STUDIES ON THE BENTHIC FAUNA OF THE MANGROVE SWAMPS OF COCHIN AREA

THESIS SUBMITTED TO THE
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN THE
FACULTY OF MARINE SCIENCES

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1993

To My
Loving Parents

C E R T I F I C A T E

This is to certify that this thesis is an authentic record of research work carried out by Shri Sunil Kumar, R., under my scientific supervision and guidance in the Division of marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, in partial fulfilment of the requirements for the degree of Doctor of Philosophy of the Cochin University of Science and Technology and that no part thereof has been presented before for the award of any other degree, diploma or associateship in any university.

Cochin-16
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D E C L A R A T I O N

I, Sunil Kumar, R., do hereby declare that this thesis entitled "STUDIES ON THE BENTHIC FAUNA OF THE MANGROVE SWAMPS OF COCHIN AREA" is a genuine record of the research work done by me under the scientific supervision of Dr. A. Antony, Reader, School of Marine Sciences, Cochin University of Science and Technology, and has not previously formed the basis for the award of any degree, diploma or associateship in any University.

Cochin-16

Sunil Kumar, R.

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude to Dr. A. Antony, Reader, School of Marine Sciences, Cochin University of Science and Technology, for suggesting the topic, guidance and critically going through the manuscript.

I am thankful to Prof. (Dr.) N. Ravindranatha Menon, Director, School of Marine Sciences and Head, Division of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology for providing me all the facilities and encouragement during the tenure of work.

I am greatly indebted to Dr. C.S. Gopinatha Pillai, Principal Scientist, C.M.F.R.I., Cochin, who has channeled my interest in scientific research and for his critical suggestions towards the improvement of the text.

My sincere thanks are due to Shri. H. Krishna Iyer, Principal Scientist, C.I.F.T, Cochin and Dr. M.V. Mohan, Assistant Professor, Kerala Agricultural University for their invaluable help in the statistical analysis of the data presented.

I am grateful to Dr. N. Gopalakrihna Pillai, Scientist, C.M.F.R.I., Cochin and Dr. K.Y. Mohammed Salih, Reader, School of Marine Sciences for their valuable help in the identification of some of the specimens.

I wish to express my gratitude to Dr. R. Damodaran, Professor, Dr. V.J. Kuttyyamma, Reader, and Dr. K.J. Joseph, Reader, School of Marine Sciences for their valuable suggestions and encouragement.

My thanks are also due to Dr. A. Mohandas, Head, School of Environmental Studies for permitting me to use the computer facilities. The favours received from Dr. K.J. Padmakumar and Shri. C.K. Rajendran, Associate Professors, Kerala Agricultural University are also gratefully acknowledged.

Special gratitude is called for to Shri. Balakrishnan, Shri. Dinesan and late Shri. Joshi for their help in field work and collection of data.

I would like to express my sincere gratitude to Dr. P.G. Suresh, Shri. G. Nandakumar, Dr. K. Asok Kumar, Shri. A.K. Unnithan and Mrs. P. Geetha for their assistance and various other support. The co-operation and help from my colleagues of Marine Biology and Marine Geology Divisions are also gratefully acknowledged.

I thank the authorities of Cochin University of Science and Technology for awarding me a Junior Research Fellowship during the tenure of which the present work was carried out.

CONTENTS

P R E F A C E

Mangroves have long been a natural resource of importance to mankind by virtue of their utility and aesthetic value. To the scientists they are of interest, particularly because of specific morphological, anatomical and special physiological adaptations, and for their value in the study of shore line protection and paleohistory of shores. Some authors (Unesco, 1981) consider mangroves as possible transitional species in the evolution from aquatic to terrestrial plant life.

Biologically, mangroves play a dominant role in the nutrition and shelter of juvenile fish, crustaceans, shellfish and other animals of higher trophic levels. The detritus and organic content mostly derived from the mangals enter into the initial food chain.

Despite the importance, in general, the mangroves throughout the Indian subcontinent, particularly in Kerala, have not hitherto received the attention they deserve and it was evidently been subjected to persistent human interferences and ruthless exploitation. In recent years, there is an International awareness about this fragile ecosystem. At present extensive research on various aspects of mangroves all over the world, with special reference to their conservation and management, is being carried out. The mangroves of Cochin needs urgent measures for their conservation and management and for this a better understanding of their status is sine-qua-non.

Realising this, an attempt is made here to evaluate the Cochin mangroves with special reference to their benthic *organisms: its community structure, adaptability to environmental variables, diversity, richness and evenness, similarity and coexistence and also its structural complexity in vertical and horizontal zonation.*

It is sincerely hoped that the information provided in this "Thesis" will be of much use in formulating an action plan for the conservation and management of this endangered ecosystem of our coast.

Chapter I

INTRODUCTION

1.1 THE MANGROVE ECOSYSTEM

The term "Mangrove" is commonly used to denote a community of tress or shrubs, or it may be applied to any one of the individual species which constitute that association (Macnae, 1968). Mangroves grow between the level of high water of spring tides and a level close to but above mean sealevel.

Mangrove vegetation is characteristically present along river mouth, estuaries and sea coasts. They are also called as 'tidal forests' or 'coastal wetlands'. Locally it is known as 'kandal kadu'. The important components of this ecosystem are water, soil and the biota - an admixture of *euryhaline* fauna and flora.

Mangroves exhibit numerous physiological and structural adaptations such as special root systems - pneumatophores, prop roots, knee roots etc, viviparous germination and salt glands. One of the most distinctive features of mangrove vegetation is its characteristic zonation. The specialised root system of these trees, reduce wave action and trap the sediments and serve as store house of organic matter. There is an export of organic matter from the mangroves to surrounding water. Thus, mangroves enrich the organic productivity of coastal waters, which in turns leads to a dense population of secondary and tertiary consumers.

The mangrove ecosystem is self sufficient in production and utilization of food material. The protein rich detritus is mostly consumed by the detritivorous organisms from the riverine or near shore areas, which come to mangrove swamps for feeding, breeding and nursery purposes (Odum and Heald, 1975). The use of mangrove areas as nursery grounds by fish (Bell *et al*., 1984; Little *et al*., 1988) and prawns (de Freitas, 1986; Stoner Zimmerman, 1988 and Vance *et al*., 1990) has been well studied and a positive correlation between commercial yields of fish and prawns and the extent of mangrove forests has been found (Sasekumar and Chong, 1987).

More recently, mangroves have become of great economic significance, both in terms of their direct resource of forest and fishery, as well as their indirect value in protecting coastlines and enriching biological productivity. According to Saenger *et al*. (1983) and FAO Report, (1982) there are several direct as well as indirect economic gains of this ecosystem. There are various traditional and modern methods of exploitation of mangrove ecosystem. The capture and culture fishery of mangrove rich areas is of great economic significance. The mangrove swamps are also used for collection of juveniles of the economically important organisms like fishes, prawns, crabs, oysters and mussels.

Use of mangrove trees for timber, thatching, charcoal, tannin, paper and pulp, resins, dyes, oils, medications, animal fooder, fish poisons and firewood are of direct economic importance in many southeast Asian countries. However, in India the major use of mangrove trees is only the firewood as a source of energy, while fishery and fish farming is also prevalent in these regions (Untawale, 1987). Biologically and economically, one of the most important aspects of man-mangrove interaction is the mangrove dependent or associated capture fisheries and aquaculture (Silas, 1987). A thick belt of mangrove forest, not only minimises the coastal erosion but also traps valuable sediment, protect the inner land from cyclones, storms or high tidal bores (Saenger *el al*., 1983).

Man has had a long association with mangrove communities. Historically, mangrove environments have been favoured sites for human settlement because of their sheltered coastal locations. Thus mangroves form an important resource in the economy of a country.

1.2 FACTORS CONTROLLING GROWTH

The mangrove ecosystem is an ecotone between aquatic and terrestrial environments. The effects of environmental factors such as climate, hydrological conditions and other physical conditions determine the extent and distribution of the mangrove.

Temperature is an important factor in the growth and distribution of mangroves (Chapman, 1977). These plants require warm, tropical temperature to develop. The amount of freshwater supply also affects the growth and distribution of mangroves. The water supply comes from rainfall, runoff from the land and flooding by tide. Mangroves occur on tropical shores from regions of high rainfall and humidity to regions of low rainfall and excessive evaporation, but only in the former they reach the maximum development (Macnae, 1966).

Mangroves grow best where the freshwater supply is available in adequate amounts. Freshwater flow from upland brings nutrients and silt, both important for the growth of mangroves. Mangroves are thus best developed on muddy coastal plains where adequate freshwater supplies from river discharges are available. According to Saenger *et al.* (1983) the fine sediments which settle in river mouth region as a result of 'flocculation effect' help the mangrove propagules to settle and grow further. They also develop on shores which are sheltered from strong wave action.

Development and geographic distribution of mangrove vegetation are influenced by soil conditions. Mangrove soils are mostly alluvial in nature. They have a high salt and water content, low oxygen and abundant hydrogen sulphide. They are fine-grained soils, often semi-fluid, consolidated poorly and with abundant humus in parts (Macnae,1968). The type of soil conditions influence the type of plants growing on it.

The chemical factors, influence the distribution of mangrove forest. The daily variation and annual average of salinity affect the mangrove growth and distribution. Although mangroves will grow in freshwater, they do not flourish there because of competition from freshwater plants (Odum and Heald, 1975). Each species of mangrove has tolerance range of salinity which is characteristic.

The optimum salinity tolerance therefore varies from species to species. At salinities higher than the optimum, respiration increases and there is decreased net growth. At salinities lower than the optimum, competitor species better adapted to the conditions gain the upper hand (Snedaker, 1978). Rainfall and humidity affects the salinity of the soil and so too the composition of the mangrove species.

Vegetation has an important role to play in the development of the mangrove soil. The vegetation stabilizes the loose sediment which would otherwise be washed away by currents and strong wave action. Organisms such as bacteria and fungi contribute to the fertility of the mangrove area by decomposing the litter fall. During microbial growth the soil becomes enriched with compounds released by the decomposition process (Camacho, 1984).

1.3 DISTRIBUTION OF INDIAN MANGROVES

According to the FAO report (1982) the total mangrove area in Asia and the Pacific is about 6-8 million ha. Mangrove along the Indian coast and Islands has been estimated to be about 700, 000 ha (Sidhu, 1963). According to Blasco (1975) the total area has been reduced to 355, 500 ha. Apart from this there have been some regional mangrove surveys (Mathauda, 1957 and Khan, 1957).

Out of 90 mangrove species (Chapman, 1976) in the world, the Indian mangroves comprises only 59 species in 41 genera and 29 families (Untawale, 1984). Several attempts have been made earlier to survey the mangrove areas along the Indian coasts (Qureshi, 1957; Blasco, 1977 and Untawale *et al*., 1982). It has been reported that about 8% of the Indian coastline is occupied by mangroves (Untawale *et al*., 1982).

The extent of mangroves along the east coast of India is larger than along the west coast. It has been estimated that about 82% of the total mangrove forest in India, is along the east coast (including Andaman-Nicobar Islands), while the west coast of India has only 18% mangrove cover (Untawale, 1984).

Mangroves grow along the embankment of almost all the estuaries deltas, backwaters, creeks and other protected areas of the west coast. The total area occupied by the mangrove vegetation alone is approximately 114, 000 ha (Sidhu, 1963). If the mangrove waters of marshes are taken into consideration, then the total area would be much more. The west coast mangroves are found along the coasts of Gujarat, Maharashtra, Goa, Karnataka and Kerala. 34 species of mangal are reported from the west coast.

The deltaic system of Ganga, Godavari, Mahanadi, Krishna, Cauvery and Aandaman-Nicobar Islands harbour the major mangrove forests along the east coast. The Gangetic Sunderbans of West Bengal is the largest mangrove forest of India where 420, 000 ha area is covered by these tidal forests. Andaman-Nicobar Islands is the second largest mangrove area with about 115, 200 ha. The major mangrove formations around the east coast are the Mahanadi delta, Godavari, Krishna, Cauvery, Pichavaram and Muthupet (Untawale, 1984). There are 48 species of mangrove plants recorded from the east coast of India.

1.4 DESTRUCTION OF MANGROVE FORESTS

It has been noticed that throughout the world vast areas of mangrove forests are being destroyed every year, either intentionally by man or as a secondary result of other activities. The degree of destruction in each country depends on specific purposes. Demographic pressure is leading to an increased demand for food, fuel, building material, urbanization and land for cultivation. The causes of mangrove destruction in various countries are many and these can be classified as overexploitation by traditional users, convertion to aquaculture, agriculture, salt pans and urban development. Natural calamities such as cyclone and freshwater discharges also destroy the mangrove ecosystems (Aksornkoae, 1985).

The threats, as a result of human interference, are the deforestation, reclamation, pollution and diversion of freshwater. Most of the Indian mangrove areas have been lost because of these reasons. Increasing population pressure, rapid industrialisation as well as rural and urban development has been responsible for the reclamation of roughly 200, 000 ha of the total mangrove area along the Indian coast. Moreover, this has positively created manifold problems and also affected the nearshore fishery production (Snedaker and Snedaker, 1984 and Natarajan, 1984). Deforestation and overexploitation of mangroves has resulted into the degraded or open marshy land of approximately 100, 000 ha. Mangroves along the west coast of India are considered as highly degraded areas (Blasco, 1975, 1977). The coastal areas like Gulf of kutch, Bombay coast and Cochin backwaters are the glaring examples of deforestation, reclamation, pollution as well as population pressure

(Untawale, 1984). All these natural and manmade causes have reduced the total mangrove area along the Indian coast considerably. Overall mangrove habitat in India is threatened and needs protection.

1.5 MANGROVE FAUNA

The fauna of mangroves, derived from adjacent terrestrial and marine or estuarine habitats, has been less studied than the mangrove vegetation itself. Broad patterns of zonation can be discerned both horizontally through the swamp and vertically from the sediment to the canopy. Vertical stratification depends mainly on tidal inundation and salinity. The canopy is largely free from tidal influences and supports a fauna that is essentially terrestrial origin. These species generally show no special adaptations for life in mangroves, though many of them do feed on the food material below. They also contribute to the nutrient input into the mangrove ecosystem in the form of faecal material. Leaves, stems, root-holes and clefts provide several valuable micro habitat. Below the canopy euryhaline species appear. The distribution of these species in the tidal area depends on the availability of food and suitable substratum.

Mangroves are directly or indirectly associated with a variety of benthic communities. Studies on the benthic fauna have attained considerable importance due to the increasing knowledge of their significant role in the trophic cycle. According to Carter *et al.*, (1973) the mangrove themselves are the primary food-producing agents in tropical estuarine ecosystems, producing as much as 80% of the total organic materials available to the aquatic food chain. The primary production of mangrove trees is high (Bunt *et al.*,1979 and Ong *et al.*, 1984) and since few animals graze on them, this production may be important to coastal ecosystems (Chong *et al.*, 1990). The benthic animals are responsible for secondary productivity. The benthic invertebrates play a very active role in the degradation of leaf material of the mangrove trees. Detritus, together with the benthic fauna becomes food for animals at higher trophic level, either directly or indirectly, through intermediaries.

1.6 REVIEW OF LITERATURE

The benthic fauna of several mangrove swamps have been studied in different parts of the world. Macnae and Kalk (1962) have studied the ecology of the mangrove swamps of Inhaeca Island, Mozambique. Berry (1963) has investigated the faunal zonation of Malayan mangrove swamps. Macnae (1963, 1967, 1968) has studied the distribution of both plants and animals in mangroves in South Africa, in North Queensland, Australia and in the Indo-West Pacific region. Walsh (1967) made ecological observations of a Hawaiian mangrove swamp. The occurrence and distribution of crabs in a Jamaican mangrove swamp has been studied by Warner (1969). Sasekumar (1974) has investigated the distribution of macrofauna of Kapar mangrove forests in Malaya. The mangrove fauna of Morrumbene estuary, Mozambique has been studied by Day (1975). Evink (1975) has studied the macrobenthos of Southwestern Florida mangrove estuary. Richmond and Ackermann (1975) have investigated the flora and fauna of mangrove formations in Fiji. Wilcox *et al.* (1975) have studied the ecology of mangroves in the Jew fish chain Island, Bahaman. Frith *et al.* (1976), Nateewathana and Tantichodok (1980) and Shokita *et al.* (1983) have conducted investigations on the macrofauna in the mangrove areas of Thailand. Victoria and Perez (1979) have studied the mangrove benthic fauna in Colombia. Amador and Espinosa (1981) have made studies on the macrobenthic invertebrates and their distribution in the Balandra mangrove swamp. Espinosa *et al.* (1982) have investigated the benthic ecology of the mangrove areas in Mexico. Wells (1983) has studied the distribution of marine invertebrates in a mangrove swamp in northwestern

Australia. The faunal variation in Trinidad mangroves has been studied by Durham and Ramcharan (1985). Rueda and Gosselck (1986) have carried out studies on the benthos of mangrove coastal lagoons in southern Cuba. The benthic macrofauna dwelling on mangrove trees in Jiulong Jiang estuary, Fujian, has been worked out by Zhou *et al.* (1986). Dye and Lasiak (1988) have carried out the feeding ecology of fiddler crabs from a tropical mangrove area. Studies on the benthic fauna of the mangrove area in Iriomote Island, Okinawa, have been carried out by Shokita *et al.* (1989) and Omori (1989). Polychaete fauna from mangrove root-mats in Belize has been investigated by Weiss and Fauchald (1989). Guelorget *et al.*, (1990) have studied the macrobenthofauna of lagoons in Guadeloupean mangroves.

Though marine and estuarine benthic studies have been carried out in India over a period of half a century, only very little attention has been paid to benthic fauna of mangrove environments in relation to hydrological parameters and sediment characteristics.

The important benthic faunal and ecological studies of mangrove swamps in India include the following. Untawale *et al.* (1973), Dwivedi *et al.* (1975a) and Untawale and Parulekar (1976) have conducted ecological studies of an estuarine mangrove area of Goa. Joshi and Jamale (1975) have carried out ecological studies in the mangroves of Terekhol and Vashisti rivers. Untawale *et al.* (1977) has made productivity studies in a detritus rich mangrove swamp in Kollur estuary in Karnataka. Radhakrishna and Janakiram (1975) have studied the molluscan fauna of the mangrove swamp of Godavari and Krishna estuaries on the east coast. Pillai and Appukuttan (1980) have made observation on the molluscan fauna of the mangroves in southeastern coast. Dwivedi and Padmakumar (1980) and Padmakumar (1984) have investigated the benthos of mangroves in Bombay with reference to sewage pollution. Bhunia and

Choudhury (1981) and Nandi and Choudhury (1983) have studied the benthic macrofauna of Sagar Island in Sunderbans. Ali *et al.* (1983) has worked out the enrgy flow through the benthic ecosystem of the mangrove with reference to nematodes in Pichavaram mangroves in Tamilnadu. Singh and Choudhury (1984) have reported the occurrence of an enteropneust hemichordate from the mangrove swamps of Sunderbans. Choudhury *et al.* (1984a, 1984b) have investigated the macrobenthos in Sunderbans. Krishnamurty *et al.* (1984) has carried out the structure and dynamics of the aquatic food web community with special reference to nemetodes in Pichavaram mangrove. Rajagopalan *et al.* (1985) has conducted a comparative study of ecological aspects of mangrove biotopes in four different regions of India. Misra and Choudhury (1985) studied the polychaetous annelids from the mangrove swamps of Sunderbans. Kasinathan and Shanmugam (1985) conducted an investigation on the molluscan fauna of Pichavaram mangroves. Chakraborthy and Choudhury (1985) have studied the distribution of fiddler crabs in Sunderbans. Sing and Choudhury (1985) have investigated the biology of *Saccoglossus* sp. from the mangrove mudflats of Sunderbans. Studies on the benthic insects in Sunderbans mangrove ecosystem have been made by Ray and Choudhury (1985a, 1985b) and Poddar and Choudhury (1985). Mall *et al.* (1985) and Rajagopoalan (1987) have made studies on the ecological aspects of mangrove forest in Andamans. Devi *et al.*, (1986) have studied the heterotrophic bacteria flora of the gut contents of the polychaete *Ceratonereis costae* and the amphipod *Paracalliope fluviatilis* associated with the sediments of Pitchavaram mangroves. Community structure and assemblage of economically important benthic penaeid and non-penaeid juvenile prawns from the mangrove biotope in Porto Novo has been studied by Sambasivam and Krishnamurty (1986). Parta *et al.*, (1988, 1990) have investigated the ecology of macrobenthos in a tidal creek and adjoining mangroves in West Bengal. Singh and Choudhury (1992) have reported on a new record of *Protankyra similis* (Semper), a detritivore holothuroid from the mangrove swamps of deltaic Sunderbans. Chakraborty and Choudhury (1992) have elucidated the zonation of brachyuran crabs in Sunderbans mangrove ecosystem.

A concise account of the mangroves of Kerala could be found in the work of Troup (1921), who also summarised Bourdillon's (1908) account on Kerala mangrove. Bourdillon (*loc. cit*) reported the occurrence of *Bruguiera gymnorhiza* and two species of *Avicennia* from Quilon. Gamble (1915-'36) also dealt with the mangroves of Kerala coasts. Thomas (1962) and Rao and Sastri (1974) recorded nine species mangrove flora from Veli, Trivandrum. Blasco (1975) recorded *Acanthus ilicifolius*, *Rhizophora* sp. and *Cerbera manghas* from the Quilon backwaters. Kurian (1984) reported the occurrence of *Acanthus ilicifolius*, *Avicennia alba*, *Rhizophora* sp. and *Bruguiera* sp. in Cochin estuary. He observed the larval forms of some species of fishes and prawns in the area.

The colonization of the mangrove *Acanthus ilicifolius* in the sea acreted regions of Cochin has been worked out by Muralidharan (1984). Thomas (1985) has carried out studies on the nutritional value of fresh and decomposed leaves of mangrove plants for juveniles of the prawn. The habitats dominated by *Avicenia officinalis* has been carried out, including germination and growth of seedlings, by Meenakshy (1985). Mini Raman (1986) has studied the rhizophere microflora of the tropical mangrove plant *Acanthus ilicifolius*. A total of 30 bacterial strains were isolated and six genera were identified from these isolates.

