factor loading. At station 8 out of the 5 factor groups obtained only the first four were statistically significant. At station 9 Q-mode analysis presented 4 statistically significant factor groups and provided only 47.85% of the seasonal variation in its distribution. At station 12 a unique characteristic for the benthic distribution was observed and explained 79.99% of the over all seasonal distribution. At station 14, three factor groups were obtained and explained about 57.35% of the seasonal variability.

The fourth chapter deals with the mangrove environment of Puduvypin. This environment is a shallow salt marsh with a depth of about 1 to 1.5m and has a width ranging from 40 to 50m. Six stations were sampled from this area for 10 months (June 1993 to April 1994).

The various environmental parameters indicated well-defined differences, the variability to a certain extent being imposed by the monsoonal regime. Monsoonal discharges directly affect the concentration of nutrients, salinity and suspended load. The overall picture of water quality of Puduvypin mangrove area revealed little fluctuation between stations. The spatial variation in salinity and temperature was not pronounced since the stations are very close. Freshwater condition prevailed during monsoon. Well-oxygenated condition existed in the study area throughout the observation period and all the values were above 2 ml/l. BOD_5 values were low (<5 mg/l).

Among nutrients ammonia and phosphate showed high values (12.40 to 32.20 μmol/l). The relatively high values of the above nutrients in this area may be attributed to the heavy freshwater discharge during this period in addition to the non-point sources.

Comparatively high values of chlorophyll 'a' (4.87 to 37.65 mg/m^3) and particulate organic carbon (3.95 to 12.81) was noticed during monsoon period. High suspended load was noticed throughout the observation (47.39 to 76.37 mg/l). In general phosphate, Chlorophyll 'a', particulate organic carbon and suspended load showed an inter-relationship. High values of nitrite, nitrate and phosphate might have contributed to the high phytoplankton growth and thereby high pigment content. The shallow nature of the area and the litter fall from the mangrove trees contributed substantially to the suspended load and thereby increase in particulate organic carbon content.

The substratum of the mangrove area was dominated by clayey silt with rich organic matter content. The organic matter showed good relationship with fine grained material and the values varied from 1.25 to 7.11% (av. 4.36%).

The total number of specimens of bottom fauna recorded from this area varied from 6698 (station P4) to 53343 (station P6). The average density and biomass for the different stations varied from 670 to 5334/m^2 and 10.11 to 25.74g/m^2 respectively. Though a total of 11 groups were encountered from this area the number and percentage composition of different groups varied from station to station. A total of 28 species belonging to different groups were encountered from this area. Ten groups were observed at station P1, 9 groups at station P2, 8 groups at station P3, 10 groups at station P4, 6 groups at station P5 and 7 groups at station P6. Maximum number of groups was noticed at P4 (10) and minimum number of groups at P5 (6). Species composition of the different stations in the mangrove area showed that tanaidaceans, the dominant and common group was represented by two species viz. *Apseudes chilkensis* and *A. Gymnophobium*. The second dominant group amphipod was represented by *Melita zeylanica, Quadrivisio bengalensis* and *Grandidierella gilesi*. The third dominant and common group was polychaete represented by 8 species belonging to 5 families. Among decapod penaeid prawn was collected from all stations and crab was noticed at stations P3 and P5 only. Mysid and isopod occurred rarely. Gastropods and bivalves were also noticed at one or two stations only. The insect chironomid and water beetle were observed at P1 and P4. Juvenile fishes were collected from all stations.

Mangrove enclaves being an important component of estuarine ecosystems have been identified as producers and exporters of organic matter. The ground litter on the substratum produced by trees, shrubs and herbaceous plants contribute substantial amount of organic matter to the complex estuarine food webs and energy transfer, consequently, litter production in the mangrove ecosystem has been used as a measure of productivity in view of the importance of litter to detritivorous organisms.

Clay and silt with high organic matter content (av. 4.36%) dominated the substratum in the mangrove ecosystem of Puduvypin, which favoured the group of detritivorous organisms like tanaidaceans and amphipods.

Species richness index ranged between 0.71 (station P5) and 7.76 (station P4). The average temporal distribution ranged between 2.55 (station P6) and 3.71 (station P2). Seasonal distribution showed a normal pattern for temporal variation increasing from station P1 with a peak value at station P2 and values decreased in other stations. Species concentration index ranged between 0.10 (station P1) and 2.26 (station P4). Average species concentration index was more or less same in the study area. The temporal variability was least (12.90%) at station P5 and highest (38.65%) at stations P1 and P4. Species diversity index varied between 0.35 (station P1) and 3.83 (station P4). Average distribution of diversity was maximum (1.87) at station P1 and least (1.40) at station P4 with maximum (41.54%) temporal variation.

Species dominance index ranged between 0.31 (station P1) and 2.25 (station P4). Average distribution of dominance index showed that temporally maximum (1.48) dominance was obtained at station P4 and least (0.62) at station P3. The temporal variability showed the same pattern as that observed for species diversity index. Species evenness index which invariably related to dominance showed comparatively higher value at station P1 and least value at station P5. The evenness index ranged between 0.21 and 2.13 both, at station P1. The average temporal distribution showed peak value (1.25) at station P4 and low value (0.87) at station P5.

In mangrove area the niche breadth was dependent on the temporal variation. The range in number of species was 13 (station P5) to 18 (station P6) and the range for niche breadth was between 1.09 (*Littorina littorea)* and high correlation with dissolved oxygen and 4.52 (Juvenile fish and *Lycastis indica)* highly correlated with nitrate. At station 2 niche breadth varied between 2.35 (*Lycastis indica)* and 5.43 (*Prionospio polybranchiata).* These species were controlled by chlorophyll a, nitrate and clay. At station 3, 83.33% of the species, the niche breadth ranged between 2.03 (*Capitella capitata)* and 7.78 (*Melita zeylanica),* both were highly correlated with organic matter and silt. For the remaining species niche breadth was very low (< 1.95). At station 4, (*Melita zeylanica)* showed a niche breadth ranging between 2.01 and highly correlated with phosphate, organic matter and salinity. Juvenile fish showed a high niche breadth of 4.92 and controlled by organic matter. At station 5, the maximum niche breadth (6.55) was for *Melita zeylanica* and it was highly dependent on organic matter and minimum niche breadth was (2.35) for *Grandidierella gilesi* and highly controlled by salinity. The trend observed here was higher abundance, lower seasonal variation, higher is the niche breadth. The niche breadth at station 6 ranged between 2.69 (Penaeid prawn) and 8.57 (*Melita zeylanica)* and highly correlated with chlorophyll 'a', suspended load and silt.

In the mangrove area, total benthic density was related to the parameters such as dissolved oxygen, phosphate, nitrite, ammonia, organic matter, particulate organic matter, BOD_5, suspended load and silt. It was found that the standardised original values of the parameters, dissolved oxygen, phosphate, nitrite, ammonia. organic matter, particulate organic matter, suspended load and silt and their first order interaction effects could predict total benthic density.

This model was highly significant (P = < 0.05) and it explained about 90.81% of seasonal and spatial variation in the total benthic density. The individual as well as the interaction effects of the water quality and sediment characteristics were graded along with their significance standard error and confidence interval. This indicated that in the mangrove area the interaction effects were more significant than the individual factor effects.

The seasonal similarity was studied using Bray Curtis and community coefficient methods. At station 1, April showed invariably high similarity with other months of the year. The common occurrence of the species was observed more in January. At station 2, between months of the monsoon season high similarity for abundance was observed. Using presence/ absence, 32.60% similarity could be observed between June to September and November to January. At station 3, different picture was observed for between months similarity. June showed high similarity (> 90%) with other months of the year. Based on the presence/ absence of species August to November showed 50 to 85% similarity. At station 4 unlike the other study area throughout the study period 80 to 100% similarity was observed except during June and November (< 70%) and during August and February (< 60%) based on the abundance of the species. At station 5, June to November showed > 70% similarity in the abundance of common species except August and September (51%) and August and November (56%). Based on presence/ absence of species it has been observed that higher similarity in common species was only between June and August, November and April (71%). In all other months only < 60% similarity could be observed. At station 6, a strange pattern for similarity between months has been observed. It showed a striking difference when compared to other 5 stations. All combinations of months, other than with September (> 70%), showed < 50% similarity in the abundance of the common occurrence of species. Similarity, based on presence/ absence of species a strange difference was observed in this station in all the months (< 33%). Common species occurred but in different abundance as indicated by Bray Curtis similarity index.

The fifth chapter discusses the environmental impact on bottom fauna of the dredging and dumping sites of Cochin Port during pre-monsoon and monsoon seasons. Thirty six stations located in and around the Cochin harbour, covering an area of 130 km^2 of the estuarine and nearshore areas were selected for the collection of sediment and benthic samples. Of these eight stations were sampled over complete tidal cycles for water quality parameters with stations 1 to 4 in the estuarine region, 5 & 6 in the outer channel and 7 & 8 at the dredge spoil dumping grounds.

The environment in and around Cochin harbour which has been under sustained and varying degrees of stress due to dredging over the last 5 decades has not shown any sign of serious environmental impairment as can be seen from the present study and documented data.

The present data and the data collected earlier indicate that there is build up of various nutrients in the harbour region and close to the coast. A comparison of the data collected over the years indicate that since 1965 there has been more than two fold increase in the general levels of inorganic phosphate of the river mouth (1.23 to 3.3 μmol/l). Similarly, the average nitrate values have also increased from 7.72 to 19.7 μmol/l in the backwater system. This is due to the effect of the effluents discharged from the fertilizer factory in the upstream. Earlier studies from this region have shown the release of nutrients and metals to the overlying water during dredging. But these nutrients come to normal levels within 20 minutes after dredging. So the long- term impact to the environment due to dredging is negligible.

Dissolved oxygen saturation in the surface and bottom waters varied in general, from 60 to 80 % and BOD_5 was within in the permissible limits. Particulate matter and sediment also did not indicate high levels. So, long term impact to the environment due to dredging is negligible.

The silty clay and sandy clay substratum predominated the study area except for one or two stations. Compared to monsoon, organic matter was low during pre-monsoon, the average organic matter in the areas 1, 2 and 3 ranged from 4.07 to 5.27% during monsoon and 3.71 to 4.27% during pre-monsoon. In the dredging channel the value were 3.40% during pre-monsoon and 3.51% during monsoon. In the disposal area the average organic matter content was 4.51 and 4.00% during pre-monsoon and monsoon periods respectively. On either side of the dredging channel the organic matter content values varied from 3.83 to 4.53 % and 3.61 to 4.34% during monsoon and pre-monsoon respectively. The average organic matter of this area varied ~ from 3 to 5%. High organic matter content in the region can be ascribed to high productivity of the overlying waters. Sewage and municipal discharge and clayey nature of the sediment may also be responsible for high organic matter.

The sediment characteristics and bottom topographic features will be restored after a period of intermittent dredging. The tidal flushing characteristics and river discharge plus material inputs help the dredged site to return to its initial status as reported by earlier researchers.

The quantitative and qualitative study of benthos in the area showed a wide variation in their distribution, abundance and composition. This may be probably due to various biological and physico-chemical environmental factors. Wide fluctuations in salinity and nature of substratum and organic enrichment in the sediment are the important factors restricting the abundance of benthos. A sufficient quantity of sediment will be removed as a result of dredging. The fauna will be exposed to a new substratum.

Benthic fauna in the study area was comprised of polychaetes, oligochaetes, amphipods, tanaidaceans, isopods, decapods, mysids, cumaceans, sergestids, alpheids, barnacles, molluscs, fishes and rare groups like amphioxus, foraminifera, sea anemone, nematodes and echinoderms. Of these, polychaetes were the common and dominant group. Twenty one species were recorded during monsoon and 19 species during pre-monsoon. Fifteen species were common to both seasons. The damage caused to the bottom community by dumping the spoil was minimal and was well reflected in the data. Therefore it has been deduced that an increase in the quantum of dredge material and its disposal at selected site was unlikely to cause any serious damage to the bottom community. The impacts were essentially short term. The behaviour of organisms in the reference area was similar to that in the disposal area and no definite impact could finally be established. It was not perceptible since the species composition of benthos was observed to be similar with that in the neighbouring areas over the years. The absence of accumulation of dead shells in this area during the study period suggests that there was no indication of mortality due to impact of dredging and dredge spoil disposal. High species density and diversity were noted at the nondredged location compared to dredged area and under favourable condition the recolonization is possible in this dynamic environment.