Rajagopalan *et al*. (1986a) in an appraisal of the mangrove ecosystem in Cochin backwater, suggested that, they are formative, mostly developing on small reclaimed or natural Islands, with the dominant vegetation constituted by species of *Acanthus*, *Excoecaria*, *Clerodendrum*, *Aegiceras*, *Avicennia* and *Rhizophora*. Rajagopalan *et al*. (1986b) has conducted a field study on the productivity in three different mangrove areas - Cochin Backwater, Killai Backwater and Andaman Nicobar Islands. They estimated that the average quantity of detritus resulting from mangrove litter fall as 1500 kg/ha/annum from the mangrove areas at Cochin. Ramachandran *et al.* (1986), after a detailed survey along the entire coastal stretches of Kerala, reported 39 species of mangroves and mangrove associates. They included some new species that were not reported earlier. They considered two species namely *Syzgium travancorium* and *Ardisia litoralis* are unique to Kerala mangrove. According to Ramachandran and Mohanan (1987), until a few centuries ago, backwaters of Kerala were fringed with rich mangrove vegetation. An estimate, based on authentic record (Blasco, 1975), indicated that there were about 70, 000 ha of mangroves in Kerala, which have become reduced to a few hundred ha, largely confined to some estuaries and creeks. Along the Kerala coast, the mangrove formations are found at Veli, Quilon, Kumarakom, Cochin, Chetwai, Nadakkavu, Edakkad, Pappinisseri, Kunjimangalam and Chitheri. The highly restricted occurrence of mangroves could be directly attributed to the gross interference of man, most callously felled them down either to convert these areas for settlement, mariculture or for other land use purposes.

Prabhakaran *et al.* (1987) have carried out a systematic study of the fungal flora and their decomposing activity for the three seasons prevailing in Cochin, and their possible role in nutrient regeneration in Mangalvan, an estuarine mangrove area of Cochin backwater. They recorded 31 fungal isolates from the soil and 27 from decaying, leaves, stems, roots, pneumatophores and from free floating plants. Josileen Jose (1989) estimated the total litter production from the habitats dominated by *Bruguiera cylindrica* within the Cochin estuarine system to be 76.30 tonnes/ha/year. According to her, the maximum litter fall was observed during premonsoon period. During June and middle August, the litter production was found to be more. Prabhakaran and Gupta (1990) have studied the enzymatic and phosphate solubilization abilities of fungal isolates in the mangrove soil of Mangalvan.

Preetha (1991) estimated the total litter production from *Rhizophora* sp. dominated mangrove ecosystem at Cochin to be 8.568 tonnes/ha/year of which 12.7, 23.5, and 63.6% is contributed by twig, leaves and fruits respectively. Sivadasan (1991) has made a systematic study of mangrove and allied species of Mangalvan. He reported on 19 different plants growing in Mangalvan and among these 10 are halophytes, usually seen growing in saline areas, and the rest in waste land as well as other areas. The texture and geochemical aspects of the sediments of Kumarakom mangroves have been studied by Badarudeen (1992). Radhakrishnan (1992) has conducted a study on the micro algae of the mangrove ecosystem in and around Cochin.

1.7 SCOPE OF THE PRESENT WORK

All the above mentioned works in Kerala mainly deal with the mangrove flora and associated ecosystem. Eventhough, the taxonomy, distribution, and other aspects of mangroves have been investigated for the last few years, no attempt has been made to study the benthic fauna in the area. The benthos play an important role in the mangrove habitat. Since the mangrove area is an important nursery ground for many economically important fin and shell fishes, an understanding of their benthic fauna is necessary to obtain a thorough knowledge of the food chain in the area. The paucity of the work on benthic fauna of the mangrove areas in the south west coast of India and the importance of mangrove swamps in fishery, has necessitated the present study. The investigation was undertaken with a view to studying in detail the benthic macrofauna of the mangrove swamps of Cochin area, in relation to their environmental parameters.

Chapter II

COMPOSITION AND CONSERVATION OF THE MANGROVES OF COCHIN AREA

2.1 USE OF MANGROVES TO MANKIND

The importance of mangroves in apiculture and wild life management and in serving as feeding, roosting and breeding grounds for several migratory birds has been reviewed by Choudhury and Chakraborty (1974) and Mukherjee (1959, 1975). Kumarakom mangroves, in Kerala, is a famous bird sanctuary, managed by the Kerala Tourism Department Corporation. The Mangalvan, in Cochin, is declared as a protected area, by the Forest department in 1991. Many migratory birds visit this area as winter migrants. Similarly Pulicat mangrove was declared as bird sanctuary by the forest and rural development department in Andhrapredesh (Jayasundarama *et al.*, 1987).

The aquaculture importance of mangrove ecosystem has been stressed by Jeyaseelan and Krishnamurthy (1980), Macintosh (1982), Chakraborty (1984), Parulekar (1985), Krishnamurthy and Jayaseelan (1984, 1986) and Silas (1986, 1987). Mangroves act as critical habitats for several marine species of fin fishes and crustaceans during their early growth, and then returning to the sea for spawning. These are also areas where some species migrate to spawn. Mangrove areas support fortuitous distribution as well as diel and seasonal ingress of species from the inshore waters, besides harbouring a rich resident population of aquatic organisms. The mangrove ecosystem eventually provides an excellent supply of organic detrital matter in the early food chain of coastal and insular habitats.

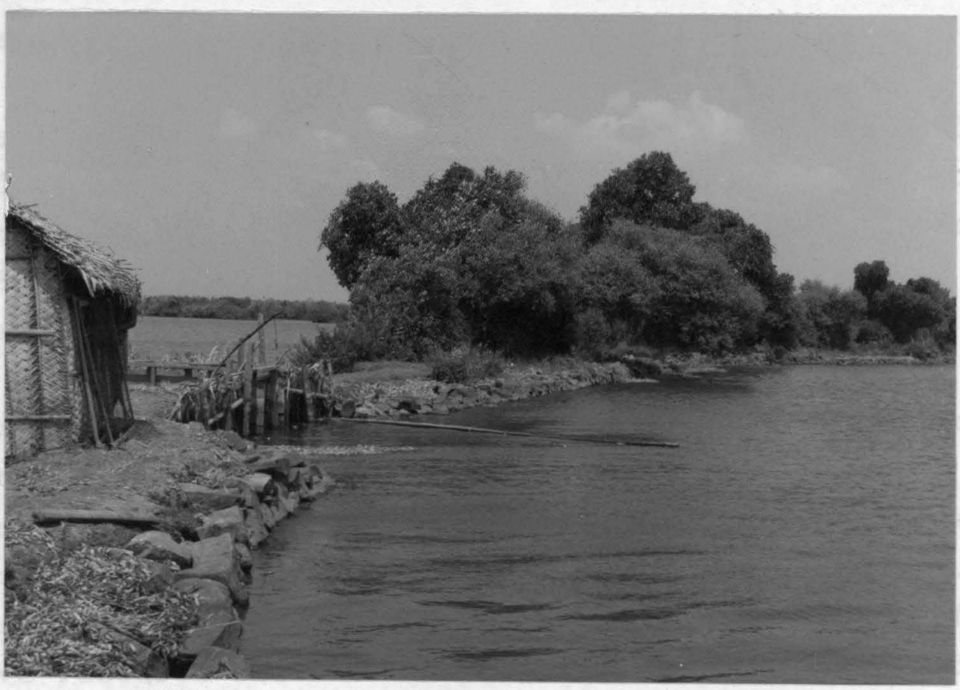
Abundance of particulate organic matter, so important for life history stages of crustaceans and fin fishes, helps enhance recruitment to the neritic population of the concerned species (Silas, 1987). According to Parulekar (1985) for the past many centuries, the conversion of mangroves for setting of fish ponds, is in practice in the central zone of India; variously called 'chemmeen kettu' in Kerala (Fig. 2.1), 'bheris' in West Bengal, 'gazari' in Karnataka, 'khazan' in Goa and 'khar lands' in Maharashtra. In India, especially in the last decade, a number of experimental aquaculture farms, have been developed in the mangrove habitats or in estuaries linked with mangrove vegetation.

The waters, around mangrove harbours rich fishery resources. The major fishery resources found in these waters are detritivorous species of fishes, crabs, crustaceans and molluscs. Krishnamurty (1984) has estimated the yield of mangrove-cum-estuarine dependent fisheries of India. Krishamurty and Jayaseelan (1984) have compared the animal production in the Pichavaram mangroves with the adjacent area without mangrove. According to them, prawn production in the mangrove area was 110 kg/ha/yr and in the adjacent area 20 kg/ha/yr; fish productions were 150 kg and 100 kg, respectively. Mangrove swamps are ideal locations for brackishwater fish seed (Dwivedi and Reddy, 1976; Sundararaj, 1978). Mangrove swamps are very important from the fishery point of view, not only because they enrich the coastal waters by their high primary productivity and nutrient export, but also due to their role as major nursery grounds for many commercially important fishes and prawns.

Despite their importance, mangroves are being destroyed throughout the world. This is an acute problem in developing countries, where conservation programmes are not in practice. The Cochin mangrove areas have been converted into many useful purposes such as paddy-cum-prawn culture, human settlement and

Figure 2.1 A traditional 'chemmen kettu' field showing the mangroves on the bund

Below: Sluice gate for tidal water control



coconut plantation (Rajagopalan *et al*. 1986a; Vannucci, 1984, 1986 and Silas, 1987). According to Krishnamurty (1985) human impact has already resulted in large-scale disappearance of many species of mangrove vegetation all over India. The illicit cutting of trunks and branches of *Avicennia*, *Rhizophora*, the stilt roots of *Rhizophora* result in a short canopy. The mangroves observed in many areas of Cochin are dwarf, indicating the prevalence of indiscriminate cutting of the trees. Dwarfing has been found to be acute in areas where the swamp is partially cut off due to reclamation in Bombay (Dwivedi *et al*., 1975b). A number of multistoried residental buildings have come up in the last decade on the reclaimed mangrove areas in Bombay (Padmakumar, 1984). Along with mangrove plants, mangrove fauna is also exploited. According to Kasinathan and Shanmugam (1989) overexploitation of molluscan fauna for the sake of utilization in the lime industries from Pichavaram mangroves has led to the complete depletion of this fauna. Since gastropods and bivalves constituted an important part in the food chain, their preservation becomes still more important to save the crustacean and fish populations of this biotope.

The need for preservation of the mangroves in different parts of India has been emphasized by Krishnamurty *et al*., 1975; Krishnamurty, 1985; Rao *et al*., 1985; Jayasundaramma *et al*. 1987; Rahaman, 1987; Ramachandran and Mohanan, 1987; Rajagopalan, 1987; Silas, 1987 and Untawale, 1985, 1987.

Mangroves are valuable resources. Many countries are now trying to conserve, as much as possible, this type of forest ecosystem. In recent years there has been an international awareness about this fragile ecosystem. The Asian countries now recognise the need for management and conservation of this extensive resource and the desirability of introducing advanced technology to further increase its economic potential. Best management for full economic potential, and optimum conservation of mangrove areas should be determined before they are all removed in the interest of other activities.

Knowledge on mangrove ecosystem in various aspects is very important for effective conservation, management and utilization of mangrove resources. So far, the knowledge on mangrove ecosystem is inadequate, especially functioning of the ecosystem. However, for the effective conservation of this resource, several steps have to be taken into consideration. Educational programmes should emphasize the ecological and economic values of mangrove ecosystems as natural resources and should help support and enforcement of regulations protecting the mangroves. The participation of public is very important for the conservation of mangroves. As the inhabitants are the real users of the resources, their good understanding of mangroves is very important (Aksornkoae,1985).

In order to conserve mangroves, serious and sustained efforts should be made to promote the studies on mangrove ecosystem. Even now our surveys of mangrove areas are far from adequate. There has been no attempt to conduct such a survey on all-India basis, simultaneously even once in ten years like the census. We have already lost a great many mangrove areas and what is left now would be only a part of what existed about a century ago. If this rate of depletion goes on unchecked, mangroves will get completely wiped out from our country in a very short time.

Although mangrove trees, swamps and other products have been exploited in India since time immemorial, the research and development concept in this field is quite recent. According to Untawale (1987) the idea of exploration and exploitation of the mangrove resources has taken root in India during the last 2-3 decades. However, conservation of mangrove forests and its environment has not received adequate attention till recently and we have to go a long way. No other plant community in the world has, perhaps, attracted more scientific attention than this one.

Recently, there is greater awareness on the values of this specialised ecosystem and the Ministry of Environment and Forest of Government of India is taking positive steps to promote research, and conservation measures, though the patchy mangroves of Kerala is yet to get deserving attention. The importance of mangroves is now accepted by all concerned. However, this in itself is not sufficient and often not adequate. Both modern scientific research and traditional practices have proved that if properly exploited or wisely converted, mangroves can offer high economic returns on a sustained yield basis without disturbing the ecological balance.

2.2 COMPOSITION OF COCHIN MANGROVES

In the present investigation an attempt was made to study the phytosociology of the mangrove assemblage in study area. The mangrove flora in the three sampling areas consists of 10 species belonging to 9 genera and 7 families; as is shown in Table 2.1. Some species of plants growing in Cochin have been shown in Figs. 2.2-2.12.

Station 1

Avicennia officinalis and *Bruguiera* sp. are the dominant species found in this area. They grow densely on the shoreward side, while *Acanthus ilicifolius* and *Clerodendrum inerme* occur in the interior of the mangrove forest. *Derris trifoliata* is a conspicuous climber on mangal. Less dominant and scattered species include *Acrostrichum aureum* and *Rhizophora apiculata*.

Table 2.1 Classified list of mangroves in Cochin area

No.	Mangals	Family
1.	*Rhizophora mucronata*	Rhizophoraceae
2.	*Rhizophora apiculata*	Rhizophoraceae
3.	*Avicinnia officinalis*	Verbenaceae
4.	*Acantus ilicifolius*	Acanthaceae
5.	*Bruguiera* sp.	Rhizophoraceae
6.	*Acrostrichum aureum*	Fern
7.	*Clerodendron inerme*	Verbenaceae
8.	*Cerebra odollom*	Apocyanaceae
9.	*Derris trifoliata*	Leguminosae
10.	*Sonneratia apectala*	Sonneratiaceae
	Associates of mangroves	
1.	*Ipomoea* sp.	Convolulaceae
2.	*Hydrophila angustifolia*	Acanthaceae
3.	*Sphaeranthus indicus*	Compositae
4.	*Xanthium strumarium*	Compositae
5.	*Achyranthus aspera*	Amarataceae

Station 2

Rhizophora mucronata is the dominant species found along the shoreward side of station 2 and it grow about 9 metre in heigt. The other species of sparse population are *Avicennia officinalis, Acanthus ilicifolius, Acrostrichum aureum, Cerbera odollam* and *Derris trifoliata*. Thick trees of *Rhizophora apiculata* are also seen here.

Station 3

Rhizophora mucronata and *Avicennia officinalis* are the dominating species found in this area. The other flora consists of *Acanthus ilicifolius, Bruguiera* sp., *Derris trifoliata, Acrostrichum aureum, Rhizophora apiculata, Cerbera odollam* and *Sonneratia apectala*. The area is mostly interspersed with *Rhizophora mucronata, Bruguiera* sp. and *Avicennia officinalis*. The shoreward side consists of dense patches of *R. mucronata*, as seen in station 2.

The associates of mangrove flora in the area consist of *Ipomoea sp., Hygrophila angustifolia, Sphaeranthus indicus, Xanthium strumarium* and *Achyranthus aspera*.

The mangrove formation in the area is of fringing nature and shows different ranges of distribution. *A. officinalis, A. ilicifolius, D. trifoliata, A. aureum and R. apiculata* are found to occur in all the stations, while the remaining species have a restricted distribution. Since the mangroves are of fringing type, the characteristic natural zonation of mangrove is not seen in the study area.

Around Cochin, good mangrove formation is seen in areas like Kannamali, Maradu, Elamkulam, Vypeen and Vallarpadam. Small patches and isolated strands are seen in Kumbalam,

Figure 2.2 *Avicennia officinalis*

Figure 2.3 *Bruguiera* sp.

Figure 2.4 *Clerodendrum inerme*

Figure 2.5 *Rhizophora apiculata* Figure 2.6 *Sonneratia apectala*

Figure 2.7 *Acrostrichum aureum*

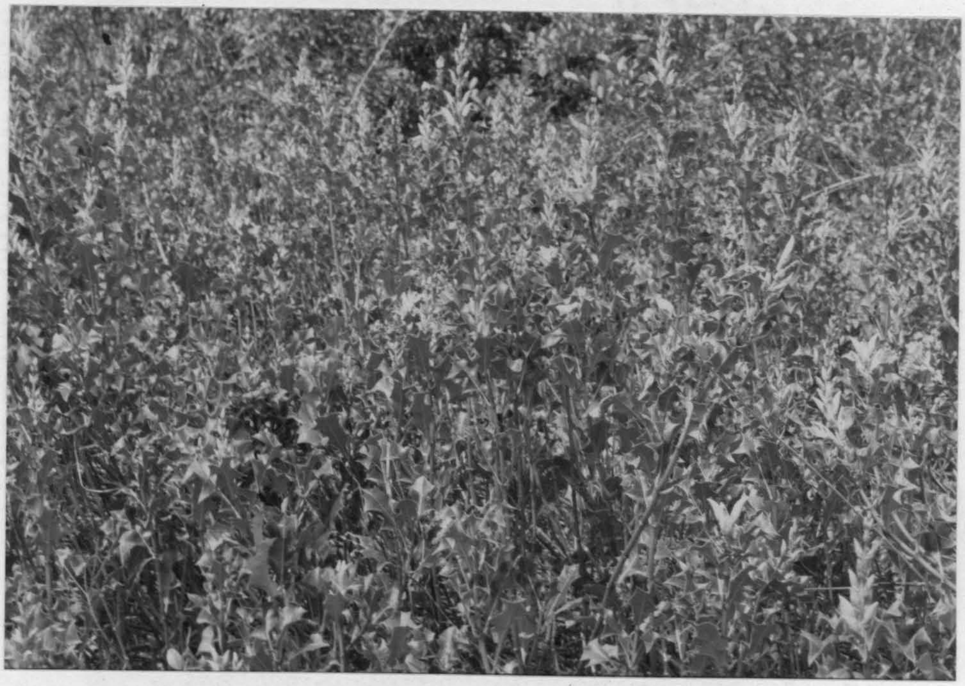


Figure 2.8 *Acanthus ilicifolius*

Figure 2.9 *Derris trifoliata*

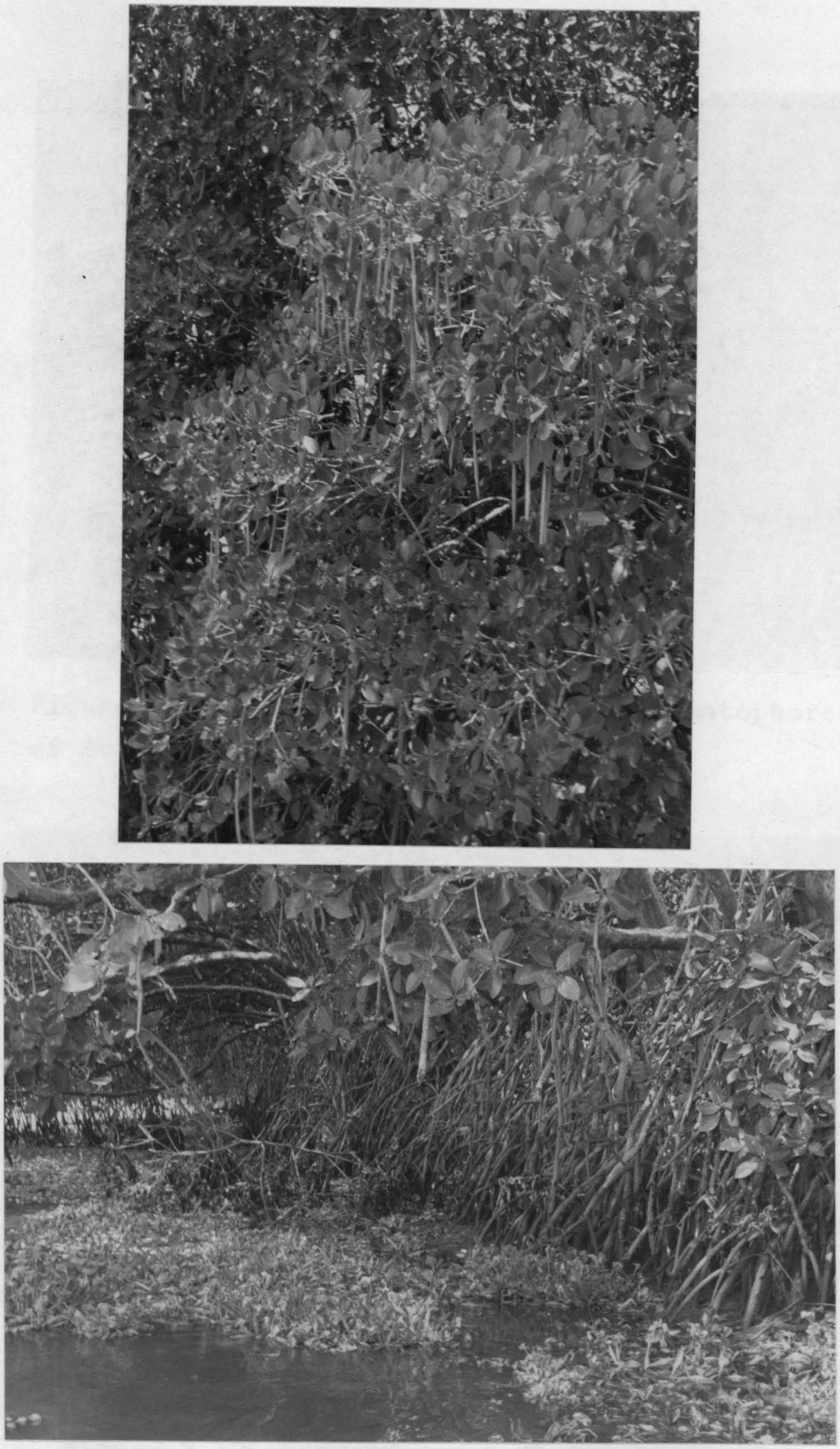


Figure 2.10 *Rhizophora mucronata*
Above: Branch with propagules
Below: Prop roots

Figure 2.11 Tidal area showing the pneumatophores of *Avicennia officinalis*

Figure 2.12 Exposed roots of *Bruguiera* sp.