During pre-monsoon species richness was high in areas 1 and 2 compared to other areas. Not much variation in the richness of the species was observed during monsoon. Species concentration factor showed the same trend during both season having high values at stations of areas 1 and 2. The highest average diversity was in area 2 with lesser variability and least average diversity was in area 3 during pre-monsoon. During monsoon the diversity index showed a decreasing trend from area 1 to area 7. Based on the average distribution, species dominance index was highest in area 5 followed by area 2 and area 1. Least dominance was obtained in area 4, 6 and 7. During monsoon dominance index was less in areas 1 to 3 but not much significant difference at areas 4 to 7 during monsoon compared to pre-monsoon. Species evenness in distribution showed high values in area 1 and area 4. The disparity in community structure observed may be attributed to the dredging effect.

Of the 28 species encountered during pre-monsoon from Area 1, *Prionospio pinnata* showed high niche breadth (>3.1). All other species had a niche breadth <2. In area 2, the niche breadth varied from 1.07 (*Corophium triaenonyx)* and 5.19 (*Nephthys dibranchis*). In area 3, of the nine species encountered *Nephthys dibranchis* and *Prionospio polybranchiata* showed high niche breadth (2.2). In area 4, out of the 18 species, *Prionospio pinnata* showed a maximum niche breadth 2.87 and moderately depend on organic matter content. *Lumbrinereis simplex* was highly correlated with sand and this indicated that sediment characteristics to a moderate extent could control the niche breadth. Of the 10 species encountered from area 5, Gastropod sp. showed a niche breadth of 1.08 and *Cossura coasta* 2.05, both were controlled by organic matter. As in area 4, *Lumbrinereis simplex* was highly correlated with sand content with niche breadth of 1.85. In area 6, the niche breadth varied between 1.11 (*Scyphoproctus djiboutiensis*) and 2.75 (*Cossura coasta*). In area 7, Gastropod sp. showed the highest niche breadth of 3.16 and was negatively correlated with sand and organic matter.

During monsoon 36 species were encountered from area 1. *Paraheteromastus tenuis* and *Apseudes gymnophobium* showed high niche breadth of 6.34 and 7.88 respectively and these species were moderately correlated with silt content. In area 2, of the 21 species, *Scyphoproctus djiboutiensis* showed the maximum niche breadth (4.52) and was highly correlated with clay content. In area 3 with 17 species the niche breadth distribution was more consistent with lower values ranging between 1.00 (gastropod sp.) and 3.11 (*Ancistrosyllis constricta*). In area 4, of the 11 species, maximum niche breadth (3.56) was for *Prionospio pinnata* and was highly controlled by organic matter. In area 5 the highest niche breadth (2.73) was for *Lumbrinereis simplex* and it was moderately correlated with sand. *Perinereis cavifrons* and *Heteromastides bifidus* were highly dependent on organic matter. In these areas the relation between niche breadth, abundance and spatial variation was the same as in the other areas and same as that observed during pre-monsoon and higher niche breadth was correlated with high organic matter.

Benthic density and sediment characteristics studied during pre-monsoon showed that the log transformed standardised values of sand, silt and clay and organic matter content could predict the log standardised values of benthic density from the regression model applied. Relation between total benthic density and sediment characteristic during monsoon showed that sediment characteristic were not enough to predict the benthic density in the dredging area during this season.

Similarity between stations was obtained using parametric as well as non-parametric methods. In the parametric method, Bray Curtis coefficient of similarity based on actual counts of the species in the stations were used. In the non-parametric method community coefficient, which depends only on presence/ absence of the species. was used. In area 1 during pre-monsoon >90% similarity was observed between stations 1 to 3 and 8 to 10. Similarity based on presence/ absence was very low between stations. In monsoon more or less the same pattern of similarity was obtained between stations. On the whole a marginal increase in commonness was observed during this season. In area 2 during pre-monsoon highest similarity was observed between station 13 and other stations. During monsoon a slight reshuffling was observed in the number of common species in station 13 keeping a lower level of similarity in the rest of the stations. even though the trend was almost the same. Regarding the presence/ absence of species not much significant difference could be observed for the pattern of station wise similarity during the two seasons. In area 3 the five stations studied did not present much difference in the station wise similarity based on the abundance of species during the 2 seasons while the presence of common species was more during monsoon than during pre-monsoon. In area 4 the abundance of species showed almost the same pattern in both seasons. In areas 5 and 6 higher similarity was observed between stations during monsoon and premonsoon where as in area 7 it was in reverse order.

The Q-mode factor analysis applied to dredging areas 1, 3 and 4 during premonsoon showed that 4, 3 and 3 significant factor groups. During monsoon season Q mode factor analysis has been carried out only areas 1, 2 and 3. In area 1 only 3 statistically significant groups were obtained. In area 2, the 2 factor groups were important whereas in area 3 all the 4 factor groups were ecologically important.

The sixth chapter highlights the benthic productivity and fishery potential of the three different areas studied. Primary producers occupy the base of the ecological pyramids, which produce organic matter with the help of nutrients and sunlight. Productivity of benthos is also related to the primary productivity of the overlying water column. The herbivorous and carnivorous plankton and some of the benthic forms together occupy the second stage in the ecological pyramid. They in turn form the food of higher carnivores including fishes, which are the tertiary producers. Thus, it is evident that the benthos is a very important link in the food chain and any reduction in benthic productivity may adversely affect the demersal fishery.

The fishery potential of the three environments was estimated based on the benthic productivity to evaluate the change in the production potential of the area.

The maximum benthic production and potential were observed in the southern limb and this may be due to the high biomass obtained at station 3 and 4. At station 3 a large number of small gastropods were obtained and these were considered to be a potential contributor to the next trophic level. At station 4, the high biomass obtained was due to the presence of the bivalve sp., *Villorita cyprinoides*, which are considered to be subsistence fishery resource.

In the northern limb the high values obtained at station 8 were due to the presence of tube dwelling polychaetes and at station 12 it was due to the occurrence of polychaetes in large numbers. However, along the industrially polluted northern limb the fishery potential has reduced by a factor of 2 compared to the earlier report.

The fishery potential at barmouth during the previous and present investigations is comparable, probably due to lack of long term and persistent changes.

In the mangrove area the production was high compared to that of the estuarine and near shore regions. Along the dredging channel also the fishery potential was high and this could be attributed to the fresh recruits from adjacent area leading to recolonisation of a rich / healthy benthic community.