Nettor, Panangad, Kundannor and Vytila. Most extensive and highly developed mangroves are found in Kannamali and Maradu. Among the flora *R. mucronata* is the most dominant species, followed by *A. officinalis* and *A. ilicifolius* (Fig. 2.13). *R. mucronata* is the largest species which grows upto 9 metre high.

According to Radhakrishnan (1985) eleven species of mangrove are found in Maharashtra; *R. mucronata* and *A. officinalis* being the dominant species. The mangals of Goa coast consists of 15 species of 10 genera and 7 families (Jagtap, 1985a). The dominant mangroves of Goa are *R. mucronata*, *A. officinalis*, *Derris heterophylla*, *Sonneratia alba*, *S. caseolaris*, *Acanthus ilicifolius* and *Acrostichum* sp. Mall *et al.* (1985) noted the presence of 26 species in Andaman. The Deogad estuary harbours 18 species of mangroves and associates (Krishnamurty and Untawale, 1985). Jayasundaramma *et al.* (1987) reported that the mangroves of south coastal Andrapradesh is dominated by *Excoecaria agallocha* and *Avicennia marina*. According to Rahaman (1987) the mangrove of Cauvery delta at Muthupet consist of *Avicennia marina*, *A. officinalis*, *Exoecaria agallocha*, *Suaeda maritima*, *Acanthus ilicifolius* and *Aegiceras corniculatum*. Of these, *A. marina* is the dominant form. Rao and Rao (1988) recorded 17 plants from Godavari delta complex. The dominant species of Sunderbans are *Aegiceras corniculatum*, *Sonneratia apetala*, *Excoecaria agallocha*, *Rhizophora mucronata*, *Avicennia alba* and *Acanthus ilicifolius* (Matilal and Mukherjee, 1989). According to Shanmukhappa and Neelakantan (1989) the dominant species are *Avicennia marina*, *Sonneratia alba* and *Rhizophora apiculata* in Kanwar mangroves. *Avicennia marina* is the dominant species, followed by *Acanthus ilicifolius* and *Avicennia alba*, in Lothian Island of Sunderbans (Ghosh *et al.*, 1990). Besides, *Excoecaria agallocha*, *Bruguiera gymnorrhiza* and *Sonneratia apetala* are also present. The dominant species of Cochin mangroves are *Rhizophora mucronata*, *Avicenia officinalis* and *Acanthus ilicifolius*.

Figure 2.13 Mangroves on the bank of Cochin estuary
Above: *Rhizophora mucronata*
Below: Mixed forest of *Avicennia officinalis*, *Rhizophora apiculata* and *Acanthus ilicifolius*

The exact nature of early mangrove vegetation on the banks of Vembanad lake is not fully known. This is because that the vegetation has undergone considerable disturbance during the last few years, due to human interference. They have been destroyed and used for fuel, and the land has been used for paddy cultivation, prawn culture, coconut plantation and other purposes (Fig. 2.14). The destruction of mangrove plants leads soil erosion and silting of Cochin backwaters. When accretion along the coast takes place, colonization by mangrove is rapid. In places where human interference is not affected, colonization of mangrove takes place along some stretches of Cochin backwaters, at present.

2.3 CONSERVATION OF COCHIN MANGROVES

As already stated in this work, with rapid industrialization and urbanization, the Cochin mangrove areas are subjected to persistent human interferences and relentless devastation. Conservation of mangroves of Cochin has not received much attention till recently. Therefore, an urgent effort is necessary to conserve this valuable ecosystem before they are completely destroyed.

The Cochin mangroves are very productive habitats and hence require better management practices to revive and strengthen them. The restoration of degraded or destroyed mangrove areas of Cochin could be beneficial to capture fisheries and aquaculture. The following general approaches are suggested in an action plan to be adopted in future to protect the existing mangroves of Cochin backwaters.

(a) Promoting awareness among fishermen communities and other people living along the coastal area, about the importance of the mangrove ecosystem and its protection.

(b) Attempts should be made, not only to preserve the entire

Figure 2.14 Destruction of mangroves for coconut plantation

mangrove vegetation, but also to improve it by aforesting with appropriate mangrove species along the coastal areas of estuarine system. In connection with the National 'Mangrove Generation Project', State committee on Science, Technology and Environment, Government of Kerala has taken step to develop the mangroves along Kerala coast. As a part of this project, mangrove plants have been replanted at Chetwai, Kandasamkadavu and Ponnai in Kerala. This scheme should be extended to other suitable areas.

(c) For the effective operation of conservation and protection of mangroves, laws and regulations should be established, and strictly implemented.

(d) An urgent and major effort is necessary to carry out precise surveys of the mangrove areas, by using and developing the modern techniques.

(e) In Cochin, only the Mangalvan is under the forest department of Kerala, as a protected area. The rest of the mangrove areas also has to be included as notified.

It is felt that the implementation of the above suggestions may help in a large way in the conservation of this valuable ecosystem in this state.

Chapter III
MATERIAL AND METHODS

3.1 THE STUDY AREA

The mangrove swamps situated in the Vembanad lake, the largest estuarine system in the south west coast of India, is located between latitudes 9° 30' and 10° 28' N and longitudes 76° 13' and 76° 31' E. This lake forms part of a Chain of the brackish water lagoons and estuaries, which stretch parallel to the coastline of Kerala extending over 325 km in length. Vembanad estuary is an open type and it has permanent connection with the Arabian sea (Lakshadweep sea) by a narrow channel, about 500 m wide. This ghut transmit tidal energy and sea salts into the lake. The average tidal range of the lake is about 1 m in the lower part of the estuary and it diminishes progressively towards the upper region. Tidal current from the arabian sea into the lake on one hand and the discharge of freshwater from the rivers and their tributaries on the other, mix salt and fresh water and make the lake a typical estuary.

A preliminary survey of the mangrove areas in the Vembanad lake was conducted during July-September 1989. Based on the results of the preliminary survey on the distribution of benthic fauna in different mangrove areas along the lake, three representative mangrove areas were chosen for sample collections. These three sampling stations are located along the lower part of the Cochin estuary, situated between latitudes 9° 52' and 10° N and longitudes 76° 15' and 76° 22' E (Fig. 3.1). Of these three localities, the first station is located at Guntu Island, near the Cochin barmouth and the third station at Maradu, about 22 km away from Cochin barmouth. The

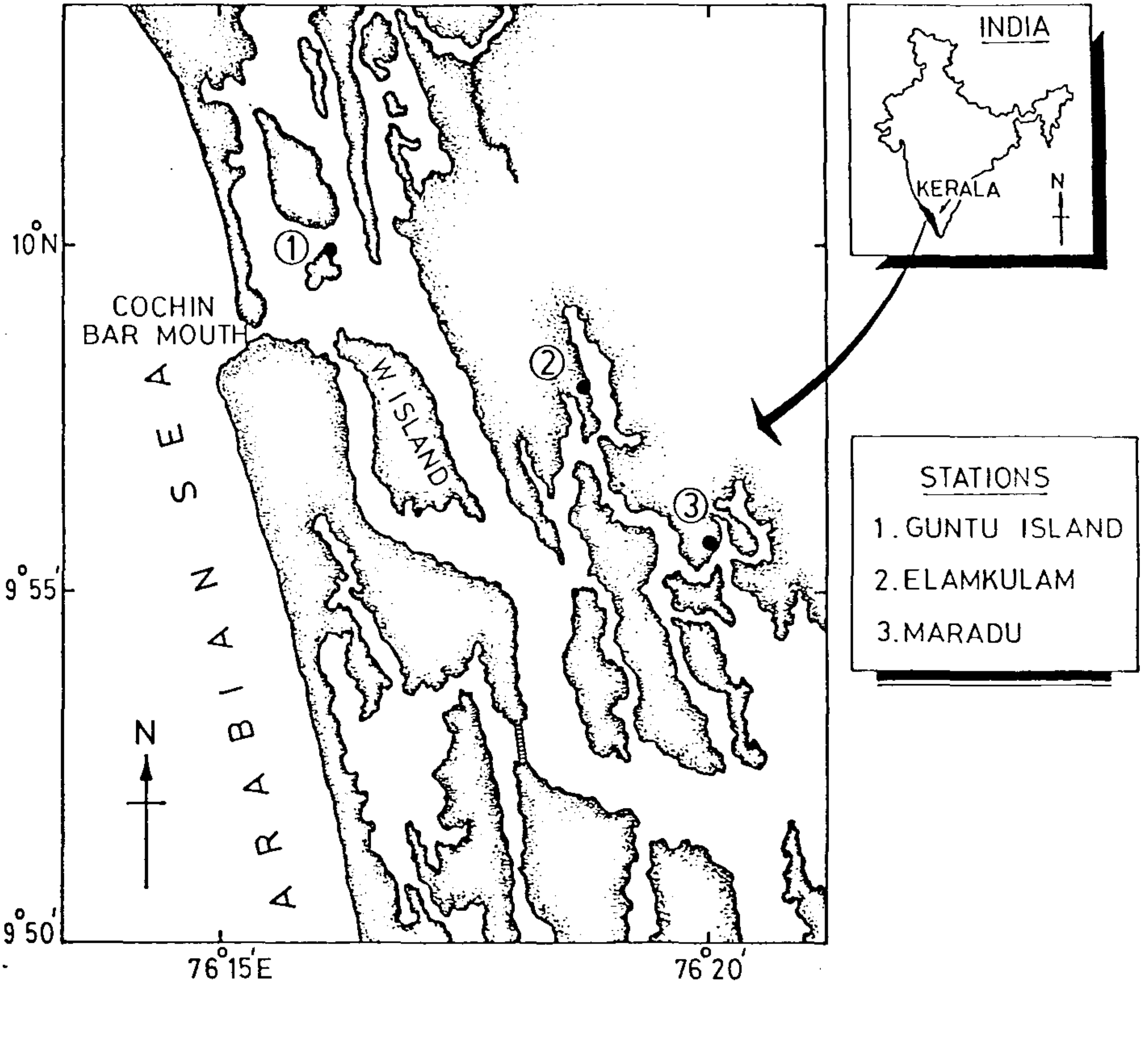


Figure 3.1 Map showing the location of stations

second station is situated at Elamkulam, in between stations 1 and 2.

Each station was divided into three sub zones - the low tide level (LTL), the mid tide level (MTL) and the high tide level (HTL). Based on the topography and the width of the tidal zone of each locality, transects were made across each tidal zone from low water mark to high water mark. Three points were fixed at equidistant intervals-the first one at the lower level of the receding tides, the third one at the highest level of the tidal zone and the second one at the mid region in between the first and the third (Fig. 3.2). These three zones constitute the tidal range area of the mangrove swamp. The study area receives tidal influx daily and it is of mixed semi-diurnal type with an average range of 1 m. The maximum tidal influx was observed at station 1, near to the barmouth.

Monthly collections were taken from three tidal zones for a period of two years from September 1989 to August 1991 and the monthly mean values were taken. All the collections were taken during low tide period.

3.2 FIELD COLLECTION

For the collection of sediment samples, methods described by Sasekumar (1985) and Home and Mc Intyre (1971) were adopted. Sediment samples were taken using a box corer (120 cm^2 area) to a depth of about 20 cm. From this, the top 15 cm of the sample was taken for the study. According to Holme and Mc Intyre (1971) on some shores the majority of species and individuals occur in the top 15 cm. According to Sasekumar (1985) in a mangrove swamp, only organisms like large sesarmid crabs and mud-lobsters burrow below 20 cm depth. From a preliminary study, it was found that only a few organisms burrow beyond 15 cm depth. So in the present study the sampling depth was limited to 15 cm. Triplicate core samples were taken from the

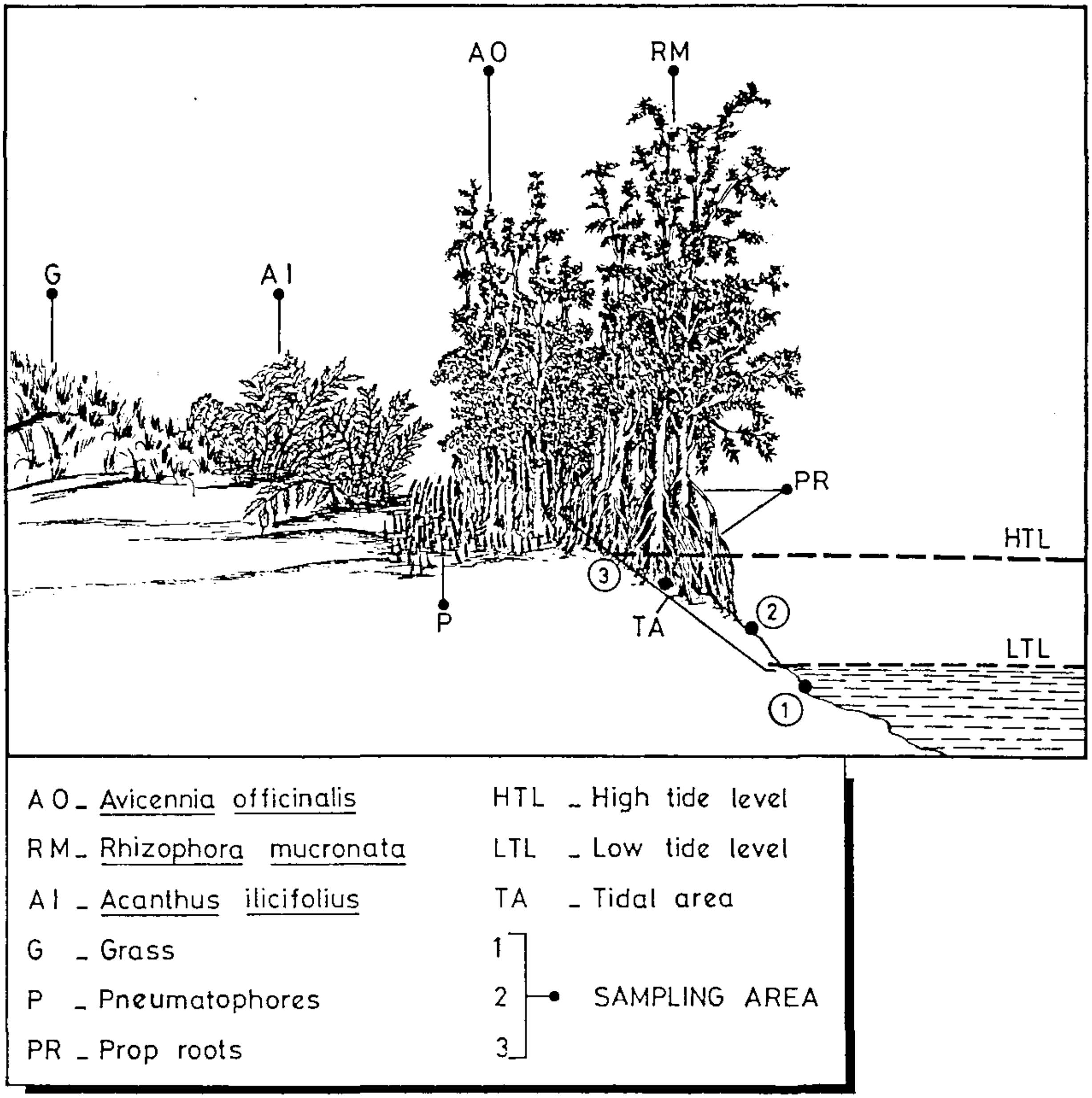


Figure 3.2 Diagrammatic representation of the tidal area showing location of sampling (not drawn the scale)
(1) Low tide level (2) Mid tide level (3) High tide level

transects of each tidal level for the analysis of fauna. The edge of the sample frame was sharpened so as to cut through roots and wood.

The contents of the corer was emptied using a plunger into a large plastic tray and the debris were removed. Each core sample was taken in a plastic tub and mixed well by pouring water and sieved by using a 0.5 mm mesh sieve and the mud and other materials were removed from the sample. The mesh size of the sieve used is of critical importance, and it is suggested that 0.5 mm sieve should be used for macrofauna (Birkett and Mc Intyre, 1971). From the preliminary study it was noted that sand particle form the major constituent in the area than silt and clay. Hence, 0.5 mm sieve was found more suitable for the present work. The sieved materials were preserved, using 5-10% neutralised formalin.

Based on size, the benthic organisms can be divided into three categories-macrobenthos, meiobenthos and microbenthos (Mare, 1942). The size limits of the three groups of benthic animals are arbitrary and different according to various workers. In general, the lower size limit of macrobenthos depends upon the mesh size of the sieve used, and usually varies between 0.5 and 2.0 mm, according to the international standard. A mesh size of 62 or 50 μ is appropriate for meiofauna separation, since one of these is usually accepted as demarking the upper limit of the silt-clay fraction of the sediment. But even finer meshes, 30 or 40 μ, are often used to ensure that most of the fauna is retained in the sieve (Home and Mc Intyre, 1971). The microbenthos include those organisms that are not retained in the finest sieve used for meiofauna separation and include bacteria and most of the protozoa. In the present study 0.5 mm sieve was used for the separation of macrobenthos.

For studying the vertical distribution of organisms in the mangrove substratum, the sample was cut into sections of suitable length, immediately after the collection, to avoid errors due to migration of the fauna (Sasekumar, 1985). In the present study the sediment core sample (15 cm) was split into 5 cm long vertical sections (0-5 cm, 5-10 cm and 10-15 cm strata) and each of which was taken and preserved. A small portion of the sediment sample from each strata was taken in a polythene bag, for determining the particle size, organic carbon and organic matter.

The environmental parameters such as air, water and sediment temperatures, salinity, dissolved oxygen, sediment *p*H and water *p*H were studied during the period of investigation. The temperature was measured using a standard mercury thermometer. Air temperature was recorded at about five feet above the ground and sediment temperature was recorded from a depth of 3-4 cm below soil surface.

3.2.1 Collection of polychaetes from the estuary

For a comparative study of the mangrove polychaete fauna with the polychaete fauna of the adjacent areas in the estuary, bottom samples were collected every month from three stations in the estuary, adjacent to the mangrove stations, for a period of one year from June 1990 to May 1991. These collection sites in the estuary were situated about 8-10 metre away from the respective mangrove stations. Simultaneous collections were taken from these areas. A van Veen grab of size 0.05 cm^2 was used for the collection of bottom sediments. Two grab samples were taken for the present study (Pillai, 1978). The contents of the grab were emptied into a large plastic tub and mixed well by pouring water. All organisms retained in a 0.5 mm mesh size were collected and preserved in 5-10% neutral formalin for further study. Sediment samples were also taken from the estuary for the analysis of particle size, organic carbon and organic matter.

3.3 LABORATORY METHODS

3.3.1 Estimation of hydrographic parameters

In the laboratory, chlorinity of water was estimated using the Mohr method (Barnes, 1959) and from chlorinity, the salinity was calculated using knudsen's table. Winkler's technique (Strickland and Parsons, 1965) was employed for the estimation of dissolved oxygen. *p*H of water and sediment were determined using a *p*H meter.

3.3.2 Analysis of benthic organisms

The sorting of the samples were done after washing and re-sieving using tap water, to remove residual sediment and formalin. The washed materials were transferred to a petri dish and the organisms were sorted carefully. Large size organisms were removed using forceps and smaller organisms using fine brush. All the animals in each sample were identified wherever possible, up to species level, counted and stored in 5% neutral formalin. The polychaetes were identified, following Fauvel, 1953 and Day, 1967. For the identification of molluscs, Gude (1921), Hirase (1934) and Tebble (1966) have been followed. Chhapgar (1957) was followed for the identification of brachyuran crabs. In order to compare the fauna, the number of animals present were converted into values per 0.1 m^2 (Thorson, 1957a).

3.3.3 Biomass estimation

Biomass is defined as the total amount of living matter present, and it is normally expressed as the biomass per unit area of habitat. It can be expressed in units of volume, mass or energy and may refer to the whole or part of the body of the organisms (Holme and Mc Intyre, 1971). In estimating the biomass, the water was drained and then the animals were weighed (Crisp, 1971). In the present study the biomass of the macrobenthos is represented in wet and dry weights.

The wet weight was taken after washing the preserved samples with distilled water. The shells of molluscs and the tubes of the tube dwelling polychaetes were removed before weighing. The water particles sticking to the body surface was wiped with blotting paper before weighing. Lovergrove (1966) has shown that preservation of animals in formalin may change the biomass. The changes are marked during the first few days of preservation. Therefore the wet weight for all the organisms were taken after eight weeks of preservation, in order to have uniformity in weight.

According to Lovergrove (1966) drying the animal tissue at 60°C for 16 hours is the best method for determining the dry weight of plankton, and this procedure was followed in the present study for determining the dry weight of macrobenthos. The dry and wet weight of the dominant group, polychaeta was taken separately. Crustacea, mollusca and the 'other groups' were taken together for determining the wet and dry weights. Both the values of wet and dry weights of the macrobenthic animals were expressed in square metre area, inorder to facilitate comparison of the values.

3.3.4 Sediment analysis

Sediment sample was thoroughly mixed and a portion of the sample was taken for the analysis. All debris and roots of plants were removed. The samples were dried in an oven at a temperature around 65°C. For textural study the sediment samples were subjected to combined sieving and pipette analysis, method described by Krumbein and Pettijohn (1938). 20 gm of dried sample was kept over-night in 0.25 N solution of sodium hexametaphosphate. The silt-clay fractions were separated by washing the dispersed sediment through a 230 standard mesh sieve. The coarser fractions retained in the sieve were dried and weighed. The washing collected in a measuring jar was analysed for silt and clay, by pipette method. The results were plotted in triangular diagrams (Shepard, 1954).

The organic carbon present in the sediment sample was determined by the method described by Walkley and Black (1934) and El Wakeel and Riley (1957). Organic matter in the sediment is obtained by multiplying the organic carbon values by a factor 1.724 (Trask, 1955).

3.4 STATISTICAL ANALYSIS

3.4.1 Diversity indices

Species diversity indices used were worked out by four formula suggested by Margalef (1958), Shannon and Weaver (1949), Hill (1973) and Sheldon (1969).

3.4.1.1 Richness indices

The formula used for calculation of Margalef's index or Richness index (R1) is,

$$R1 = \frac{S-1}{\text{In } (n)}$$

where S = total number of species in community
n = total number of individuals observed

3.4.1.2 Shannon's index

The Shannon's index (H') has probably been the most widely used index in community ecology. It is based on information theory (Shannon and Weaver, 1949) and is a measure of the average degree on "uncertainty" in predicting to what species an individual chosen at random from a collection of 'S' species and 'N' individuals will belong. This average uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even. Thus, H' has two properties that have made it a popular measure of species diversity: H' = o if and only if there is one species in the sample, and (2) H' is maximum only when all 'S' species are represented by the same number of individuals, that is, a perfectly even distribution of abundance.