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02-11

CHLOROPHYLL 'a' PARTICULATE ORGANIC CARBON AND SUSPENDED LOAD FROM THE MANGROVE AREAS OF COCHIN BACKWATERS

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Abstract: Chlorophyll 'a', Particulate Organic Carbon and suspended load were estimated for one year from two distinct mangrove areas of Cochin backwaters, viz. Puthuvypeen and Nettoor. Environmental parameters like T°C, S‰ and pH were also measured. Chlorophyll 'a', Particulate Organic Carbon and suspended load were high at Puthuvypeen. The annual average for 6 stations ranged between 6.35 and 30.67 mg/m^3, 4.05 and 21.27 mg/l and 48.78 and 146.24 mg/l respectively. Seasonal variation was well marked during monsoon. Mangrove region at Nettoor showed comparatively low values for all the above parameters. The annual average for chlorophyll 'a', Particulate Organic Carbon and suspended load for 4 stations varied from 2.41 to 3.18 mg/m^3, 1.96 to 2.39 mg/l and 31.89 to 37.79 mg/l respectively. High pigment values coincided with high POC values in both regions. The values of present study are well comparable with values reported from the mangrove areas of South East coast. The POC, chlorophyll 'a' and suspended load of the mangrove areas of the study are high compared to other areas of Cochin backwaters.

1. Introduction

Mangroves are considered to be ecologically interesting environment. They are buffers between land and sea and prevent free flow of minerals from land to sea. Several hundreds of years ago, Kerala coastal plain was dominated by rich mangroves which occupied nearly 70,000 hectares. But now, only small patches of them sprawl out along this coast on account of population pressure, rapid industrialization and reclamation which wiped out vast expanse of mangroves in Kerala. Due to their economical, ecological, socio-cultural, aesthetic and scientific value, mangroves have assumed a world wide importance in recent years. Mangroves in Cochin area vary sparse and affected by pollution from adjacent oil complex and effluents from industrial complex. So far no thorough ecobiological study has been made on this ecosystem. The present paper deals with the distribution of chlorophyll 'a', Particulate Organic Carbon and suspended load, which form a part of ecobiological study from two distinct ecosystems of Cochin backwaters. The mangrove area at Puthuvypeen is shallow with thick vegetations such as *Avicennia sp, Rhizophora sp, Bruguiera sp, and Exoecaria sp*, and is influenced by tides whereas the stations at Nettoor are located on the bank of Chitrapuzha river having less tidal influence.

2. Materials and methods

Water samples from the surface were collected monthly from six and four stations from the mangrove areas of Puthuvypeen and Nettoor respectively, during 1993. Chlorophyll 'a' and POC were analysed following the methods of UNESCO (1966) and El Wakeel and Riley (1957) respectively. The suspended load was estimated by filtering a known volume of water through previously weighed Whatman GF/C filter paper dried to constant weight at 70°C and the differences in weight was taken as the amount of suspended load. Environmental parameters such as T° C, S‰ and pH were also measured.

3. Results and Discussion

The temperature differences during the year was 4-7° C. The variation in salinity was very large, from almost freshwater to seawater conditions and the pH ranged from 6.80-7.91, during the year.

The seasonal and annual ranges and averages for chlorophyll 'a', POC and suspended load are giver in Table I & II.

At Puthuvypeen, the annual average for the 6 stations ranged from 6.35 to 30.67 mg/m^3, maximum value being at station 4 and minimum at station 5. Seasonal variation was well pronounced during monsoon and average chlorophyll 'a', ranged between 4.87 and 37.65 mg/m^3 during this period, the peak value being 87.3 mg/m^3 in September at station 4 and the minimum being 0.37 mg/m^3 in June at station 1. Station 4 showed high chlorophyll 'a' content throughout the investigation period. At Nettoor, the annual average ranged from 2.41 to 3.18 mg/m^3. Compared to Puthuvypeen, the chlorophyll 'a', content is low in this area. Here the maximum value (5.86 mg/m^3) for chlorophyll 'a' was noticed in August at station 3 and minimum (0.06 mg/m^3) in January at station 1. Premonsoon showed higher values (3.01 to 3.36 mg/m^3) compared to other seasons.

Maximum value for POC (98.28 mg/1) was noticed at station 4 at Puthuvypeen. The average value was high during monsoon. The annual average for POC varied from 4.05 to 21.27 mg/1 and 1.96 to 2.39 mg/1 at Puthuvypeen and Nettoor respectively. At Puthuvypeen, the highest value for POC was noticed in September and lowest in December. At Nettoor, the

Table 1. Seasonal and Annual ranges and averages for Chlorophyll 'a', POC and suspended load at Puthuvypeen.

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	Pre-monsoon	1.39-18.54 (7.43)	2.98-19.17 (13.66)	10.30-17.76 (14.10)	7.64-67.95 (25.19)	4.97-13.74 (8.02)	3.30-14.36 (9.75)
Chl 'a' mg/m^3	Monsoon	0.37-32.85 (11.12)	1.25-25.06 (10.32)	1.57-36.35 (18.10)	1.68-87.34 (37.65)	1.94-8.35 (4.87)	1.20-14.44 (8.30)
	Post monsoon	0.05-4.96 (2.13)	1.86-8.94 (5.14)	4.45-16.53 (11.97)	4.96-4.37 (19.78)	4.24-9.28 (6.00)	5.00-10.57 (7.08)
	Annual	0.05-32.85 (7.44)	1.25--25.06 (9.77)	1.57-36.35 (15.22)	1.68-8.73 (30.67)	1.94-13.74 (6.35)	1.20-14.44 (8.49)
	PRE-monsoon	1.39-7.94 (4.87)	2.14-5.67 (4.37)	5.67-7.25 (6.45)	10.40-17.01 (12.81)	1.64-5.42 (3.95)	1.64-8.66 (5.28)
	Monsoon	1.89-13.86 (6.56)	6.17-15.44 (9.53)	4.41-22.68 (13.03)	3.40-98.28 (33.41)	2.65-7.88 (5.28)	0.38-11.34 (6.54)
POC mg/l	Post monsoon	1.39-5.83 (2.93)	0.63-4.88 (2.38)	1.95-5.51 (4.06)	3.40-28.04 (13.53)	2.14-2.84 (2.52)	1.58-5.42 (3.64)
	Annual	1.39-13.86 (4.97)	0.63-15.44 (5.84)	1.95-22.68 (8.37)	3.40-98.28 (21.27)	1.64-7.88 (4.05)	0.38-11.34 (5.29)
	Pre-monsoon	34.32-74.60 (59.15)	20.28-88.88 (57.37)	11.75-39.16 (20.93)	21.29-129.30 (74.49)	26.32-87.16 (51.32)	42.65-94.36 (64.66)
	Monsoon	9.10-84.10 (40.74)	5.50-83.60 (48.00)	9.20-136.20 (61.25)	22.50-776.00 (220.62)	30.00-86.10 (62.24)	11.10-98.70 (47.58)
S.L mg/l	Post monsoon	34.40-120.75 (70.74)	30.70-92.95 (52.18)	25.88-109.25 (59.99)	43.40-266.90 (118.83)	16.76-77.04 (44.9)	39.45-95.80 (58.58)
	Annual	9.10-120.75 (55.66)	5.50-92.95 (52.06)	9.20-136.20 (48.78)	21.29-776.0 (146.24)	16.76-87.16 (53.73)	11.10-98.70 (56.00)

peak value for POC was noticed in October and lowest in November. Seasonal variation was not well marked here.

The suspended load showed the peak value during post-monsoon at Nettoor and the values ranged from 46.89 to 55.35 mg/l. No well marked seasonal variation was noticed at Puthuvypeen. The annual average ranged from 48.78 to 146.24 mg/l at Puthuvypeen, whereas it was between 31.89 and 37.79 mg/l at Nettoor.

The mangrove environment showed very much restricted light penetration and this would have favoured relatively higher production by nannoplankton (Ramadhas et al., 1976). Local rainfall, influence of tide, high nutrient content and falling of mangrove leaves may be attributed to high pigment content, POC and suspended load at Puthuvypeen. The pigment studies in the present survey yielded higher values compared to the values reported by Sundararaj and Krishnamurthy (1973) and Ramadhas et al. (1976) for Pichavaram mangroves which ranged from 4.36 to 39.80 mg/m^3 and 0 to 6.52 mg/m^3 respectively. When the concentration of the pigments of the mangrove waters was compared with that of Cochin backwaters (DOD Report 1993) it was found to be three to four fold increase and this may be an indication of higher production in mangroves. The higher pigment content of the mangrove area in the present study may probably due to the detrital chlorophyll associated with stirred up sediments (Qasim and Reddy, 1967). Sundararaj and Krishnamurthy (1973) stated that though the number of phytoplankton species were low in mangrove, it would appear to be rich in chlorophyll 'a' bearing organisms and also in primary production. The autotrophic organisms which are smaller in size (1.1μ pore size) either endemic to that place or migrated via back-

Table 2. Seasonal and annual ranges and averages for chlorophyll 'a', POC and Suspended load at Nettoor.

		Station-1	Station-2	Station-3	Station-4
Chl 'a' mg/m^3	Pre-monsoon	1.14-7.89 (3.01)	2.63-4.56 (3.36)	2.38-4.45 (3.14)	2.63-3.93 (3.36)
	Monsoon	1.34-4.27 (2.89)	0.90-4.16 (2.40)	1.29-5.86 (2.67)	1.60-3.31 (2.32)
	Post monsoon	0.06-2.10 (1.57)	1.01-2.92 (2.05)	1.07-2.29 (1.57)	1.02-1.89 (1.59)
	Annual	0.06-7.89 (3.18)	0.90-4.56 (2.58)	1.07-5.86 (2.48)	1.02-3.93 (2.41)
POC mg/l	Pre-monsoon	1.13-4.57 (2.80)	1.83-5.80 (3.68)	1.20-3.53 (1.97)	1.45-4.54 (2.63)
	Monsoon	1.73-4.03 (2.62)	0.69-3.28 (2.20)	1.13-3.94 (2.48)	0.63-3.28 (1.89)
	Post monsoon	0.82-1.76 (1.32)	0.25-2.46 (1.37)	0.50-1.64 (0.84)	0.88-2.84 (2.16)
	Annual	0.82-4.57 (2.29)	0.25-5.80 (2.39)	0.50-3.94 (1.96)	0.63-4.54 (2.20)
S.L mg/l	Pre-monsoon	38.82-49.68 (44.58)	7.56-71.32 (42.99)	7.44-63.16 (40.09)	11.54-75.08 (48.79)
	Monsoon	2.80-39.92 (21.94)	6.35-30.30 (18.16)	4.30-23.32 (14.49)	2.70-26.40 (17.05)
	Post monsoon	23.40-103.88 (52.15)	29.62-89.60 (55.35)	29.52-79.40 (46.89)	19.16-93.80 (52.29)
	Annual	2.80-103.88 (37.79)	6.35-89.60 (36.76)	4.30-79.40 (31.89)	2.70-93.80 (37.15)

water to sea and or estuary, might be responsible for higher production in mangrove region.

The POC and the suspended load also showed higher values. Higher POC showed a good standing crop and thereby showing high life sustaining capability of these waters. The suspended load in the present study varied considerably with the state of tide and season, this may be originated from domestic sewage and mangrove vegetation. The POC was higher in the mangrove region when compared to other areas of Cochin backwaters. This may be attributed to the autocthonous contribution resulting from primary production and allocthonous contribution by transportation of materials from upstream sources.

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NUTRIENTS FROM THE MANGROVE AREAS OF COCHIN BACKWATERS

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Nutrient like ammonia, nitrite, nitrate and inorganic phosphate and some hydrographic parameters were estimated for one year from two distinct mangrove ecosystems of cochin backwaters viz. Puduvypeen and Nettoor. The ammonia values showed higher concentrations at Puduvypeen as well as at Nettoor and the annual average for the different stations ranged from 13.13 to 37.84 µmol/l and 64.44 to 70.78 µmol/l respectively. Seasonal variation was well marked during monsoon at Puduvypeen whereas at Nettoor it was during premonsoon. The annual averages for Nirite, Nitrate and Phosphate ranged from 0.74 to 1.87 µmol/l, 2.72 to 7.41 µmol/l and 14.79 to 30.61 µmol/l respectively at Puduvypeen whereas at Nettor it ranged from 4.04 - 4.75 µmol/l, 10.09 - 14.53 µmol/l and 18.97-20.22 µmol/l respectively. The annual ranges of Temperature and pH were 26.50 to 35.0°C and 6.46 to 8.64 respectively. The salinity varied from almost freshwater to sea water conditions. The dissolved oxygen values ranged between 2.00 and 8.75ml/l.