The Shannon's index (H') is calculated by the formula,

$$H' = -\sum_{i=1}^{S}\left[\left(\frac{n_i}{n}\right)\ln\left(\frac{n_i}{n}\right)\right]$$

where ni = number of individuals belonging to the i^{th} of 'S' species in the samples

n = total number of individuals in the sample

3.4.1.3 Hill's diversity index

Hill's diversity index was worked out by the formula,

$$N1 = e^{H'}$$

where H' = Shannon's index

3.4.1.4 Evenness index

Evenness index (E2) was calculated by the formula,

$$E2 = \frac{e^{H'}}{S}$$

where H' = Shannon's index

S = total number of species in community

3.4.2 Anova technique

To study the significance of diversity indices with respect to seasons and tidal levels, anova technique was used (Snedecor and Cochran, 1968 and Fisher and Yates, 1957).

3.4.3 Faunal similarity

Trellis diagram (Sanders, 1960 and Wieser 1960) was used to study the similarity of the benthic fauna.

3.4.4 Correlation matrix

Pearson's coefficient of correlation (Snedecor and Cochran, 1968) was employed to find out the effect of environmental parameters on the distribution and abundance of benthic animals.

3.4.5 Multiple regression

Multiple regression model (Snedecor and Cochran, 1968) was used to study the effect of hydrological factors on the benthic biomass.

Chapter IV
ENVIRONMENTAL FACTORS

4.1 HYDROLOGY

The study of the hydrological parameters of the mangrove environment is important, since the spatial and temporal variations in the environmental parameters have profound influence on the benthic population of the ecosystem. So, the hydrological study of the Cochin mangrove area was conducted simultaneously, for a period of two years and the monthly mean value was taken. Ecological parameters such as temperature, salinity, dissolved oxygen and *p*H were studied during the period of investigation.

An important feature of the Cochin mangrove areas is the influence of south west monsoon which affects the hydrological conditions in a remarkable manner. Based on the influence of monsoon rains and the associated environmental conditions, the year can be conveniently split into three well defined seasons having characteristic hydrological features. The premonsoon season (February-May) is with very little rain fall and characterised by a fairly uniform high salinity and high temperature, the monsoon season (June-September) is characterised by heavy rain fall and high inflow of river waters into the estuary, causing considerable lowering of salinity. The postmonsoon season (October-January) shows an increase in the salinity and temperature values. The hydrological parameters of the mangrove areas of Cochin are shown in Figs. 4.1-4.3.

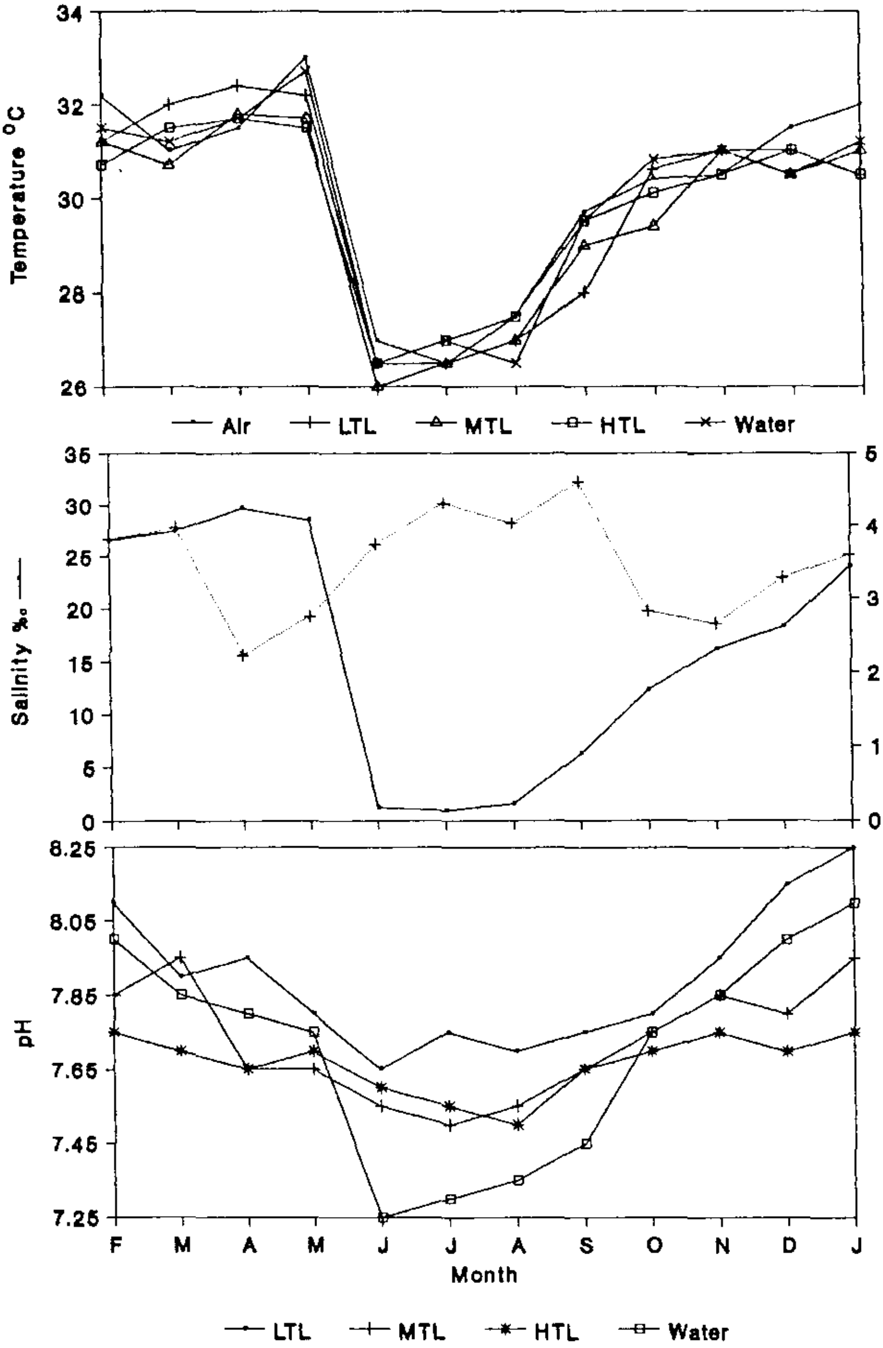


Figure 4.1 Monthly mean values of environmental parameters at station 1

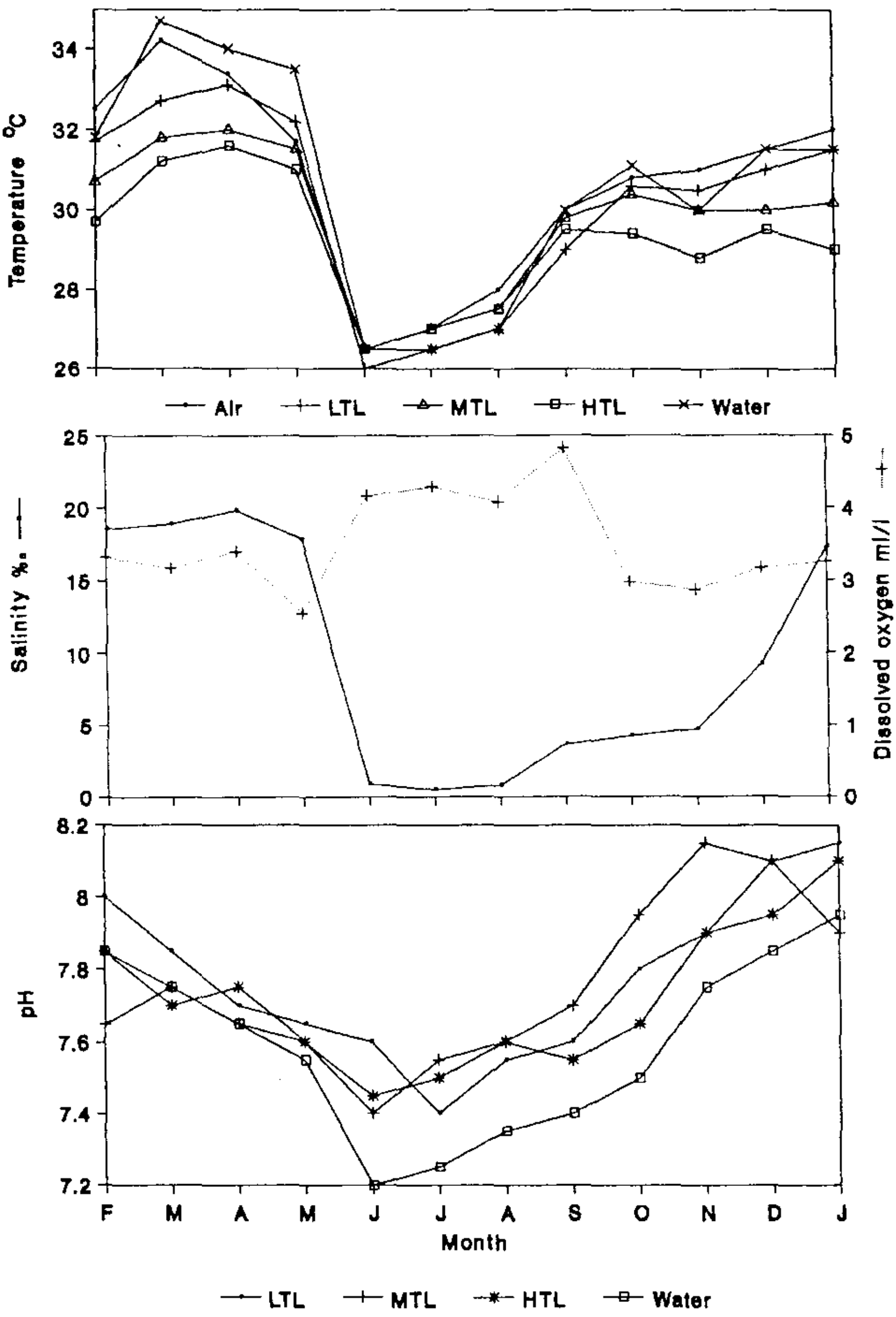


Figure 4.2 Monthly mean values of environmental parameters at station 2

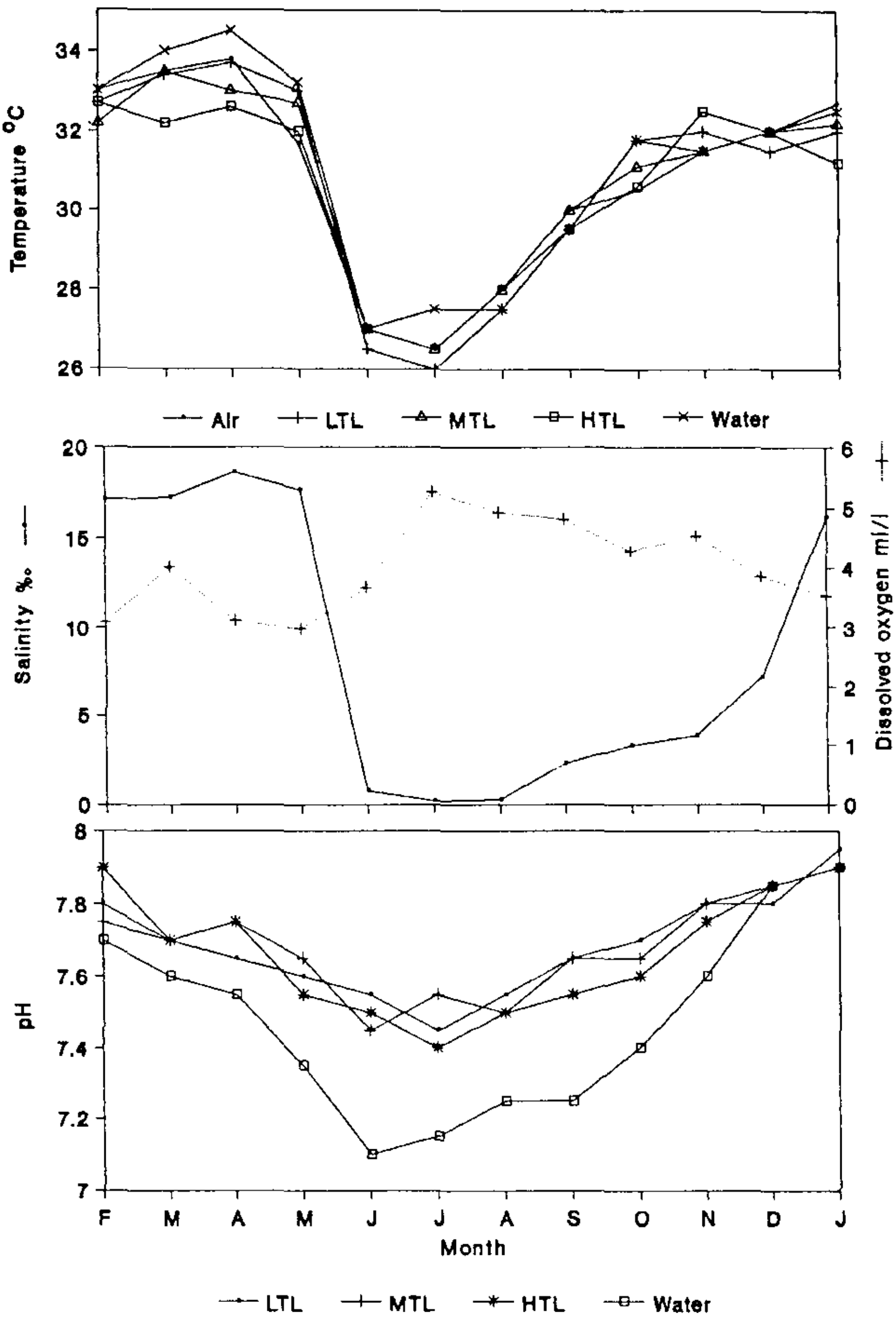


Figure 4.3 Monthly mean values of environmental parameters at station 3

4.1.1 RESULTS AND DISCUSSION

4.1.1.1 Temperature

During the premonsoon season the highest temperature of the atmosphere, water and sediment was observed in all the three stations. The highest atmospheric temperature of 33°C, 34°C and 33.8°C were recorded at station 1, 2 and 3 respectively. The sediment temperature varied from 30.7 to 32.4°C at station 1, 29.7 to 33.1°C at station 2 and 32 to 33.7°C at station 3. The highest sediment temperature of 33.7°C was recorded in the low tide level at station 3 in April. The water temperature varied from 31.2 to 32.7°C at station 1, 31.8 to 34.7°C at station 2 and 33.2 to 34.5°C at station 3. The highest water temperature of 34.7°C was noted at station 2 during this season.

The lowest atmospheric temperature of 26.5°C was noted during monsoon season. The temperature of sediment varied from 26 to 29.5°C at station 1, 26 to 29.8°C at station 2 and 26 to 30°C at station 3. During this season the water temperature ranged from 26.5 to 29.5°C, 26.5 to 30°C and 27 to 29.5°C at stations 1, 2 and 3 respectively.

At station 1 the sediment temperature varied from 29.4 to 31°C during postmonsoon period. It varied from 29 to 31.5°C at station 2, and 30.6 to 32.5°C at station 3. The water temperature varied from 30.5 to 31.2°C, 30°C to 31.5°C, and 31.5 to 32.5°C.

The importance of favourable temperatures for the establishment and development of mangroves has been emphasized by Macnae (1968) and Chapman (1977). Mangroves cannot tolerate temperatures less than 20°C for a continuous period. Therefore, mangrove formations are only found in the tropical and some sub-tropical coasts of the world (Untawale, 1987).

The water temperatures observed by the previous workers from different mangrove areas of India include that of Untawale *et al.* (1973), Shanmugam *et al.* (1986) and Rajagopalan *et al.* (1986a). In the present study, water temperature ranged from 26.5 to 34.7°C. The air, water and sediment temperatures were higher during the premonsoon and postmonsoon periods. The temperature showed comparatively low values during the monsoon months. The temperature in the Cochin mangrove areas was affected by the south west monsoon. The temperature showed its lowest value in June-July (air-26.5°C, water-26.5°C and sediment-26°C) and the highest in March-April (air-34.2°C, water-34.7°C and sediment-33.5°C). A decline in temperature was evident during the monsoon period. In the present study, the temperature of the air, water and sediments was always above 26°C and thus suitable for mangrove growth.

4.1.1.2 Salinity

A more or less stable salinity distribution pattern was observed during the premonsoon period. It ranged from 26.5 to 29.76‰ and 18.59 to 19.85‰ at station 1 and 2 respectively during this season. At station 3 the salinity varied from 17.13 to 18.64‰. The highest salinity of 29.76‰ was recorded in April at staion 1.

There was a sudden decline in salinity throughout the area during June-July with the onset of the southwest monsoon. The salinity varied from 0.97 to 6.25‰ at station 1, 0.48 to 3.69‰ at station 2 and 0.19 to 2.31‰ at station 3. The lowest salinity of 0.19‰ was recorded during this season at station 3.

During the postmonsoon period, a steady and regular increase in salinity was recorded in all the stations. The increase in salinity was from 12.26 to 24.01‰ at station 1, 4.29 to 17.31‰ at station 2, and 3.3 to 16.16‰ at station 3.

Among various hydrological factors studied, salinity is found to be the most fluctuating factor. The salinity pattern in the area is considerably influenced by the fresh water influx and rainfall. Most of the time of the year, brackish water conditions prevail in the area. The maximum salinity is recorded in April-May. This period is dry with less rainfall. With the onset of the south west monsoon, the flood water discharge from the rivers, causes a steep decline in salinity during June-July. During this period very low saline conditions (0.27-1.55‰) prevail in the study area. The influence of intermitant rain can again be seen during September-October, when the area is under the influence of the north-east monsoon. From october onwards the salinity gradually increases to reach the annual peak in April-May.

In general, the salinity conditions in the study area is as follows: During June-August, the entire area is *oligohaline* in nature (salinity 0.19-1.55‰). From September to November *mesohaline* condition (5-18‰) is observed at station 1. *Mesohaline* condition is seen from November to January at stations 2 and 3. *Polyhaline* condition is noticed from December to May at station 1 (18-29.76‰), and from February to May at stations 2 and 3 (18-19.85‰).

The salinity variations in different mangrove ecosystems in India were studied by Untawale *et al.* (1973), Joshi and Jamale (1975), Untawale and Parulekar (1976), Matondkar *et al.* (1980), Nandi and Choudhury (1983), Palaniappan and Baskaran (1985), Kasinathan and Shanmugam (1985), Shanmugam *et al.* (1986), Rajagopalan *et al.* (1986a) and Venkatesan and Natarajan (1987). Prabhakaran *et al.* (1987) reported that salinity in Mangalvan area of Cochin ranged from 2 to 3‰ during monsoon season. In the present observation in the Cochin mangrove areas, the salinity ranged from 0.27 to 6.25‰ during monsoon period. As mentioned earlier three pattern of salinity distribution has been observed in the study area. A high saline condition with very little fluctuations, during February to May; a comparatively low saline period from June to september; a period of increasing trend in salinity from October and reaching its maximum in April.

4.1.1.3 Dissolved oxygen

The dissolved oxygen content of water varied from 2.23 to 3.98 ml/l at station 1, 2.55 to 4.17 ml/l at station 2, and 2.98 to 4.02 ml/l at station 3 during premonsoon period. The minimum dissolved oxygen content of 2.23 ml/l was recorded during April at station 1.

Highest dissolved oxygen values were recorded during monsoon season at all stations. It ranged from 3.73 to 4.61 ml/l at station 1, 3.28 to 4.83 ml/l at station 2 and 3.67 to 5.26 ml/l at station 3. The highest dissolved oxygen value of 5.26 ml/l was recorded at station 3 during this season.

During postmonsoon season the dissolved oxygen content ranged from 2.64 to 3.58 ml/l, 2.86 to 3.26 ml/l and 3.28 to 4.53 ml/l at station 1, 2, and 3 respectively. During this season the maximum dissolved oxygen value of 4.53 ml/l was recorded at station 3.

The dissolved oxygen content of water in the area showed seasonal variations. Taking the whole area under investigation, it varied from 2.23 to 5.25 ml/l. Similar observations were made by some previous workers in different mangrove areas of India (Untawale *et al.*, 1973; Dwivedi *et al.*, 1975a; Sundararaj and Krishnamurthy, 1975; Untawale and Parulekar, 1976; Matondkar *et al.*, 1980; Palaniappan and Baskaran, 1985; Shanmugam *et al.*, 1986; Kasinathan and Shanmugam, 1985 and Rajagopalan *et al.*, 1986a).

In the present study, the highest values of dissolved oxygen content were recorded during the monsoon period, unlike salinity and temperature. According to Qasim *et al*. (1969) the higher oxygen content during the monsoon period may be due to the high primary production during this period. Further to that the high dissolved oxygen in the fresh water brought by rivers may also increase the oxygen content. During monsoon months, due to fresh water influx, the dissolved oxygen content increases (Untawale *et al*., 1973). The decrease in temperature may also be favourable for the increase in the dissolved oxygen values during this period.

4.1.1.4 pH

During premonsoon period the *p*H of sediment varied from 7.65 to 8.0 at station 1, 7.6 to 7.9 at station 2, and 7.55 to 7.8 at station 3. The water *p*H varied from 7.75 to 8.0, 7.55 to 7.85 and 7.35 to 7.7 at station 1, 2 and 3 respectively.

The *p*H showed a tendency to decrease in monsoon period. The sediment *p*H ranged from 7.5 to 7.75, 7.4 to 7.7 and 7.4 to 7.65 at station 1, 2 and 3 respectively during this period. The lowest sediment *p*H of 7.4 was recorded. The water *p*H ranged from 7.25 to 7.45 at station 1, 7.2 to 7.4 at station 2, and 7.1 to 7.25 at station 3. The lowest *p*H of water recorded was 7.1 at station 3 in June.

During postmonsoon months an increasing trend of *p*H was noticed. The *p*H of the sediment varied from 7.7 to 8.25 at station 1, 7.65 to 8.15 at station 2, and 7.6 to 7.95 at station 3. The highest sediment *p*H value of 8.25 was recorded at station 1 during January in the low tide level. The *p*H of water ranged from 7.75 to 8.1 at station 1, 7.5 to 7.95 at station 2, and 7.4 to 7.9 at station 3. The highest water *p*H of 8.1 was noted at station 1 during January.

Many of the life processes are dependent on and are sensitive to the hydrogen ion concentration in the surrounding medium. The *p*H of a medium depends on many factors like photosynthetic activity, rain fall, nature of dissolved materials, discharge of industrial effluents etc.

The *p*H of the sediment in different mangrove ecosystems were studied by some workers (Joshi and Kumar, 1985; Blasco *et al.*, 1985; Mall *et al.*, 1985; Sah *et al.*, 1985; Matilal *et al.*, 1986 and Ramamuthy *et al.*, 1990). Matilal *et al.* (1986) reported that the *p*H of the soil varied from 7.9 to 8.4 in Sunderbans mangroves. Joshi and Kumar (1985) recorded the *p*H in the mangrove soil of Gugarat coast ranged from 7.6 to 8.5. According to Frith *et al.* (1976), Mall *et al.* (1985) and Misra (1986) the *p*H of the sediment varied from acidic to alkaline in the Phuket and Andaman-Nicobar mangrove soils. Ramamurty *et al.* (1990) reported that the *p*H of sediment remained almost neutral (7-7.5) at Pichavaram mangroves. The *p*H is reported to be more often acidic in the Nypa zones, along the landward margins, while it is frequently alkaline in the seaward *Avicennia* fringes (Macnae, 1968). Navalker and Bharucha (1949) reported neutral to slightly acidic *p*H in the mangrove swamp of Bombay. The acidity of the mangrove soil is probably due to the activity of bacteria on oxidizable sulphur (Hart, 1959). The CO_2 arising from decomposition of organic matter and from animal respiration also lowers the *p*H values in the soil (Sasekumar, 1974). In the present study, it appears that *p*H of the sediment is subjected to decrease during monsoon period. The fresh water influence during the monsoon period may also favoured for the lowering of *p*H value in the sediment.

During the present study, *p*H of water varied from 7.1 to 8.1 in differnt seasons. The highest *p*H value of 8.1, 7.95 and 7.9 were recorded at station 1, 2 and 3 respectively during the end of postmonsoon period. This is attributed to the high saline condition and the excessive photosynthetic activity of algae, which may results in depletion of the amount of CO_2, and increase the *p*H value (Silas and Pillai, 1975 and Nair *et al.*, 1975). It is also noted that *p*H value gradually decreases from station 1 to station 3. This may be due to the reduced influence of the seawater intrusion into the interior part of the estuary, as is evident from the salinity gradient.

4.2 SUBSTRATUM

The nature of substratum plays a sigificnat role in the distribution and abundance of benthic assemblage. The physical and chemical properties of the sediments in relation to the qualitative and quantitative distribution of benthic organisms have been worked out by many workers from several geographic areas (Sanders, 1958; Johnson, 1971; Bloom *et al.*; 1972, Damodaran, 1973; Parulekar and Dwivedi, 1974; Parulekar *et al.*, 1975, 1980; Pillai, 1977; Chandran *et al.*, 1982; Govindan *et al.*, 1983, Ansari *et al.*, 1986; Harkantra and Parulekar, 1987; Varshney *et al.* 1988; Bhat and Neelkantan, 1988; Raman and Adiseshasai, 1989; Devi and Ayyakkannu, 1989; Devi and Venugopal, 1989; Murugan and Ayyakkannu, 1991; Vijayakumar *et al.* , 1991 and Prabhu *et al.*, 1993). The grain size, sand,silt and clay fraction and the percentage of organic matter in the substratum are significant factors which influence the distribution of benthic fauna.

The nature of sediment in any particular region is determined by the complex interaction of several factors such as, (1) source and supply of sedimentary material (2) the transportation and (3) factors determining deposition. If the interaction of the various factors remain stable over a period of time, nature of sediment will continue substantially unchanged. Any short term or long term change taking place in any one of the factors will always result alteration in the nature and composition of the sediment and associated fauna. During the process of transportation and deposition, the sediment is subjected to physical and chemical changes which are reflected in its character (Bloom *et al.*, 1972). According to Nelson (1962) the sediment of any particular region is a unique assemblage of matter retaining its own character and complexity. The nature of sediment in an area, may in turn give an indication of the factors operating in the transportation and deposition of sediments in that particular region. All these clearly show the importance of the study of sediments as one of the abiotic factors of the ecosystem, in understanding the complexity of ecological factors significant to benthic fauna.

Sediment characteristics of the Vembanad estuary were studied earlier by Josanto (1971), Veerayya and Murthy (1974), Pillai (1978), Antony (1979), Batcha (1984) and Nair *et al.* (1993). But no critical analysis of sand, silt, clay fraction and organic matter in the substratum of the Cochin mangroves has been carried out so far. Hence the present investigation was undertaken for a proper elucidation of these factors.

4.2.1 Results

The structure and composition of sediment particles of the mangrove areas of Cochin varies among the three tidal levels and at different locations. The results are plotted in triangular diagram (Fig. 4.4). The details of the texture of the sediments are given in Tables 4.1-4.3 (mean value of data given in Tables 4.6-4.8) and Figs. 4.5-4.7.

4.2.1.1 TEXTURE

Low tide level

In this area, the sediment was predominantly sand at station 1. The sand content of the sediment ranged from 79.67 to 86.34%. The percentage of silt varied from 5.19 to 11.56%

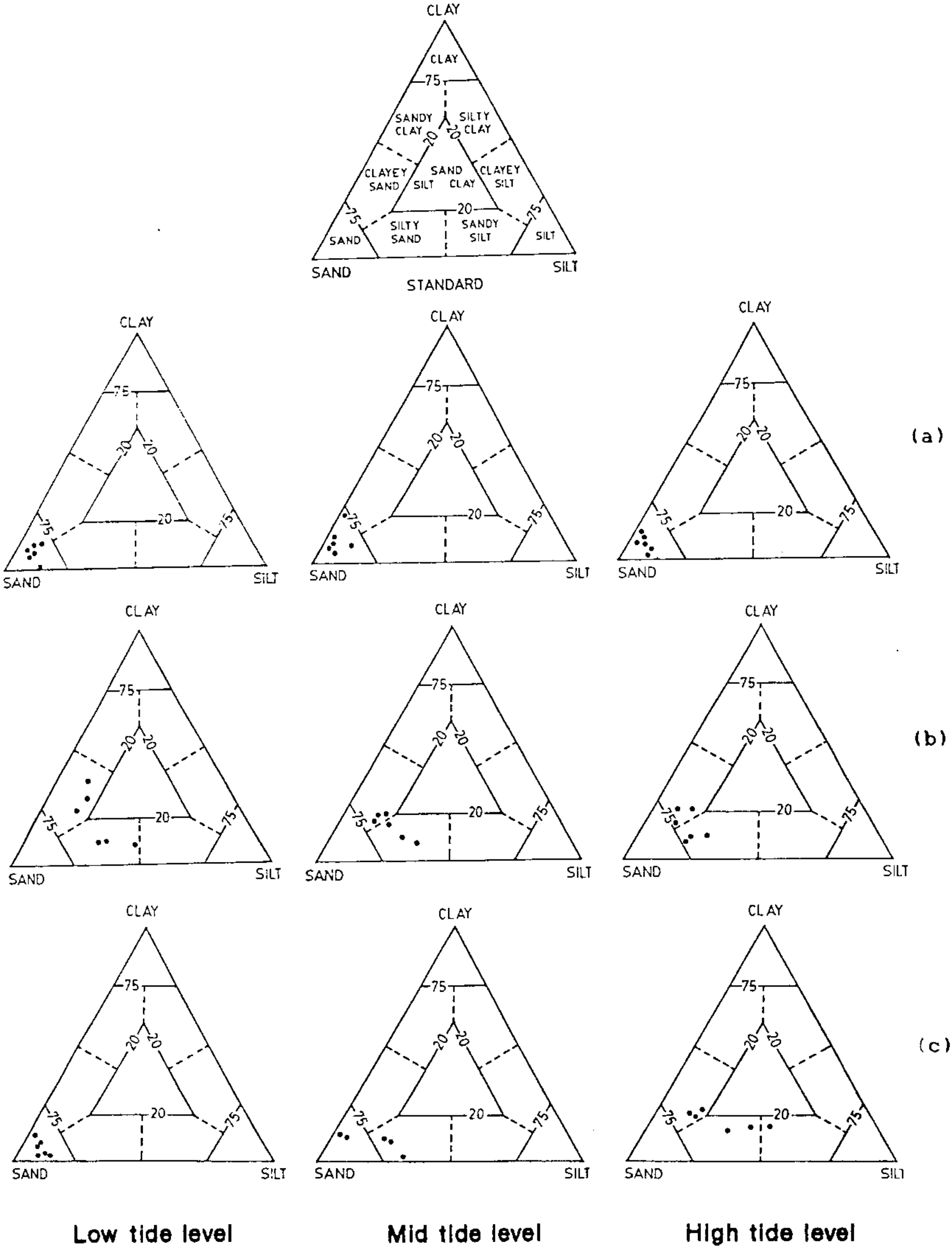


Figure 4.4 Triangular diagram showing texture of the sediment (a) Station 1 (b) Station 2 (c) Station 3

and the clay content ranged from 2.75 to 11.31%. At station 2 the sediment type was clayey sand during postmonsoon and premonsoon periods. The highest contribution of 35.33% clay was recorded during January. During monsoon period the sediment type was changed to silty sand. The clay particles showed a decreasing trend in this season. The highest silt content of 44.28% was noted during September. In this station the percentage of sand ranged from 47.77 to 62.37%. The silt component varied from 12.81 to 44.28%. The clay fraction was found to vary from 7.95 to 35.33%. At station 3 the sediment type was sandy. The sand content was between 84.26 and 88.5%. The silt and clay composition of the sediment varied from 3.48 to 12.14% and 2.01 to 11.04% respectively.

Mid tide level

The mid tide level was sandy at station 1 through out the year. Sand constituted 77.24 to 88.80%, silt 2.66 to 11.38% and clay 3.62 to 20.1%. As in the case of low tide level, the type of sediment was silty sand during postmonsoon and premonsoon periods in this tidal level at station 2. The highest composition of 19.15% clay and 34.22% silt were recorded during January and June respectively. The sand composition varied from 58.45 to 69.55%; silt portion varied from 13.49% to 34.22% and clay portion from 7.33 to 19.15%. At station 3 the substratum was sandy during post monsoon and premonsoon periods. But it was changed to silty sand during monsoon period. The silt content of sediment showed an increasing trend in this season and the highest silt percentage of 31.91 was recorded in September. The percentage of sand ranged from 66.76 to 85.28 and the silt from 3.32 to 32.06. The percentage of clay varied from 1.17 to 11.4%.

High tide level

Sand fraction dominated at station 1 and the sediment type

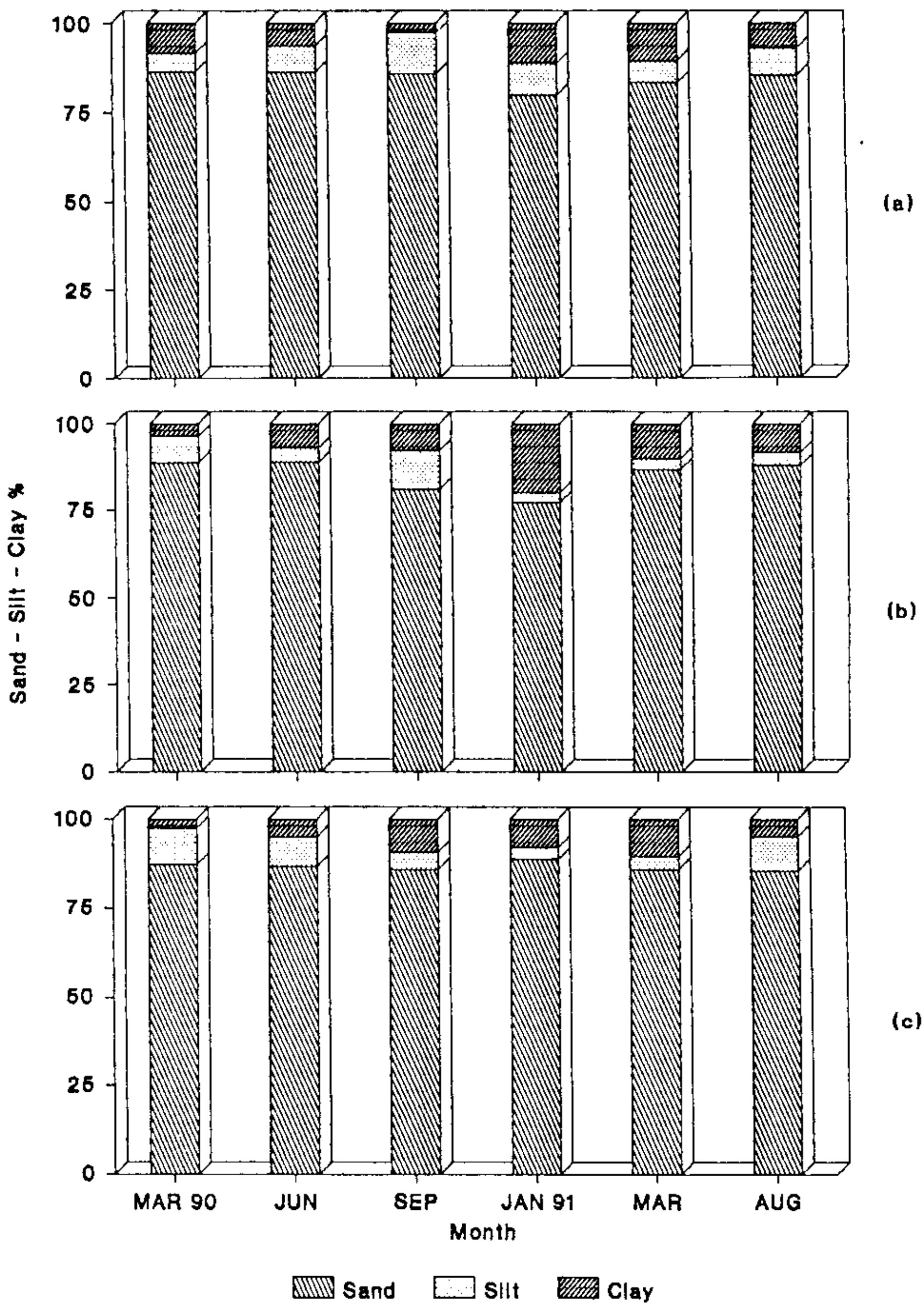


Figure 4.5 Sand-silt-clay percentages of the sediments at station 1

(a) Low tide level (b) Mid tide level (c) High tide level

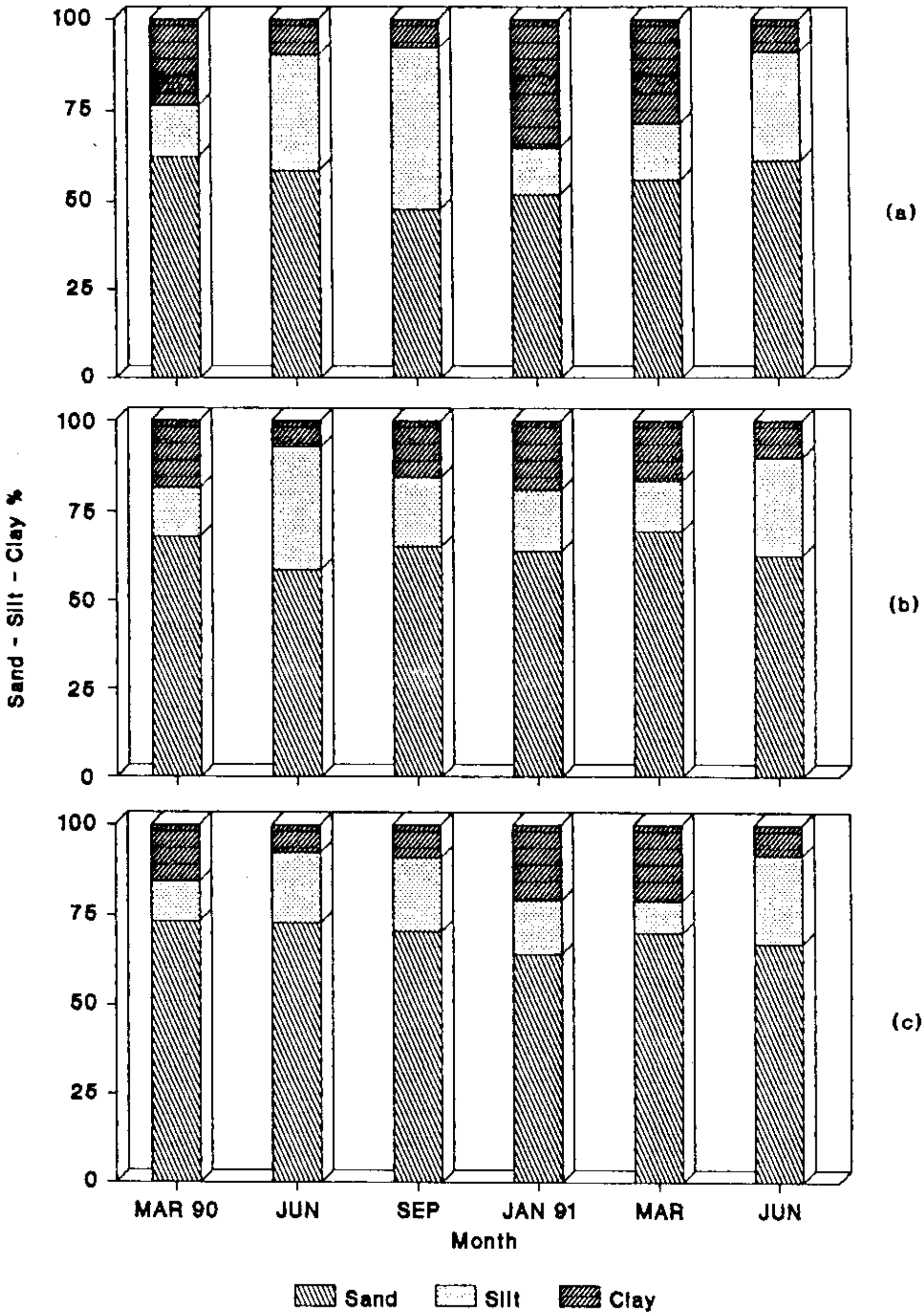


Figure 4.6 Sand-silt-clay percentages of the sediments at station 2

(a) Low tide level (b) Mid tide level (c) High tide level

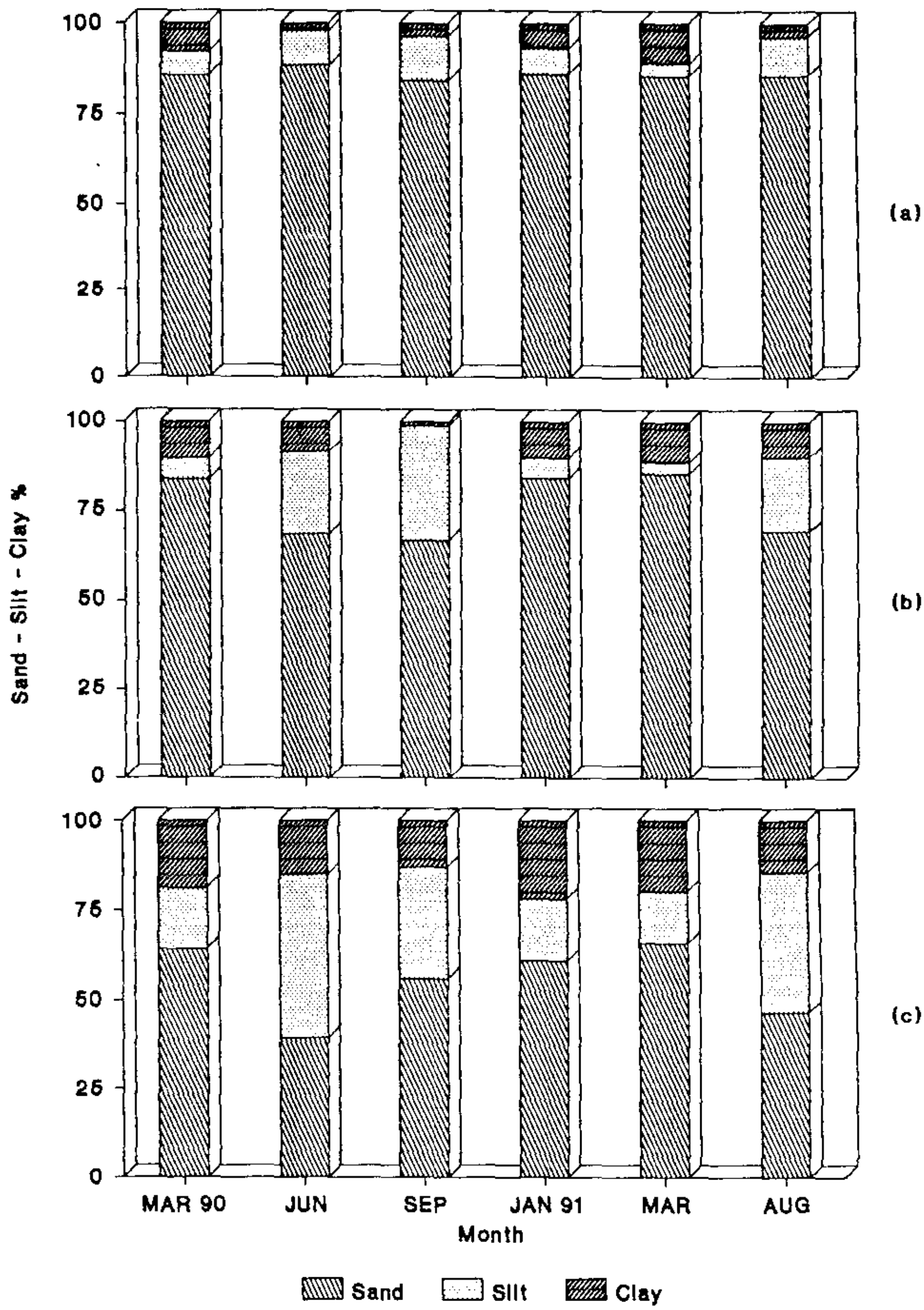


Figure 4.7 Sand-silt-clay percentages of the sediments at station 3
(a) Low tide level (b) Mid tide level (c) High tide level

was sand in all the seasons. Sand ranged from 85.56 to 88.76% and silt 3.31 to 10.38%. The clay content ranged from 2.4 to 10.44%. At station 2 the type of sediment was silty sand during monsoon period and clayey sand during postmonsoon and premonsoon periods. The maximum silt content of 24.42% and clay content of 20.98% was found in August and March respectively. The sand, silt and clay fraction constituted 64.12 to 73.33%, 9.03 to 24.42% and 7.62 to 20.98% respectively. At station 3, sediment type was clayey sand during postmonsoon and premonsoon periods. In the monsoon period it was sandy silt and silty sand. The highest composition of 45.47% silt and 22.18% of clay was noted in June and January respectively. The sand composition of the sediment varied from 39.2 to 65.6% and the silt varied from 14.28 to 45.47%. The clay content varied from 13.21 to 22.18%.