In general ammonia showed high concentration at all stations through out the year. The high values recorded may be due to the biodegradtion of urea and domestic sewage. The irregular monthly fluctuation of ammonia concentration could be due to the intermittent discharge of the effluent from the industrial complex at Alwaye. The higher ammonia concentrations may be due to the oxidation of NH3-N, which keeps ambient levels high. Though the ammonia content at times exceeds the lethal limit for fishes no mortality was observed during this period. However, fish mortality due to high ammonia content was reported by Venugopal et al (1980). The values reported therein are 23.0ppm at the region of mortality and 1.51 ppm stream. The increase in nitrate may be attributed to the bacterial decomposition of detritus and also due to the varia tion in the quantum of the effluent discharge. Nitrate is thermo dynamically the most stable oxidation level of N_2 in the pres ence of O_2 in sea water, hence the nitrate was found to be hig compared to nitrite and if it is unutilized, it can be accumulat also (Rajendran and Venugopalan, 1977). Like ammonia th phosphate was also high. The input may be mainly through th effluents from the fertilizer factory. The sediments and recy cling of plant nutrients are found to be the sources of phosphc rus and nitrogen.

The present study varied considerably with the state c tide and season. The incoming sea water during the high tid and also the large flow of fresh water during the monsoon ca dilute the nutrient concentration. Selvam et.al (1994) opine that the mangrove community may also remove large amour of inorganic nutrients from detritus.

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Benthic Fauna of Southwest and Southeast Coasts of India

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Abstract

Benthos, sediment characteristics and organic matter content were studied along southwest and southeast coasts of India. Number of groups/species varied with the stations and also with the depths. Population density was very low in southeast coast compared to southwest coast. Polychaetes formed the dominant group. 36 species of polychaetes were recorded along southwest coast, whereas 19 species were recorded from southeast coast. Molluscs were more common along southeast coast. Five types of substratum *viz.* clayey silt, clayey sand, silty clay, sandy silt and sandy were noticed from different stations along southwest coast. But sand percentage dominated along southeast coast. The pooled mean organic matter percentage varied from 0.08 to 4.08 in southwest coast and 0.25 to 2.18 in southeast coast. Organic matter was high in silty clay substratum (3.15%) whereas in sandy substratum this varied between 0.07 and 1.38 percent.

Introduction

Qualitative and quantitative study of bottom fauna is a pre-requisite in assessing the demersal fishery resources of a region, since they form an important source of food for demersal fishes and prawns. Benthos along southwest coast of India has been studied by several workers. See Saraladevi *et. al.*, 1991; (and references therein) Ansari *et. al.*, 1994. Harkantra and Parulekar, 1994; Sunilkumar and Antony, 1994. Reports on benthos from southeast coast is comparatively less (Ganapathi and Raman, 1970; Chandran, 1987; Prabhadevi and Ayyakannu, 1989; Murugan and Ayyakannu, 1991; Vijayakumar *et. al.*, 1991) and mostly confined to estuarine region. The present paper covers the bottom fauna and sediment characteristics of coastal regions of the southwest and southeast coasts.

Materials and Methods

Benthic fauna and sediment samples were collected from three depths *i.e.* from 5, 10 and 15m in duplicate with a van Veen grab (0.048 m^2) at 9 stations *viz.* Mangalore, Kasargod, Kannur, Calicut, Ponnani, Cochin, Alleppey, Quilon and Vizhinjam along the southwest coast and 5 stations *viz.* Cuddalore, Ennore, Karaikkal, Nagapattinam and Thondi along the southeast coast. Grab samples were sieved through 0.5mm mesh for benthos and major groups were identified upto species level wherever possible. The number of organisms were converted to no/m^2 and the biomass expressed as wet weight g/m^2 (Shell on). Sediment characteristics such as grain size and organic carbon were estimated by standard methods.

Results and Discussion

Faunal composition and distribution along southwest coast

The benthic fauna identified were classified into 4 major groups *viz.* polychaetes, crustaceans, molluscs and miscellaneous forms. Polychaetes formed the dominant and common group in most of the stations. Number of groups/species varied with stations and also with depths. Population density of different stations varied from 210 to 4771 no/m^2, the highest being off Calicut at 15m depth and lowest off Kasargod at 10m depth. Number of faunal groups were more towards north of Cochin especially Calicut, Kannur and Ponnani compared to south of Cochin. The wet weight showed a wide range between 5.60 and 286.42 g/m^2, peak being at Alleppey and lowest at Kasargod.

Polychaetes were constituted by 36 species and the percentage composition of this group was >90 at Mangalore, Ponnani and Alleppey at 5m depth, Cochin 10m, Calicut 15m and in general it varied from 16.96 to 95.83 irrespective of depths and stations. Number of species were more towards north of Cochin. The highest diversity was noticed at Kannur (26). Towards south 17 species were recorded from Quilon, 10 species from Alleppey and 12 species from Vizhinjam. Of 36 species encountered only 4 species *viz. Ancistrosyllis constricta, Nephthys dibranchis, Maldane sarsi* and *Lumbriconereis simplex* were found at all the nine stations. *Cossura* sp. showed its presence at seven stations. *Scyphoproctus djiboutiensis, Paraheteromastus tenuis, Heteromastides bifidus, Polydora ligni, Pista indica* and *Sternaspis scutata* occured at six stations. *Prionospio pinnata* was present at five stations. *P. polybranchiata, Glycera alba, G. longipinnis, Goniada incerta, Owenia* sp. and *Phyllodoce* sp. were recorded from four stations. *Lycastis indica, Sthenelais boa, Serpula vermicularis, Capitella capitata* and *Aphrodita aculeata* were present at three stations. *Magelona longicornis, Hesione* sp., *Pherusa inflata, Syllis* sp., *Lumbriconereis notocirrata, Cirratulus cirratus, Paraonella platybranchia, Dendronereis aestuarina, Heteromastus similis, Ophelina acuminata, Perinereis cavifrons, Notoproctus* sp., and *Lepidonotus* sp. were noticed at one or two stations. Olygochaetes also showed rare occurrence.