The sand, silt and clay content of sediment showed significant variation in its composition in different stations. There is much difference in the concentration of organic carbon and organic matter in the sediment at different tidal levels due to this variation in the sediment composition.

4.2.1.2 ORGANIC CARBON

The organic carbon varied from 0.35 to 0.64% at the low tide level, 0.35 to 0.81% at the mid tide level and 0.45 to 0.89% at the high tide level at station 1. At station 2 it ranged from 2 to 2.37%, 1.49% to 2.78% and 1.44 to 1.65% in the low tide, mid tide and high tide level respectively. At station 3 the organic carbon ranged from 0.49 to 0.81% in the low tide level, 0.84 to 2.77% in the mid tide level and 1.53 to 3% in the high tide level.

4.2.1.3 ORGANIC MATTER

At station 1 the organic matter ranged from 0.6 to 1.1% at the low tide level, 0.6 to 1.4% at the mid tide level and 0.78 to 1.53% at the high tide level. The concentration of organic matter ranged from 3.45 to 4.09%, 2.57 to 4.79% and 2.48 to 2.84% in the low tide, mid tide and high tide level respectively at station 2. At station 3 the organic matter varied from 0.84 to 1.4% in the low tide level, 1.45 to 4.78% in the mid tide level and 2.64 to 5.17% in the high tide level.

The correlation between the sediment particles and organic matter was calculated by using Pearson's coefficient of correlation (Snedecor and Cochran, 1968) and presented in Table 4.4. Clay is significantly positively correlated with organic matter in the low tide level and mid tide level at station 1 and mid tide level and high tide level at station 2. Silt is positively correlated with organic matter in the high tide level at station 1 and all the three tide levels at station 3. Sand is significantly positively correlated with organic matter only in the high tide level at station 1. When the whole study area is taken into consideration, there is significant positive correlation between silt and clay, silt and organic matter and clay and organic matter (Table 4.5).

4.2.1.4 Depth wise composition of texture, organic carbon and organic matter

Most of the workers have confined their studies on the texture, organic carbon and organic matter in the sediments to the upper few centimetres of the substratum. So, information on the vertical distribution of texture and organic matter in the sediments is scarce. The present work presents the results of the study of the vertical distribution of the sediment component and organic matter in the mangrove area.

Tables 4.6-4.8 reveal the percentage composition of the sediment characteristics of the substratum upto a depth of 15 cm. The values of upper strata (0-5 cm), middle strata (5-10 cm) and lower strata (10-15 cm) are given separately.

In general higher percentage of sand content was observed in the upper (0-5 cm) strata. Compared to the deeper layer of the substratum, a decreasing trend in the composition of silt and clay was noticed in the upper layer. Though the percentage of sand-silt-clay composition vary in different strata, the sediment type is not changing.

4.2.2 DISCUSSION

Sediments constitute a complex of ecological features which are of great significance to benthic organisms. Organisms are able to adapt to different sediments according to grain size, organic compounds and colonization of bacteria and other microorganisms in the sediments. Therefore, the variety and abundance of benthic fauna greatly depend on the physical and chemical properties of the substratum (Moore, 1958 and Sanders, 1958).

Sasekumar (1974) reported that the substratum included well over 50% of fine sand in a Malayan mangrove shore. Silt ranged from 12 to 54.3% and clay ranged from 4.6 to 15%. From Phuket mangrove shore in Thailand, Frith *et al.* (1976) reported that fine sand ranged from 14.5 to 46.5%. The silt and clay particle ranged from 9.4 to 33.7% and 16.2 to 48.2% respectively in this area. In the Sunderbans mangroves Matilal *et al.* (1986) observed that the sand varied from 1.06 to 7.29%. The silt varied from 53.5 to 78.87% and clay varied from 16.17 to 39.5%. Rao *et al.* (1992) reported that the sand content varied from 1 to 18%, silt varied from 7 to 63% and clay from 15 to 90% in the mangrove sediments of Godavari estuary. In the present investigation area, sand content ranged from 45.47 to 88.76%. The silt and clay ranged from 2.66 to 45.47% and 1.17 to 35.33% respectively. The sand is found dominated throughout the study area and it is more prominent at station 1. Each tidal level was represented by more than 77% of sand at this station. The second station was found to have more silt and clay content than the first station.

Based on the texture of sediment type, Rao *et al.* (1992) classified the mangrove sediment of Godavari into six categories *viz*-clay, sandy clay, clayey sand, muddy sand, sandy mud and mud. According to Matilal *et al.* (1986) the sediment type was silty clay in Sunderbans mangroves. The sediment type of Pichavaram mangroves is composed of sand, clayey sand, silty sand and sandy silt (Venkatesan, 1981). Based on the results obtained in the present study, the substratum of Cochin mangrove can be categorised into sand, clayey sand, silty sand and sandy silt.

Sandy type of sediment was found in all the tidal levels at station 1 while at station 2 silty sand and clayey sand was found. At station 3 the low tide level was composed of sandy type sediment. But the sediment type was clayey sand, silty sand and sandy silt in the high tide level. The mid tide level was composed of sandy and silty sand sediment. The sediment particles in the study area showed seasonal variation. Comparatively high clay content was observed during premonsoon and postmonsoon periods than monsoon months. Low clay content and high silt deposition was noted in the monsoon season. This shows that silt and clay portions of the sediment in the swamp vary according to the season.

Regarding the depth wise distribution of sediment particles, at the upper strata, higher proportion of sand was found in all the stations. From the data it is seen that the proportion of sand gradually decreases from the upper to lower strata in all the localities. With reference to the composition of silt and clay contents in the three strata, a slight variation was observed.

4.2.2.1 ORGANIC CARBON

The present data shows that the average value of organic carbon was relatively low (0.34%, 0.33% and 0.56% in the low, mid and high tide level respectively) in the surface (0-5 cm) when compared to the lower strata (0.48% in the low tide level, 0.6% in the mid tide level and 0.83% in the high tide level in 5-10 cm strata and 0.6% in the low tide level, 0.59% in the mid tide level and 0.78% in the high tide level in 10-15 cm strata) at station 1. At the same time it was more or less equally distributed in the three depth strata at stations 2 and 3. According to Sardessai (1993) the organic carbon in the sediment varied from 1.03 to 5.41% in the mangrove soil of Goa. It ranged from 0.4 to 0.88% in the mangrove muds of Andaman-Nicobar Islands (Misra, 1986). The organic carbon varied from 0.45 to 1.86% in the mangrove soil of Sunderbans (Sahoo *et al.*, 1985). According to him the percentage of organic carbon in the surface soil is higher than those in subsurface. The relatively higher values in the surface soil is due to the confinement of the organic residues in these layers. During the present study, in general, the organic carbon varied from 0.35 to 3%. A relatively lower percentage of organic carbon in the surface soil at station 1 may be due to constant tidal wash out. Compared to the other stations, the tidal influence and wave action is high at station 1, since it is nearer to the Cochin bar mouth. Besides, the leached organic carbon residues appear to settle more in the subsurface. These may be the reasons for the low organic carbon in the surface layer (0-5 cm) at station 1.

4.2.2.2 ORGANIC MATTER

The organic matter content of the sediment was high (3.29%) at station 2 and it was low (0.98%) at station 1 (average value of three tidal level). One of the most important features of organic matter in the sediments is that its concentration rises, as the particle size of the sediments decrease (Bordovskiy, 1965). Since the organic matter is trapped predominantly by clays, and to a lesser degree by fine silts, coarse silts and sands, the maximum organic matter can be expected in sediment with more concentration of clay (Russel, 1950). There is a correlation between organic matter and clay content. According to Sanders (1956) all clay minerals except kaolin bind organic matter. Thus the area with high percentage of clay is capable of holding a high proportion of organic matter.

In the present study also, it is seen that higher organic matter content is present in the substratum with more concentration of clay and silt particles. At station 1, 0.98% of organic matter was found in the substratum having 85.35% of sand, 6.7% of silt and 7.95% of clay particles. At the same time, at station 2, 3.29% of organic matter was recorded in the sediments where the sand, silt and clay contents were 63.49, 20.70 and 15.82% respectively. At station 3, the organic matter content was 2.56%. The percentage of sand, silt and clay contents at this station were 72.53, 16.85 and 10.63% respectively (Average value of the sand, silt, clay and organic matter content of the three tidal levels were taken). From this it is evident that the substratum with more concentration of silt and clay content and less concentration of sand content showed high percentage of organic matter. This is in agreement with the findings of several earlier workers (Trask, 1955; Murty and Veerayya, 1972; Pillai, 1978; Purandara and Dora, 1987; Devi and Venugopal, 1989 and Alagarsamy, 1991).

The organic matter content in the sediments of different mangrove areas has been studied by Walsh (1979), Sasekumar (1974), Seralathan and Seetaramaswamy (1979), Padmakumar (1984), Sahoo *et al.* (1985), Shanmukhappa (1987), Jagtap (1985b, 1987) and Sardessai (1993). According to them the organic matter content of mangrove soils is mainly derived from plant material. Mangroves are known to harbor a pool of organic matter which is governed by tidal action, fresh water inflow, litter fall and rate of primary production (Jagtap, 1985b). In the present study area also it is seen that the organic matter in the sediment is mainly the contribution of plant material. The vegetation, texture of the sediments and the detritus derived from the putrification by the bacterial action are the main factors that favoured the organic matter production in a mangrove ecosystem. Besides, the sewage and organic waste inputs into the estuary may also contribute to the organic matter in the mangrove sediment.

A comparison of the average concentration of organic matter at the three stations reveals that in general, station 2 has high concentration of organic matter, when compared to stations 1 and 3. Station 2 is characterised by a thick population of large *Rhizophora mucronata* flora. Besides, this area has comparatively high clay and silt particles than stations 1 and 3.

The litter fall was highest during premonsoon for *Bruguiera* sp. (Joseelen Jose, 1989) and for *Rhizophora* sp. (Preetha, 1991) at Cochin mangroves. The mangrove litter undergo degradation by bacteria and fungi. In the study area, it can be observed that the percentage of organic matter slightly increases in monsoon period at station 3, and in postmonsoon period at stations 1 and 2. According to Sardessai (1993) the higher litter fall during premonsoon (Wafar, 1987) mainly contributes to the high organic matter content in the monsoon, in the mangroves of Goa.

According to Sasekumar (1974) the organic content of the soil varied from 2.4 to 5.2% in the Malayan mangrove swamp. Frith *et al.* (1976) reported that the organic content ranged from 1.7 to 8.5% in the mangrove sediments of Phuket. The average organic matter in the sediment was 3.99% in the

Pichavaram mangroves (Shanmukhappa, 1987). In the present study area, the organic matter content varied from 0.6 to 5.17%. The variation in the organic matter content at different stations may be due to the variation in the physiographic conditions of the area, litter fall, tidal wash out and textural characteristics of the soil. It is stated that the the organic content in the mangrove substratum was low in the coarser soil, but it was high in very fine soil in Phuket mangrove swamp in Thailand Frith *et al*. (1976). Shokita *et al*. (1989) also observed that the organic content tends to increase with the increase of the silt-clay content in Funaura mangrove area in Japan. The study reveals that there is correlation between particle size and organic matter of sediments.

The depth wise distribution of the sediments shows slight variations in the organic matter in different strata of the substratum. The variation of the organic matter contents in different strata may be due to the difference in the percentage of sand-silt-clay content. Mixing and leaching of putrified vegetative matter at deeper strata may be less than that of the surface. Hence the organic matter does not show an increase towards the deeper layer. Detritus from the mangrove area is also exported to the adjacent water in the estuary by tidal influence.

Table 4.1 Sand-silt-clay content, organic carbon and organic matter content (%) of the sediment
(a) Low tide level (b) Mid tide level (c) High tide level

Station 1

Month	Sand%	Silt%	Clay%	Oranic carbon%	Organic matter%	Sediment type	
MAR 90	86.34	5.19	8.47	0.42	0.72	Sandy	
JUN	86.12	7.63	6.25	0.44	0.76	Sandy	
SEP	85.69	11.56	2.75	0.35	0.60	Sandy	(a)
JAN 91	79.67	9.02	11.31	0.64	1.10	Sandy	
MAR	83.13	6.33	10.54	0.62	1.07	Sandy	
AUG	85.10	7.79	7.11	0.38	0.66	Sandy	
MAR 90	88.76	7.62	3.62	0.44	0.76	Sandy	
JUN	88.80	4.33	6.87	0.43	0.74	Sandy	
SEP	80.92	11.38	7.70	0.55	0.95	Sandy	(b)
JAN 91	77.24	2.66	20.10	0.81	1.40	Sandy	
MAR	86.68	3.19	10.13	0.35	0.60	Sandy	
AUG	87.82	3.88	8.30	0.45	0.78	Sandy	
MAR 90	87.22	10.38	2.40	0.77	1.33	Sandy	
JUN	86.73	8.23	5.04	0.65	1.12	Sandy	
SEP	85.86	4.97	9.17	0.45	0.78	Sandy	(c)
JAN 91	88.76	3.31	7.93	0.89	1.53	Sandy	
MAR	85.95	3.61	10.44	0.79	1.36	Sandy	
AUG	85.56	9.56	4.88	0.80	1.38	Sandy	
Average value	85.35	6.70	7.95	0.57	0.98		

Table 4.2 Sand-silt-clay content, organic carbon and organic matter content (%) of the sediment
(a) Low tide level (b) Mid tide level (c) High tide level

Station 2

Month	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sediment type	
MAR 90	62.37	14.02	23.61	2.35	4.05	Clayey sand	
JUN	58.62	31.50	9.88	2.06	3.55	Silty sand	
SEP	47.77	44.28	7.95	2.37	4.09	Silty sand	(a)
JAN 91	51.86	12.81	35.33	2.36	4.09	Clayey sand	
MAR	55.92	15.46	28.62	2.21	3.81	Clayey sand	
AUG	61.20	29.67	9.13	2.00	3.45	Silty sand	
MAR 90	67.97	13.49	18.54	2.16	3.72	Clayey sand	
JUN	58.45	34.22	7.33	2.78	4.79	Silty sand	
SEP	65.04	19.29	15.67	1.71	2.95	Silty sand	(b)
JAN 91	63.75	17.10	19.15	1.82	3.14	Clayey sand	
MAR	69.55	13.80	16.65	1.77	3.05	Clayey sand	
AUG	62.58	27.30	10.12	1.49	2.57	Silty sand	
MAR 90	73.33	11.10	15.57	1.53	2.64	Clayey sand	
JUN	72.81	19.57	7.62	1.58	2.72	Silty sand	
SEP	70.40	20.47	9.13	1.44	2.48	Silty sand	(c)
JAN 91	64.12	15.04	20.84	1.65	2.84	Clayey sand	
MAR	69.99	9.03	20.98	1.53	2.64	Clayey sand	
AUG	67.02	24.42	8.56	1.48	2.55	Silty sand	
AVERAGE VALUE	63.49	20.70	15.82	1.91	3.29		

Table 4.3 Sand-silt-clay content, organic carbon and organic matter content (%) of the sediment
(a) Low tide level (b) Mid tide level (c) High tide level

Station 3

Month	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sediment type	
MAR 90	85.75	6.35	7.90	0.79	1.36	Sandy	
JUN	88.51	9.48	2.01	0.49	0.84	Sandy	
SEP	84.26	12.14	3.60	0.81	1.40	Sandy	(a)
JAN 91	86.21	6.89	6.90	0.79	1.36	Sandy	
MAR	85.48	3.48	11.04	0.67	1.16	Sandy	
AUG	85.75	10.58	3.67	0.67	1.16	Sandy	
MAR 90	83.64	5.92	10.44	0.99	1.71	Sandy	
JUN	68.52	23.07	8.41	2.77	4.78	Silty sand	
SEP	66.76	32.06	1.17	2.00	3.45	Silty sand	(b)
JAN 91	84.00	5.76	10.24	0.94	1.62	Sandy	
MAR	85.28	3.32	11.40	0.84	1.45	Sandy	
AUG	69.42	20.79	9.79	0.90	1.55	Silty sand	
MAR 90	64.04	16.83	19.13	1.72	2.97	Clayey sand	
JUN	39.20	45.47	15.33	2.69	4.64	Sandy silt	
SEP	55.85	30.94	13.21	2.80	4.83	Silty sand	(c)
JAN 91	60.74	17.08	22.18	3.00	5.17	Clayey sand	
MAR	65.60	14.28	20.12	1.53	2.64	Clayey sand	
AUG	46.49	38.78	14.73	2.33	4.02	Silty sand	
AVERAGE VALUE	72.53	16.85	10.63	1.49	2.56		

Table 4.4 Correlation coefficient (r values) between sediment particles and organic matter content

Stations	Sand	Silt	Clay
1LTL	-0.8363	-0.3390	**0.9985
1MTL	-0.9988	-0.1064	**0.9024
1HTL	*0.6560	**0.9197	-0.8189
2LTL	-0.8542	0.3733	-0.3829
2MTL	-0.1803	-0.3916	**0.9655
2HTL	-0.9111	-0.3310	**0.8390
3LTL	-0.2935	**0.9410	-0.8644
3MTL	-0.9983	**0.9931	-0.9973
3HTL	-0.8016	*0.6088	-0.2509

Table 4.5 Correlation matrix showing the correlation between sand-silt-clay particles and organic matter

	Sand	Silt	Clay	Organic matter
Sand	**1.0000			
Silt	-0.9467	**1.0000		
Clay	-0.9438	**0.8503	**1.0000	
Organic matter	-0.9205	**0.9688	**0.8281	**1.0000

* - Significant at 5% level ($P<0.05$)
** - Significant at 1% level ($P<0.01$)
Degress of freedom = 8

Table 4.6 Sand-silt-clay content, organic carbon and organic matter content (%) of the sediments in the three depth strata at station 1

		Low tide level					Mid tide level					High tide level				
Month	Depth	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%
	0-5	90.53	2.97	6.50	0.29	0.50	92.83	5.55	1.62	0.17	0.29	87.60	10.78	1.62	0.54	0.93
MAR 90	5-10	85.42	6.43	8.15	0.41	0.71	87.60	10.15	2.25	0.69	1.19	86.60	10.90	2.50	0.99	1.71
	10-15	83.06	6.19	10.75	0.56	0.97	85.85	7.15	7.00	0.45	0.78	87.45	9.45	3.10	0.78	1.34
	0-5	92.71	3.54	3.75	0.26	0.45	91.23	2.77	6.00	0.24	0.41	87.49	5.26	7.25	0.57	0.98
JUN	5-10	83.99	9.26	6.75	0.42	0.72	86.46	5.04	8.50	0.66	1.14	86.15	11.03	2.82	0.83	1.43
	10-15	81.65	10.10	8.25	0.63	1.09	88.72	5.18	6.10	0.38	0.66	86.54	8.41	5.05	0.56	0.97
	0-5	90.67	8.01	1.32	0.21	0.36	90.19	8.95	0.86	0.41	0.71	89.38	6.32	4.30	0.36	0.62
SEP	5-10	84.04	12.81	3.15	0.32	0.55	82.49	15.51	2.00	0.48	0.83	83.92	4.08	12.00	0.42	0.72
	10-15	82.35	13.87	3.78	0.51	0.88	70.07	9.68	20.25	0.77	1.33	84.28	4.52	11.20	0.56	0.97
	0-5	84.11	4.94	10.95	0.42	0.72	88.69	0.56	10.75	0.48	0.83	91.76	1.41	6.83	0.56	0.97
JAN 91	5-10	73.68	12.72	13.60	0.83	1.43	71.50	5.20	23.30	0.95	1.64	90.11	3.26	6.63	0.93	1.60
	10-15	81.21	9.41	9.38	0.66	1.14	71.53	2.22	26.25	1.01	1.74	84.41	5.26	10.33	1.17	2.02
	0-5	89.52	2.31	8.17	0.72	1.24	89.81	2.07	8.12	0.45	0.78	85.85	3.85	10.30	0.61	1.05
MAR	5-10	82.39	4.03	13.58	0.51	0.88	90.88	0.22	8.90	0.38	0.66	89.09	2.11	8.80	0.90	1.55
	10-15	77.47	12.65	9.88	0.64	1.10	79.34	7.28	13.38	0.22	0.38	82.92	4.87	12.21	0.87	1.50
	0-5	88.42	6.86	4.72	0.15	0.26	90.81	1.87	7.32	0.21	0.36	86.93	10.24	2.83	0.74	1.28
AUG	5-10	84.13	8.39	7.48	0.41	0.71	87.52	3.08	9.40	0.45	0.78	84.18	11.65	4.17	0.93	1.60
	10-15	82.75	8.13	9.12	0.57	0.98	85.14	6.69	8.17	0.68	1.17	85.58	6.77	7.65	0.72	1.24

Table 4.7 Sand-silt-clay content, organic carbon and organic matter content (%) of the sediments in the three depth strata at station 2