Percentage composition of amphipods was very low at most of the stations. Of the 6 species encountered Eriopisa chilkensis was noticed at Mangalore, Kannur, Calicut, Cochin and Vizhinjam, Corophium triaenonyx at Mangalore, Kasargod, Calicut and Quilon, Grandidierella bonneri at Kannur and

Quilon, Melita zeylanica at Mangalore, *Grandidierella gilesi* and *Quadrivisio bengalensis* at Vizhinjam, Alleppey and Ponnani. Other crustaceans include crabs, mysids, sergestids, cumacea, tanaidaceans and anthuridae. Except cumacea others were recorded only from one or two stations along the coasts. *Molluscs include gastropods, Dentalium* sp., *Cavolinia* sp., *Cardium sp., Donax sp.* and *Arca* sp.. Only gastropods were noticed throughout the coast. *Dentalium* sp. were observed at six stations whereas others occurred at one or two stations at deeper depths

Miscellaneous groups include echinoderms, echiuroides, sipunculids, juvenile fish, nematodes amd amphioxus. Of these only echinoderms were found at six stations and others showed rare occurrence.

Faunal composition and distribution along southeast coast

The benthic faunal density along southeast coast was very low compared to southwest coast and varied from 63 to 1209 no/m^2. The wet weight showed a wide range between 1.29 and 706.90 g/m^2 and higher values in wet weight is due to the occurrence of molluscan forms. Molluscs and polychaetes were observed at most of the stations. Crustaceans and miscellaneous groups were recorded only from few stations. 19 polychaete species, olygochaetes, 5 amphipod species, 3 other crustaceans, 3 molluscan forms and 2 miscellaneous groups were encountered from this coast. In general high numbers were noticed at Karaikkal and Thondi. Stations at Ennore (Madras) being in the estuarine mouth showed relatively high numbers. Eventhough the density of polychaete is low compared to southwest coast, the percentage composition ranged between 9.13 and 91.0. Though 19 species of polychaetes were recorded from this coast, they were represented in less numbers. *Prionospio polybranchiata* present at five stations *Pista indica* and *Cirratulus cirratus* at three stations. Others were noticed at one or two stations in smaller numbers. Number of species were more at Karaikkal and Nagapattinam.

Of the 5 species of amphipods recorded 4 were present at Ennore estuary. From Cuddalore and Thondi 2 species each and from Nagapattinam one species were encountered. Molluscs include gastropods, dentalium and bivalves. Gastropods were noticed in considerable numbers except at Karaikkal whereas sparse representation of bivalves and dentalium were noticed along the coast. Foraminifera occurred along this coast. Nematodes and cumacea were poorly recorded and present only at Thondi. In general southeast coast is very poor in benthic standing crop compared to southwest coast. Cuddalore recorded very poor benthic density compared to other areas studied.

Substratum characteristics

Five types of substratum were noticed along southwest coast *viz*. clayey silt, clayey sand, silty clay, sandy silt and sandy. Percentage of organic matter was more in the clayey silt (3.34 to 4.60) at Kasargod and low in the sandy substratum (0.07 to 1.38). Percentage of sand dominated throughout the southeast coast except at Ennore where silty clay was noticed at the mouth of the estuary. Organic matter in the sand portion ranged between 0.12 and 0.78% and in the silty clay of the estuarine region it ranged between 1.25 and 1.81%.

Total benthic density along southwest coast varied from 210 to 4771 no/m^2 irrespective of depth the peak being at Calicut and lowest being at Kasargod. The pooled density for the three depths from Mangalore to Vizhinjam varied from 596 to 3516 no./m^2 and the average for the entire southwest coast is 1538 no./m^2. Polychaete dominated the benthic population ranging between 313 and 2279 no./m^2. The pooled percentage composition of polychaetes fall within the range of 39.83 to 78.46, the highest being at Kannur and lowest at Kasargod. The second dominant group is mollusc having a percentage composition ranging between 0.00 and 49.53 followed by crustacean (0.23 - 38.23) and miscellaneous group (0.00 - 27.57).

The present study shows a two fold increase in number of polychaete species compared to earlier records (Harkantra, Ayyappan Nair, Ansari and Parulekar 1980). They noticed a decrease in population density in the samples taken from 10-20m depths. In this study restricted to 15m depth no such trend could be noticed. Density and biomass are high when compared to the earlier reports.

The total benthic density along southeast coast varied from 63 to 1209 irrespective of depth. The pooled density for three depths ranged between 217 and 461 no./m^2, the highest being at Ennore. Though the density is low (13 - 251 no./m^2) the pooled percentage composition of polychaetes ranged between 13.33 and 65.29 and miscellaneous groups were rare along this coast. The pooled value of organic matter was high in the Ennore estuary (1.49%) whereas it varied from 0.25 to 2.18% in the other areas. The high biomass was due to the presence of molluscan forms. The depth wise distribution in population density and different animal groups showed irregular pattern. More numbers of molluscan forms were observed at 10 and 15 m collection. Variation in biomass and density from station to station in this study may be attributed to the impact of localised biotic and abiotic factors.

The dominance of suspension and deposit feeders like polychaetes and crustaceans in the estuary and nearshore region and the presence of filter feeders like bivalves and gastropods etc. from deeper stations noticed in the present study was also similar to the observations of earlier workers.The macrofaunal density and biomass in the southeast coast were much higher than the earlier reports. The high benthic density was associated with sandy silt and high biomass was associated with sandy substratum where shelled forms dominated. It is well established that the sedimentary type is the main criterion in the distribution of benthos. Rich benthic fauna in the nearshore region having riverine influence is mainly due to the influx of nutrient rich river water (Parulekar and Dwivedi, 1974). In conclusion it should be stated that eventhough coastal and nearshore region receive pollutants from various sources, no marked deleterious effect was observed in benthic population.

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Table 1a. Faunal composition and occurrence at different stations along southwest coast.