		Low tide level					Mid tide level					High tide level				
Month	Depth	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%
	0-5	65.15	12.32	22.53	2.55	4.40	65.04	16.51	18.45	2.42	4.17	73.01	11.15	15.75	1.43	2.47
MAR 90	5-10	61.33	16.25	22.42	1.92	3.31	72.20	11.72	16.08	1.97	3.40	72.73	10.82	16.45	1.59	2.74
	10-15	60.62	13.50	25.88	2.57	4.43	66.68	12.25	21.07	2.09	3.60	74.26	11.24	14.50	1.56	2.69
	0-5	56.80	34.00	9.20	2.93	5.05	73.12	21.13	5.75	2.97	5.12	69.99	21.41	8.60	1.79	3.09
JUN	5-10	48.17	41.48	10.35	2.01	3.47	56.59	40.91	2.50	2.54	4.38	73.77	17.88	8.35	1.62	2.79
	10-15	70.88	19.04	10.08	1.23	2.12	45.63	40.62	13.75	2.84	4.90	74.67	19.41	5.92	1.34	2.31
	0-5	66.11	32.39	1.50	1.95	3.36	65.95	17.55	16.50	1.44	2.48	70.95	16.55	12.50	1.44	2.48
SEP	5-10	42.99	46.68	10.33	2.51	4.33	63.60	20.58	15.82	1.94	3.34	71.07	14.43	14.50	1.38	2.38
	10-15	34.21	53.78	12.01	2.64	4.55	65.58	19.72	14.70	1.74	3.00	69.17	30.45	0.38	1.50	2.59
	0-5	62.07	6.53	31.40	2.03	3.50	64.57	16.73	18.70	1.85	3.19	70.39	11.23	18.38	1.67	2.88
JAN 91	5-10	50.91	13.34	35.75	2.25	3.88	63.68	14.24	22.08	1.74	3.00	63.72	14.13	22.15	1.62	2.79
	10-15	42.59	18.56	38.85	2.81	4.84	63.00	20.32	16.68	1.86	3.21	58.24	19.78	21.98	1.65	2.84
	0-5	60.18	17.44	22.38	2.24	3.86	69.61	15.06	15.33	1.80	3.10	70.94	5.18	23.88	1.39	2.40
MAR	5-10	48.87	15.00	36.13	2.48	4.28	69.28	11.67	19.05	1.89	3.26	69.18	7.42	23.40	1.52	2.62
	10-15	58.70	13.95	27.35	1.92	3.31	69.75	14.67	15.58	1.63	2.81	69.86	14.49	15.65	1.68	2.90
	0-5	60.22	32.28	7.50	1.58	2.72	65.85	23.68	10.47	1.46	2.52	63.18	28.62	8.20	1.22	2.10
AUG	5-10	57.91	32.72	9.37	2.00	3.45	61.18	31.47	7.35	1.61	2.78	68.72	22.16	9.12	1.56	2.69
	10-15	65.48	24.00	10.52	2.42	4.17	60.71	26.74	12.55	1.40	2.41	69.15	22.47	8.38	1.67	2.88

Table 4.8 Sand-silt-clay content, organic carbon and organic matter content (%) of the sediments in the three depth strata at station 3

		Low tide level					Mid tide level					High tide level				
Month	Depth	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%
	0-5	87.92	6.71	5.37	0.79	1.36	86.78	5.87	7.35	0.81	1.40	58.26	20.75	20.99	2.56	4.41
MAR 90	5-10	85.83	6.02	8.15	0.75	1.29	82.66	5.50	11.84	0.92	1.59	65.07	17.02	17.91	1.32	2.28
	10-15	83.51	6.31	10.18	0.83	1.43	81.47	6.40	12.13	1.23	2.12	68.79	12.72	18.49	1.28	2.21
	0-5	90.51	6.94	2.55	0.35	0.60	65.73	24.55	9.72	3.50	6.03	34.52	52.65	12.83	2.79	4.81
JUN	5-10	86.53	11.85	1.62	0.68	1.17	70.10	21.95	7.95	3.15	5.43	39.90	44.07	16.03	2.15	3.71
	10-15	88.48	9.64	1.88	0.44	0.76	69.74	22.75	7.55	1.65	2.84	43.17	39.70	17.13	3.12	5.38
	0-5	89.11	9.33	1.56	0.74	1.28	60.11	38.73	1.16	3.00	5.17	58.99	34.26	6.75	3.30	5.69
SEP	5-10	82.80	11.35	5.85	0.90	1.55	68.68	29.99	1.33	1.80	3.10	60.99	34.76	4.25	2.25	3.88
	10-15	80.87	15.75	3.38	0.78	1.34	71.50	27.47	1.03	1.20	2.07	47.57	23.80	28.63	2.85	4.91
	0-5	88.51	4.09	7.40	0.69	1.19	86.44	5.06	8.50	0.96	1.66	52.46	18.54	29.00	4.05	6.98
JAN 91	5-10	84.15	9.43	6.42	0.78	1.34	82.97	6.15	10.88	0.92	1.59	63.34	17.86	18.80	3.15	5.43
	10-15	85.96	7.16	6.88	0.89	1.53	82.60	6.05	11.35	0.93	1.60	66.43	14.82	18.75	1.80	3.10
	0-5	88.51	5.11	6.38	0.56	0.97	88.10	0.57	11.33	0.96	1.66	55.20	17.88	26.92	2.10	3.62
MAR	5-10	83.62	3.23	13.15	0.62	1.07	85.01	2.56	12.43	0.81	1.40	74.22	9.20	16.58	1.38	2.38
	10-15	84.32	2.08	13.60	0.83	1.43	82.74	6.81	10.45	0.75	1.29	67.37	15.75	16.88	1.12	1.93
	0-5	88.42	9.78	1.80	0.52	0.90	70.25	22.63	7.12	0.76	1.31	45.17	38.55	16.28	2.17	3.74
AUG	5-10	85.13	11.45	3.42	0.63	1.09	66.40	22.04	11.56	1.11	1.91	51.35	36.45	12.20	2.52	4.34
	10-15	83.70	10.52	5.78	0.85	1.47	71.60	17.70	10.70	0.83	1.43	42.95	41.35	15.71	2.31	3.98

Chapter V

BENTHIC FAUNA

Benthic animals form an important component of the food web of mangrove areas and play a key role in the food chain of the mangrove soil habitat. The benthic macrofauna in the mangrove swamps of Cochin is represented by several taxonomic groups.

5.1 COMPOSITION OF BENTHIC FAUNA

The macrofaunal component in the study area was mainly composed of polychaetes, crustaceans and molluscs. Other organisms present in the area are included in the category 'other groups'. A total of 54 species were recorded from the study area. The composition of each group is given below.

5.1.1 Polychaeta

Polychaetes were widely distributed and formed the bulk of the fauna throughout the year. Altogether 33 species of polychaetes belonging to 20 genera were identified (Table 5.1). They are: *Amphicteis gunneri* Sars, *Branchiocapitella singularis* Fauvel, *Diopatra neapolitana* Delle Chiaje, *Dendronereides heteropoda* Southern, *Dendronereis aestuarina* Southern, *Dendronereis arborifera* Peters, *Eunice tubifex* Crossland, *Eunice* spp., *Glycera alba* Rathke, *Glycera longipinnis* Grube, *Lumbriconereis latreilli* Audouin and Milne-Edwards, *Lumbriconereis pseudobifilaris* Fauvel, *Lumbriconereis simplex* Southern, *Lumbriconereis* sp., *Marphysa gravelyi* Southern, *Marphysa stragulum* (Grube), *Nereis* *glandicincta* Southern, *Nereis kauderni* Fauvel, *Nereis chilkaensis* Southern, *Nereis* spp., *Paraheteromastus tenuis* Monro, *Pulliella armata* Fauvel, *Pista indica* Fauvel, *Mercierella enigmatica* Fauvel, *Ceratonereis costae* Grube, *Talehsapia annandalei* Fauvel, *Perinereis cavifrons* Ehlers, *Perinereis* sp., *Prionospio cirrifera* Wiren, *Prionospio pinnata* Ehlers, *Phyllodoce* sp., *Polydora* sp., *Goniada* sp., and Capitellidae group (unidentified).

Of these 33 species, 7 species namely *Marphysa gravelyi*, *Branchiocapitella singularis*, *Perinereis* sp., *Eunice* sp., *Paraheteromastus tenuis*, *Nereis chilkaensis* and *Nereis glandicincta* were found in all the stations. The maximum number of species (29) was recorded at station 1 and the minimum (12) at station 2. Forteen species were recorded from station 3. In general the errant polychaetes were more common than the sedentaria group. Out of the 33 species of polychaetes recorded, 24 species belong to errantia group and the remaining represented by sedentaria group (Table 5.2).

5.1.2 Crustacea

The crustaceans were mainly represented by amphipoda, isopoda, tanaidacea and decapoda groups. Totally 11 species of crustaceans were recorded. The amphipoda consists of mainly *Gammarus* sp. and *Corophium triaenonyx* Stebbing. Of these, *Gammarus* sp. was dominant and commonly found at stations 1 and 3. The group isopoda comprises of two species, *Ligia* sp. and *Sphaeroma* sp., latter forming the more common form. The tanaidacea species *Apseudes chilkensis* Chilton was found throughout the area.

The decapod fauna includes prawns, alphid and brachyuran crabs. Among prawns, the juvenile of *Palaemon* sp. was common. The alphidae group was represented by *Alphius* sp. The brachyuran crabs were comparatively poor. They were represented by *Uca annulipes* Latreille, *Uca* sp., *Dotilla* sp. and *Metapograpsus messor* Forskael.

5.1.3 Mollusca

Nine species of molluscs belonging to 8 genera were collected. Molluscan fauna includes both bivalves and gastropods.

5.1.3.1 Bivalve

Of the 6 species of bivalves collected, *Musculista* sp. (*Modiolus* sp.) and *Tellina* spp. were the common forms. *Musculista* sp. was found in large numbers at station 1 and *Tellina* sp. at station 3. The other bivalves collected were *Villorita cyprinoides* var *cochinensis* (Hansley), *Tellina tenuis* da Costa, *Tapes* sp., and *Cuspidaria* sp..

5.1.3.2 Gastropod

Three species of gastropods - *Hydrobia* sp., *Bittium* sp. and *Nerita* sp. were found. Among these *Hydrobia* sp. was common in all the stations.

5.1.4 Other group

The other groups include two species of sea anemones, gobioid fish, sipunculoidea, nemertine worm and insect larvae.

5.2 GENERAL DISTRIBUTION PATTERN OF BENTHIC FAUNA

The benthic fauna in the mangrove areas of Cochin comprises both brackish water and fresh water organisms. The true estuarine forms which are capable of withstanding wide variations in salinity are found to occur throughout the year. The distribution pattern of organisms at low tide, mid tide and high tide levels showed considerable variations. Composition of benthic organisms and their occurrence in terms of seasons and tide levels are given in Tables 5.3-5.5.

Station 1

In the low tide level the polychaetes were mainly represented by *Paraheteromastus tenuis, Marphysa gravelyi* and *Talehsapia annandalei* throughout the year. *Diopatra neapolitana, Glycera longipinnis, Nereis glandicincta* and *Phyllodoce* sp. were found during premonsoon season. *Nereis chilkaensis* was found during the monsoon period only. *Ceratonereis costae* and the unidentified capitellidae group were found during late monsoon and early postmonsoon periods. The crustaceans found throughout the year were *Apseudes chilkensis* and *Gammarus* sp.. *Dotilla* sp. and *Corophium triaenonyx* were recorded during premonsoon and postmonsoon periods. *Sphaeroma* sp. and *Palaemon* sp. were found during postmonsoon season. Among molluscs *Musculista* sp. and *Tellina* sp. were found throuthout the year. *Bittium* sp. and *Tapes* sp. were collected during the premonsoon period only. *Tellina tenuis* was recorded during monsoon months. The other groups distributed in the low tide level include sipunculid worm and sea anemone.

In the mid tide level, polychaetes were dominated by the species *Marphysa gravelyi* and *Paraheteromastus tenuis,* followed by unidentified capitellidae, throughout the year. *Diopatra neapolitana, Glycera alba, G. longipinnis, Lumbriconereis simplex, Nereis kauderni* and *Polydora* sp. were found during the premonsoon months and *Nereis chilkaensis, Mercierella enigmatica* were recorded during monsoon season. *Ceratonereis costae, Lumbriconereis pseudobifilaris, Nereis glandicincta* were collected during the end of monsoon and early postmonsoon periods. *Eunice* sp. was recorded during premonsoon and postmonsoon periods. *Pista indica* and *Dendronereis aestuarina* were found during the postmonsoon months. Among crustaceans, the dominating species *Gammarus* sp., *Uca annulipes* and *Uca* sp, were found throughout the year. *Alpheus* sp. was present during the premonsoon period. *Sphaeroma* sp. was recorded during the postmonsoon period. Among mollusc, *Musculista* sp., *Hydrobia* sp. and *Tellina* sp. were found in all the seasons. *Bittium* sp. and *Tapes* sp. were recorded in the premonsoon period and *Cuspidaria* sp. was found in the monsoon season. Among the other groups, nemertine and insect larvae were found rarely. Sea anemones were found throughout the year.

In the high tide level, among polychaetes *Branchiocapitella singularis*, *Marphysa gravelyi* and *Nereis glandicincta* were recorded in all the seasons. *Diopatra neapolitana* was found during the premonsoon period. In the monsoon period *Nereis chilkaensis* and *Paraheteromastus tenuis* were observed. *Eunice* sp., *Lumbriconereis latreilli* and *Marphysa stragulum* were collected during the premonsoon and postmonsoon seasons. Comparatively less polychaete fauna was found in this tidal level than the low and mid tide levels. Among crustaceans, *Gammarus* sp., *Uca* sp. and *Sphaeroma* sp. were the common forms found throughout the year. *Apseudes chilkensis* was present during the premonsoon months. *Ligia* sp. and *Palaemon* sp. were recorded in the monsoon period. *Corophium triaenonyx* was found during the premonsoon and postmonsoon periods. The molluscan fauna was dominated by *Hydrobia* sp. and *Musculista* sp. in all the seasons and among them *Hydrobia* sp. was the dominant form. Among the other groups, sea anemone was found throughout the year. Sipunculid worm and insect larvae were found only rarely.

Station 2

In the low tide level, the polychaete fauna was dominated by *Dendronereides heteropoda*, *Nereis glandicincta* and unidentified capitellidae group followed by *Branchiocapitella* *singularis* and *Marphysa gravelyi* throughout the year. *Paraheteromastus tenuis* and *Pista indica* were recorded during premonsoon season. Among crustacean *Palaemon* sp. (juvenile) was found throughout the year. The other crustaceans found in low numbers were *Gammarus* sp., *Apseudes chilkensis*, *Corophium triaenonyx* and *Sphaeroma* sp.. The molluscan fauna was dominated by *Hydrobia* sp. which was present throughout the year. *Tellina* sp. was recorded in the monsoon season. *Musculista* sp. was distributed in the premonsoon and postmonsoon periods. Nemertines, gobioid fish and insect larvae were also present rarely.

In the mid tide level, *Dendronereides heteropoda*, *Nereis glandicincta* and capitellidae group were dominated among the polychaete fauna. They were present throughout the year, but comparatively higher in number, in the premonsoon period. *Branchiocapitella singularis*, *Eunice* sp. and *Marphysa stragulum* were recorded during the premonsoon period. The crustacean fauna in this tidal level was mainly represented by *Sphaeroma* sp. and *Uca* sp. in the premonsoon and postmonsoon seasons. The crustaceans present in low numbers were *Corophium triaenonyx*, *Apseudes chilkensis* and *Gammarus* sp.. The molluscan fauna was represented by *Hydrobia* sp. which was found in all the months. The occurrence of *Bittium* sp. was restricted to the premonsoon period. The rest of the molluscan species *Cuspidaria* sp., *Tellina* sp. and *Musculista* sp. were found only rarely. Insect larvae, nemertine and gobioid fish were present among the other group.

In the high tide level, *Dendronereides heteropoda* and *Nereis glandicincta* were the dominant species of polychaetes found throughout the year. *Polydora* sp. was present in the premonsoon period only. *Dendronereis aestuarina* was recorded in the postmonsoon season. The polychaete fauna in this tidal level was comparatively less than that of mid and low tide levels. *Metapograpsus messor* and *Palaemon* sp. were the dominant crustaceans present in the high tide level. *Corophium triaenonyx*, *Sphaeroma* sp. and *Gammarus* sp. were found rarely. Comparatively poor molluscan fauna was found in this tidal level. Only the *Hydrobia* sp. was found in all the months.

Station 3

In the low tide level, *Dendronereis aestuarina* was the common polychaete species present throughout the year. *Dendronereis arborifera*, *Marphysa gravelyi* and *Nereis glandicincta* were recorded during the premonsoon and postmonsoon seasons. *Nereis chilkaensis* was found in the monsoon season only. *Prionospio cirrifera* and *Talehsapia annandalei* were observed during the postmonsoon and late in the monsoon seasons. Among crustaceans, *Apseudes chilkensis*, *Corophium triaenonyx* and *Gammarus* sp. were the most common forms and they were found in all the seasons. Among molluscs, *Villorita cyprinoides* and *Hydrobia* sp. were observed throughout the year, though the former is not a mangrove form. *Tellina tenuis* was recorded during the monsoon season. *Cuspidaria* sp. and *Tellina* sp. were seen in monsoon and postmonsoon periods. Sea anemone and nemertines were seen rarely.

The distribution of polychaete fauna was represented mostly by *Dendronereis aestuarina*, *Marphysa gravelyi* and *Paraheteromastus tenuis* and were found throughout the year in the mid tide level. *D. arborifera* and *Perinereis* sp. were present in premonsoon and postmonsoon periods. During the monsoon season *Nereis chilkaensis* was seen. *Gammarus* sp. and *Apseudes chilkensis* were the dominant forms of crustaceans and they were present throughout the year. *Corophium triaenonyx*, *Sphaeroma* sp. *and Palaemon* were found rarely. Among molluscs, *Villorita cyprinoides* and *Tellina* sp. were found in all the seasons. *Tellina tenuis* was present during monsoon season and *Hydrobia* sp. was observed during premonsoon and postmonsoon seasons. Among the other groups nemertines and sea anemones were found rarely.

In the high tide level *Nereis glandicincta* was dominated among polychaetes and collected in all the seasons. *Prionospio cirrifera* and *Branchiocapitella singularis* were found during the postmonsoon period. *Eunice* sp. was found during the premonsoon months. Comparatively poor polychaete fauna was found in this tidal level. Among crustaceans *Corophium triaenonyx*, *Sphaeroma* sp. and *Apseudes chilkensis* were found in small numbers. *Hydrobia* sp. was the mollusc that occured throughout the year. The other molluscs *Cuspidaria* sp. and *Tellina* sp. were present rarely. Gobioid fish and sea anemone occurred rarely.

5.3 PERCENTAGE COMPOSITION AND POPULATION DENSITY

The percentage composition and population density of benthic fauna showed variations at three stations as well as at different tidal levels, as is shown in Figs. 5.1-5.3 and Tables 5.6-5.14.

Station 1

In the low tide level the polychaetes contributed 63.26% of the total fauna whereas the crustaceans and molluscs comprised 16.92% and 17.97% respectively. Among the polychaetes, the largest number collected was *Paraheteromastus tenuis* and the maximum occurrence of this species was 330/m^2 (commuted value) in May and November. This was followed by *Ceratonereis costae* in the order of its abundance, with 280/m^2 in November. The crustacean fauna composed of *Uca* sp. with a maximum number of 170/m^2 in May and *Gammarus* sp. with 140/m^2 in September. The major species of mollusc *Musculista* sp. contributed the maximum number with 220/m^2 in January. The other groups contributed only 1.85% of the total fauna.

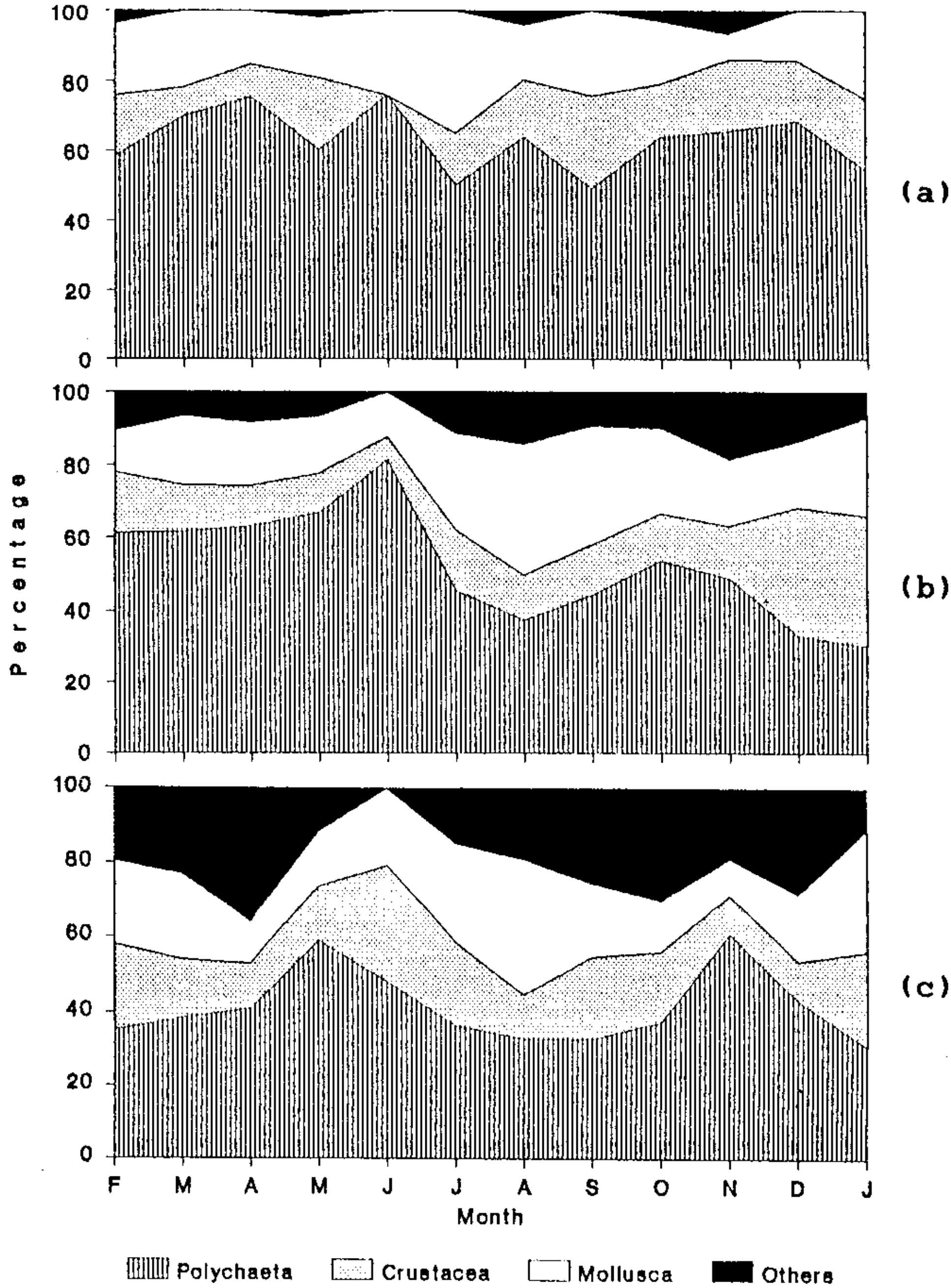


Figure 5.1 Percentage composition (monthly mean values) of major groups of benthos in 0.1 m^2 area at station 1 during September 1989 to August 1991
(a) Low tide level (b) Mid tide level (c) High tide level

In the mid tide level the polychaetes were the dominant group, constituting 48.30% of the total fauna. The crustaceans and molluscs contributed 19.76% and 21.78% respectively. Among polychaetes *Marphysa gravelyi*, *Paraheteromastus tenuis*, *Eunice* sp., and the capitellidae group were the common forms. The highest number of specimens collected was that of *P. tenuis* with 190/m^2 in February. *Corophium triaenonyx*, *Gammarus* sp. and *Sphaeroma* sp. constituted the bulk of the crustacean fauna with *C. triaenonyx* and *Gammarus* sp. recorded 560/m^2 and 250/m^2 respectively during January and December. Among molluscs, *Musculista* sp. and *Hydrobia* sp. were the dominant species and they recorded high values in January and October with 670/m^2 for *Musculista* sp. and 220/m^2 for *Hydrobia* sp.. The other group was represented mainly by sea anemones, forming 10.16% of the total fauna.