Species	MNG	KGD	KNR	CAL	PON	CHN	ALP	QUL	VZH
Ancistrosyllis constricta	+	+	+	+	+	+	+	+	+
Nephthys dibranchis	+	+	+	+	+	+	+	+	+
Maldance sarsi	+	+	+	+	+	+	+	+	+
Lumbriconereis simplex	+	+	+	+	+	+	+	+	+
Cossura sp.	+	-	+	+	+	+	-	+	+
Scyphoproctus djiboutiensis	+	+	+	+	+	-	+	-	-
Paraheteromastus tenuis	-	+	+	+	-	-	+	+	+
Heteromastides bifidus	-	+	+	+	-	+	-	+	+
Polydora ligni	-	+	+	+	+	+	-	+	-
Pista indica	+	-	+	-	-	+	+	+	+
Sternaspis scutata	+	-	+	+	+	+	-	+	-
Prionospio pinnata	+	+	+	+	-	+	-	-	-
Prionospio polybranchiata	-	+	+	-	+	+	-	-	-
Glycera alba	+	-	+	-	-	+	-	-	+
Glycera longipinnis	-	+	+	+	+	-	-	-	-
Goniada incerta	-	-	-	+	-	+	-	+	-
Owenia sp.	-	+	+	+	+	+	-	+	-
Phyllodoce sp.	-	+	+	-	-	+	-	-	-
Lycastis indica	-	-	-	+	-	+	-	-	-
Sthenelais boa	-	-	+	+	-	+	-	+	-
Serpula vermicularis	-	-	+	-	-	+	-	-	+
Capitella capitata	+	-	+	+	-	-	-	-	-
Aphrodita aculeata	-	-	+	+	-	-	-	+	-
Magelona longicornis	-	+	+	-	-	-	-	-	-
Hesione sp.	+	-	-	+	-	-	-	-	-
Pherusa inflata	-	-	+	+	-	-	-	-	-
Syllis sp.	-	-	+	+	-	-	+	-	-
Dendronereis aestuarina	-	-	+	-	-	+	-	-	-
Heteromastides similis	+	-	-	+	-	-	-	-	-
Ophelina acuminata	-	-	+	-	-	-	-	+	-
Perinereis cavifrons	-	-	-	-	-	-	-	-	+
Notoproctus sp.	-	-	-	-	-	-	+	-	-
Lepedonotus sp.	-	-	-	-	-	-	+	-	-
Cirratulus cirratus	-	-	-	-	-	-	-	+	+
Paraonella platybranchia	+	-	-	-	-	+	-	-	-
Lumbrio conereisnotocirruta	-	-	-	-	-	+	-	-	-
Olygochaeta	-	-	-	-	-	+	-	+	-
Quadrivisio bengalensis	-	-	-	-	+	-	+	-	+
Eriopisa chilkensis	+	-	+	+	-	+	-	-	+
Corophium triaenonyx	+	+	-	+	-	-	-	+	-
Melita zeylanica	+	-	-	-	-	-	-	-	-
Grandidierella gilesi	-	-	-	-	+	-	+	-	+
Grandidierella bonneri	-	-	+	-	-	-	-	+	-
Mysids	+	-	-	-	-	-	-	-	-
Sergestidae	-	+	-	-	-	-	-	-	-
Decapods	+	-	-	-	-	-	-	-	+
Cumacea	+	+	-	+	+	-	+	+	-
Apseudes ch ilkensis	-	-	-	-	-	-	+	+	-
Anthuridae	-	-	-	-	-	-	-	-	+
Arca sp.	+	+	+	+	-	+	+	-	-
Cavolinia sp.	+	+	-	-	-	-	-	-	-
Donax sp.	+	-	-	-	-	-	-	-	-
Cardium sp.	-	+	-	-	-	+	-	-	-
Tellina sp.	+	-	-	-	-	-	-	-	-
Gastopods	+	+	+	+	+	+	+	+	+
Dentalium sp.	+	+	+	-	+	-	+	+	-
Echinoderms	+	+	+	+	+	-	-	+	-
Echiuroids	+	-	-	-	-	-	-	-	-
Amphioxus	-	-	-	-	-	-	-	+	+
Nematodes	-	-	-	-	-	-	-	+	+
Sipunculids	-	+	-	-	-	-	-	+	-
Fish larvae	-	+	-	-	-	-	-	-	-
Foraminifera	+	+	+	+	+	+	+	+	+

Table 1b. Faunal composition and occurrence at different stations along souteast coast.

Species	CUD	ENR	KRL	NGP	TND
Prionospio polybranchiata	+	+	+	+	
Pista indica	+	-	-	+	+
Cirratulus cirratus	-	+	+	+	-
Goniada incerta	+	-	-	-	-
Aphrodita aculeata	-	+	-	-	-
Heteromastides bifidus	-	+	+	-	-
Ancistrosyllis constricta	-	+	-	-	-
Paraheteromastus ten uis	-	+	-	+	-
Nephthys dibranchis	-	-	+	-	-
Owenis sp.	-	-	+	-	-
Polydora ligni	-	-	+	-	-
Pherusainflata	-	-	+	+	-
Cossura sp.	-	-	+	-	-
Maldane sarsi	-	-	+	+	-
Serpula vermicularis	-	-	+	-	-
Capitella capitata	-	-	+	-	-
Sternaspis scutata	-	-	-	+	+
Euthalanessa djiboutiensis	-	-	-	-	+
Glycera longipinnis	-	-	-	-	+
Olygochaetes	-	-	+	+	-
Quadrivisio bengalensis	+	+	-	+	+
Eriopisa chilkensis	+	+	-	-	-
Corophium triaenonyx	-	-	-	-	+
Granidirella gilesi	-	+	-	-	-
Granidirella bonneri	-	+	-	-	-
Decapods	+	+	+	+	+
Cumacea	-	-	-	-	+
Anthuridae	-	-	-	+	-
Dentalium sp.	-	-	+	+	-
Gastropods	+	+	+	+	+
Bivalves	-	+	+	+	+
Nematodes	-	-	-	-	+
Foraminifera	+	+	+	+	+

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Table 2. Ranges of benthic density, percentage composition and organic matter percentage along the southwest and southeast coasts irrespective of depths and stations.

	Southwest	Southeast
Density (no./m^2)	210-4771	63-1209
Biomass (g/m^2)	6.02-286.42	1.29-706.90
Polycheates	63-4624	21-294
(Percentage)	16.76-95.83	9.13-91.00
Crustaceans	21-1916	21-314
(Percentage)	1.32-93.87	9.13-89.26
Miscellaneous groups	21-641	21 (only at Thondi)
(Percentage)	1.59-46.49	5.01
Organic matter percentage (Pooled for the three depths)	0.08-4.08	0.25-2.18
Type of substratum	**Organic matter %**	
<u>Southwest</u>		
Clayey silt	3.34-4.60	
Clayey sand	1.48-2.26	
Silty clay	3.15	
Sandy silt	1.43	
Sandy (>90%)	0.07-1.38	
<u>Southeast</u>		
Clayey sand	0.12-0.78	
Silty clay	1.25-1.81	

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