The composition of benthic fauna in the high tide level was 41.89% by polychaetes, 16.60% by crustaceans, 19.17% by molluscs and 22.34% by other groups. The polychaetes dominating in this level were *Branchiocapitella singularis*, *Nereis glandicincta*, *Marphysa gravelyi*, *Eunice tubifex* and Capitellidae group. Of these *B. singularis* was the predominant species with a maximum number of 560/m^2 in November. *Sphaeroma* sp. was the common crustacean with 190/m^2 during October. Among mollusc *Hydrobia* sp. and *Musculista* sp. were commonly present with the highest number of 140/m^2 in September and 170/m^2 in August respectively. The other group was represented by sea anemone with the maximum number of 640/m^2 in October.

Station 2

In the low tide level, polychaete fauna formed 45.66%, followed by crustacean with 20.60% of the total fauna. The molluscs accounted for 29.27% and the other group formed 4.47%. The species of polychaetes represented in this tidal level were *Dendronereides heteropoda*, *Nereis glandicincta* and the

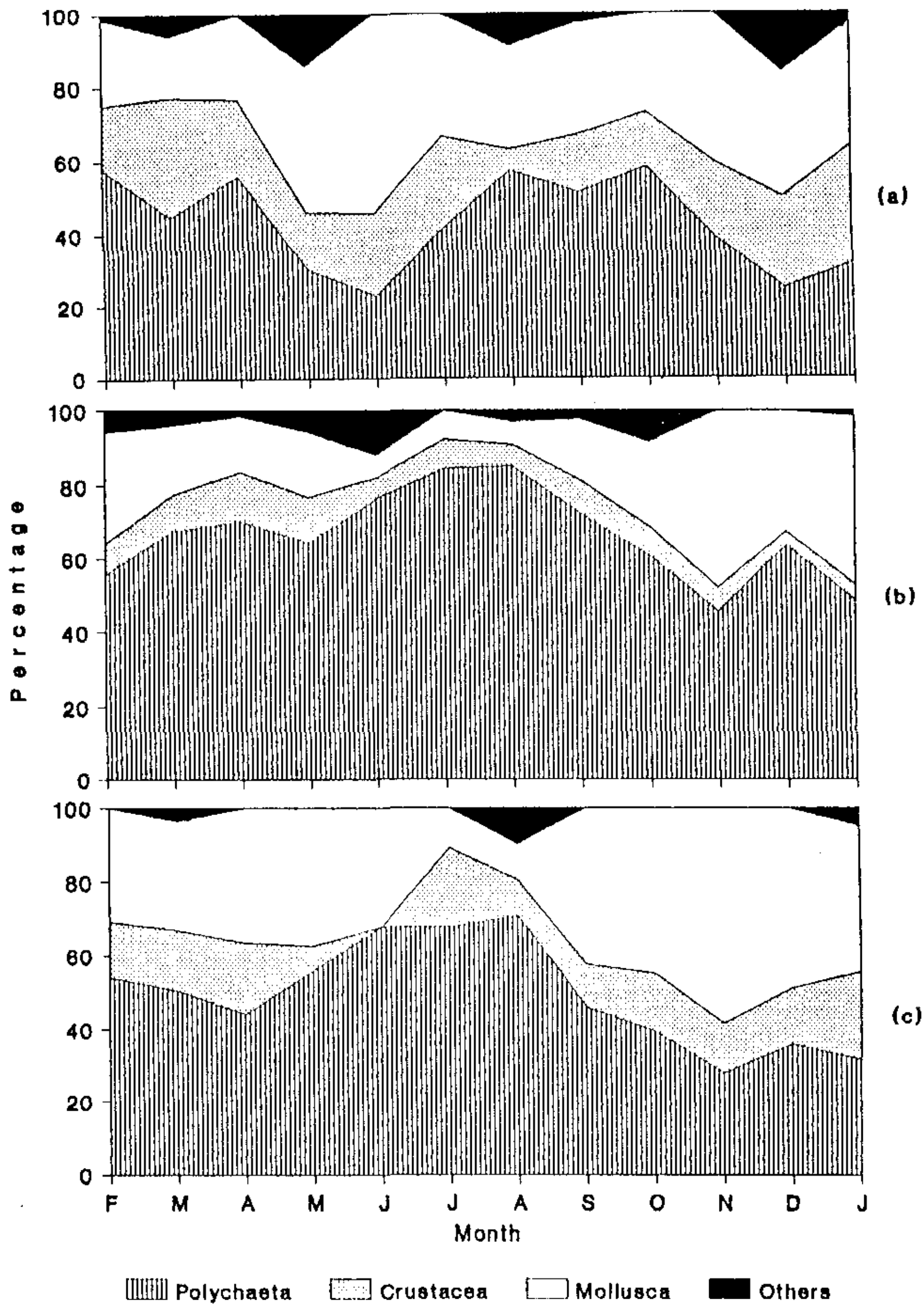


Figure 5.2 Percentage composition (monthly mean values) of major groups of benthos in 0.1 m^2 area at station 2 during September 1989 to August 1991
(a) Low tide level (b) Mid tide level (c) High tide level

capitellidae group. The highest number of polychaete fauna ($280/m^2$) recorded was that of *D. heteropoda* in August. This was followed by *Branchiocapitella singularis* with $190/m^2$ in March. Among crustaceans the common species were *Sphaeroma* sp. and *Palaemon* sp. with $190/m^2$ during March and December respectively. The numerical abundance of mollusc was due to the presence of *Hydrobia* sp. which showed the maximum number of $560/m^2$ in February.

In the mid tide level polychaetes contributed 64.01% of the total fauna, followed by 24.79% of molluscs. The crustaceans and other groups were represented by 8.32% and 2.88% respectively. Polychaete fauna was mainly composed of *Dendronereides heteropoda* and *Nereis glandicincta*. *D. heteropoda* was recorded in all the months in fairly good numbers with a maximum of $810/m^2$ in September. *Nereis glandicincta* was present throughout the year and recorded its maximum number of $250/m^2$ in May and January. The crustacean fauna, as a whole was poor when compared to polychaetes and molluscs. Among the mollusc *Hydrobia* sp. was present throughout the year and the maximum number recorded was $810/m^2$ in January. The other groups rarely represented by nemertine and insect larvae.

In the high tide level, the polychaetes were dominated by 48.22% of the total fauna, followed by mollusc (35.60%) and crustacea with 14.72%. The polychaetes dominated in this tidal level were *Dendronereides heteropoda* and *Nereis glandicincta*. The highest number of $310/m^2$ of *D.heteropoda* was recorded during March. As in the case of mid tide level the crustacean fauna was very poor. Only *Hydrobia* sp. was present among the molluscan fauna. The maximum number recorded was $310/m^2$ during March. The other groups were composed of insect larvae which form 1.46% of the total fauna.

Station 3

In the low tide level, the polychaetes contributed 48.17% of the total fauna whereas the crustaceans and molluscs constituted 12.26% and 35.48% respectively. Among polychaetes the most common species was *Dendronereis aestuarina* with the maximum number of 420/m^2 recorded in November. *Prionospia cirrifera* ranked next to *D. aestuarina* in the order of its abundance and contributed 390/m^2 during October. Among crustacean *Gammarus* sp. occured its maximum abundance in April, with the highest number of 190/m^2. *Villorita cyprinoides* dominated the molluscan fauna with the maximum number of 560/m^2 during October. *Tellina* sp. was the second dominating molluscan species with the maximum abundance of 560/m^2 in September. The other groups formed only 3.22% of the total fauna.

In the mid tide level polychaete fauna was conspicuous with 54.16% followed by molluscs with 31.52%. Polychaete fauna was mainly composed of *Dendronereis aestuarina*, *Marphysa gravelyi* and *Nereis glandicincta*. *D. aestuarina* was recorded throughout the year with maximum number of 940/m^2 in November. The crustacean fauna constituted only 12.59% and represented by *Apseudes chilkensis* and *Gammarus sp.*. Among the molluscs, *Villorita cyprinoides* (170/m^2 in November), *Tellina* sp. (190/m^2 in August) and *Hydrobia* sp. (140/m^2 in November) were the dominant forms. The other groups constituted only 1.73% of the total fauna.

In the high tide level the polychaete fauna formed 46.82% of the total fauna. In this level *Nereis glandicincta* was the major species which contributed the bulk of the population. This species was present throughout the year with the highest value of 280/m^2 in September. The crustacean fauna constituted only 11.78% and the highest number recorded were *Gammarus* sp. (110/m^2 in February) and *Sphaeroma* sp. (140/m^2 in September).

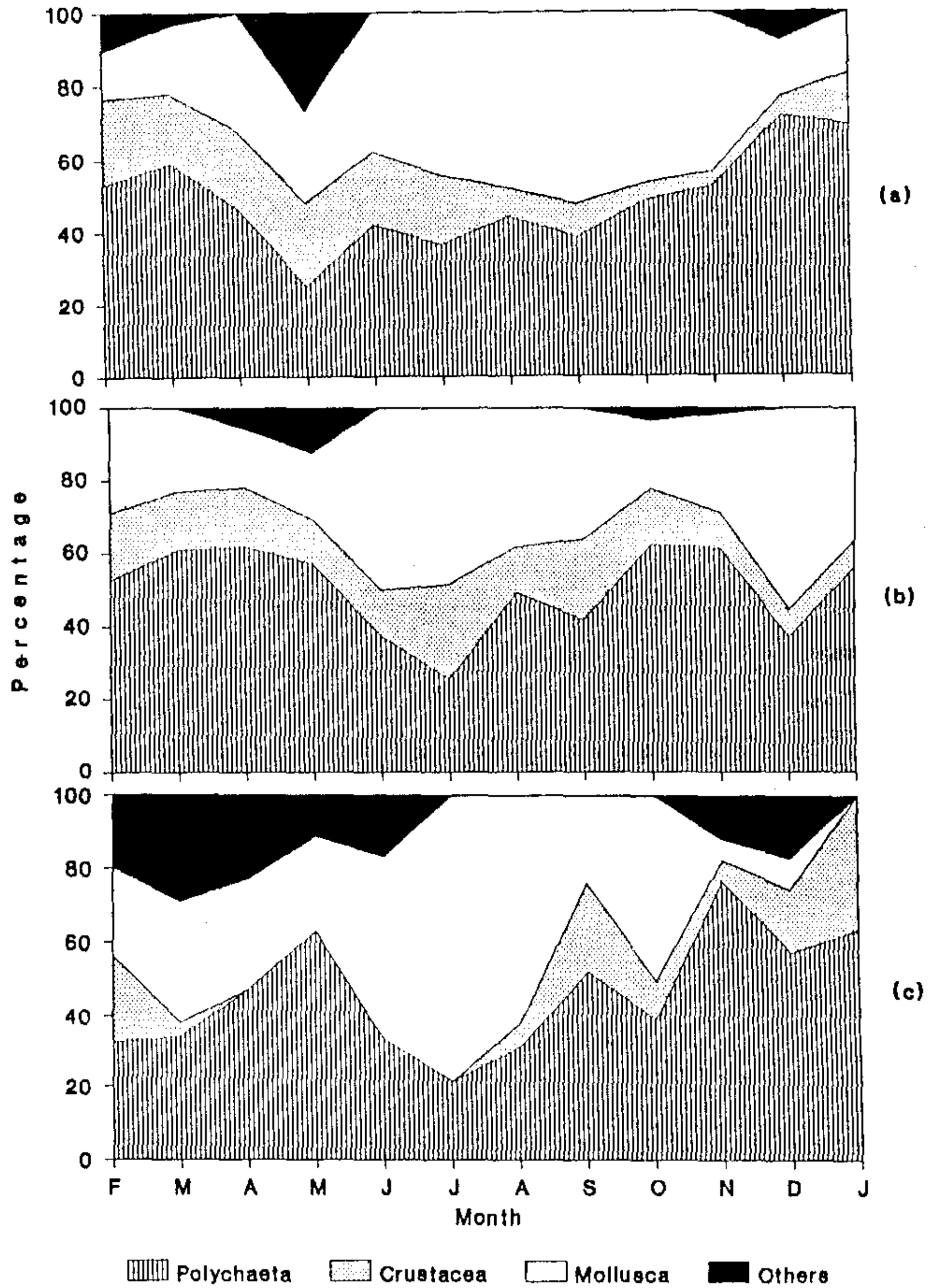


Figure 5.3 Percentage composition (monthly mean values) of major groups of benthos in 0.1 m^2 area at station 3 during September 1989 to August 1991
(a) Low tide level (b) Mid tide level (c) High tide level

The mollusc accounted for 29.92% and was mainly composed of *Hydrobia* sp. with the maximum number of 440/m^2 in October. Theother groups contributed 11.48% of the total fauna.

5.4 BIOMASS

The dry weight values of the macrofaunal groups have been taken for measuring the standing crop. The quantitative values of benthic fauna are given in Tables 5.15-5.17.

Of the total biomass of 209.416 g/m^2 (commuted value) at station 1, the polychaetes alone contributed 125.15 g/m^2 which form 59.76%. The rest of the fauna included crustaceans, molluscs and the other groups together contributed 84.266 g/m^2 which form 40.24% of the total biomass. Polychaete species which contributed to the high biomass are *Marphysa gravelyi*, *Paraheteromastus tenuis* and *Eunice* sp.. In the low tide level the polychaete contributed 20.558 g/m^2 and the crustaceans, molluscs and other groups together contributed 19.482 g/m^2. In the middle level, of the total biomass 115.427 g/m^2, the polychaetes contributed 66.163 g/m^2 which form 57.32%. The other groups contributed 49.264% g/m^2 which form 42.68% of the total biomass. In the high tide level the total biomass value was 53.949 g/m^2. The contribution of polychaete was 38.429% g/m^2 and the rest of the fauna together form 15.52 g/m^2.

At station 2, of the total biomass of 127.308 g/m^2, polychaete constituted for 57.345 g/m^2 which form 45.04% of the total biomass. The other groups together contributed 69.963 g/m^2. In the low tide level *Palaemon* sp. contributed the major portion of the total biomass. The other groups form 28.225 g/m^2 (74.96%) of the total biomass of 37.655 g/m^2. In the mid tide level, of the total biomass 61.011 g/m^2 the polychaete accounted for 42.658 g/m^2 (69.92%) and the other faunal groups contributed 18.353 g/m^2 (30.08%). In the high tide level polychaete accounted 5.257 g/m^2 (18.35%) and the crustaceans, molluscs and other groups together contributed 23.385 g/m^2 (81.65%) to the total biomass of 28.642 g/m^2.

At station 3, of the total biomass of 88.011 g/m^2, the polychaetes accounted 36.155 g/m^2 (41.08%) and the rest of the fauna formed 51.856 g/m^2 (58.92%). At the low tide level, out of the total biomass of 43.457% g/m^2, polychaetes constituted 16.21 g/m^2 (37.30%) and the other fauna formed 27.247 g/m^2 (62.7%). Among polychaete population, *Dendronereis aestuarina* alone contributed 45.53% to the total polychaete biomass. Among molluscs, *Villorita cyprinoides* contributed the major part with 29.59%. Of the total biomass of 22.101 g/m^2 in the mid tide level, polychaete contributed 12.198 g/m^2 (55.19%) and the rest of the fauna formed 9.903 g/m^2 (44.81%). *Dendronereis aestuarina* alone contributed 50.57% among the polychaete population. In the high tide level, polychaete contributed 7.747 g/m^2 (34.5%). The rest of the fauna (14.706 g/m^2) contributed 65.5% of the total biomass value of 22.245 g/m^2.

5.5 REGIONAL VARIATION OF FAUNA

The distribution of benthic fauna in Cochin mangroves shows regional variation. Polychaetes, crustaceans and molluscs were the three major groups distributed throughout the area. Among polychaetes, *Amphicteis gunneri, Ceratonereis costae, Diopatra neapolitana, Glycera alba, G. longipinnis, Lumbriconereis latrelli, L. simplex, L. pseudobifilaris, Pulliella armata, Nereis kauderni* and *Goniada* sp. were found only at station 1. *Dendronereides heteropoda* was found only at station 2. The occurrence of *Prionospio cirrifera, P. pinnata* and *Dendronereis arborifera* were restricted to station 3. Among crustaceans *Dotilla* sp., *Ligia* sp. and *Uca annulipes* were found only at station 1. Among molluscs *Tapes* sp. was recorded from station 1. *Bittium* sp. and *Musculista* sp. were found at stations 1 and 2 whereas *Villorita cyprinoides* was found at stations 2 and 3.

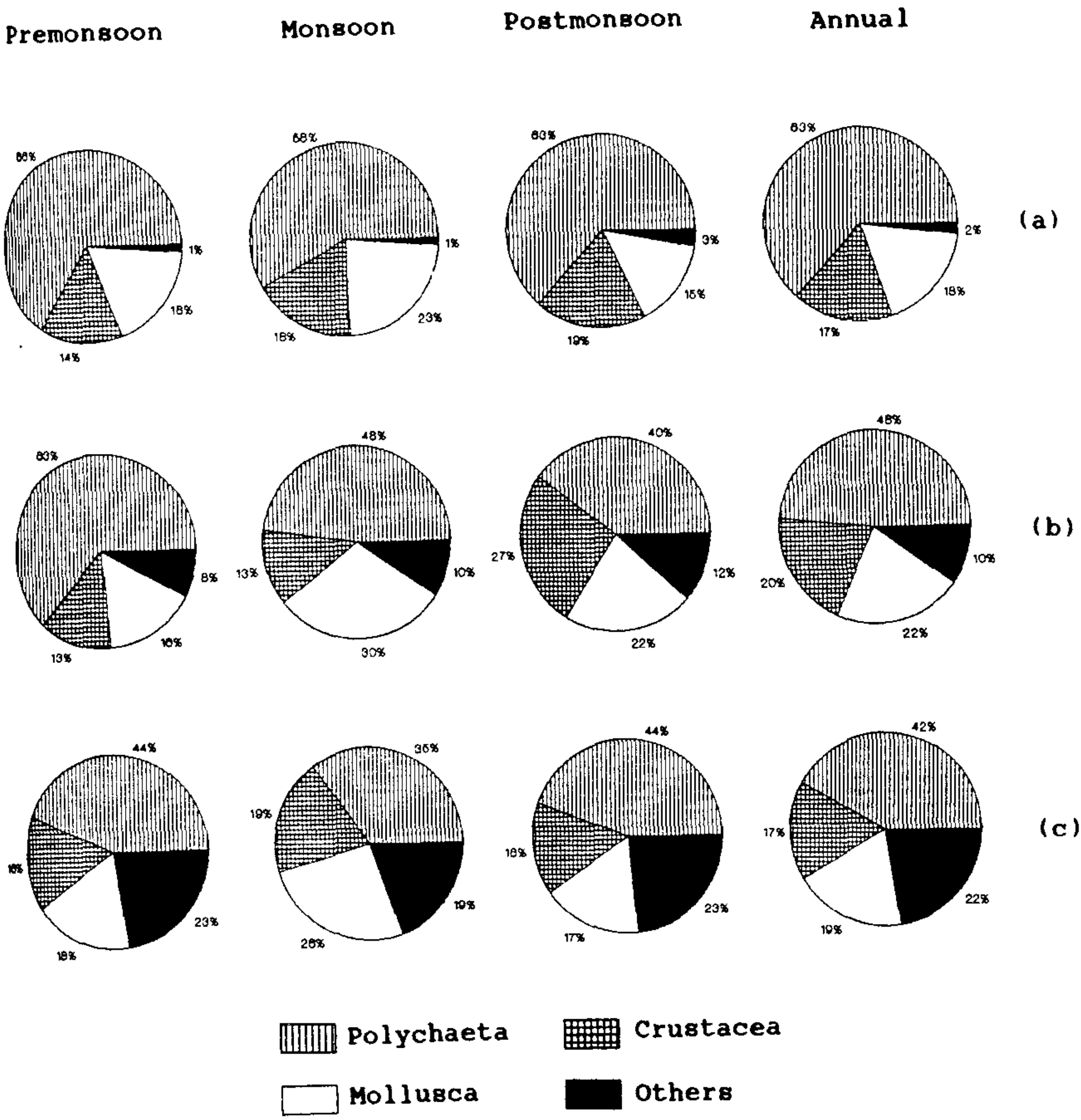
5.6 SEASONAL VARIATIONS

It is to be noted that, in general premonsoon and postmonsoon periods showed the highest composition of benthic fauna and the monsoon period (June-July) showed the lowest composition. Premonsoonal, monsoonal, postmonsoonal and annual changes in the composition of polychaeta, crustacea, mollusca and other groups are shown in Figs. 5.4-5.6.

Regarding the seasonal occurrence of benthic fauna, the maximum number was found during premonsoon and postmonsoon periods in the low tide and mid tide levels at station 1. In this station the population was found to be higher during the postmonsoon period in the high tide level (Fig. 5.7). At station 2 the highest population was found in all the three tidal levels during premonsoon period following the postmonsoon (Fig. 5.8). The maximum population density was noted during postmonsoon season in the low tide, mid tide and high tide levels at station 3 (Fig. 5.9). The number of organisms were found to be minimum in the monsoon season (June-July) in all the stations.

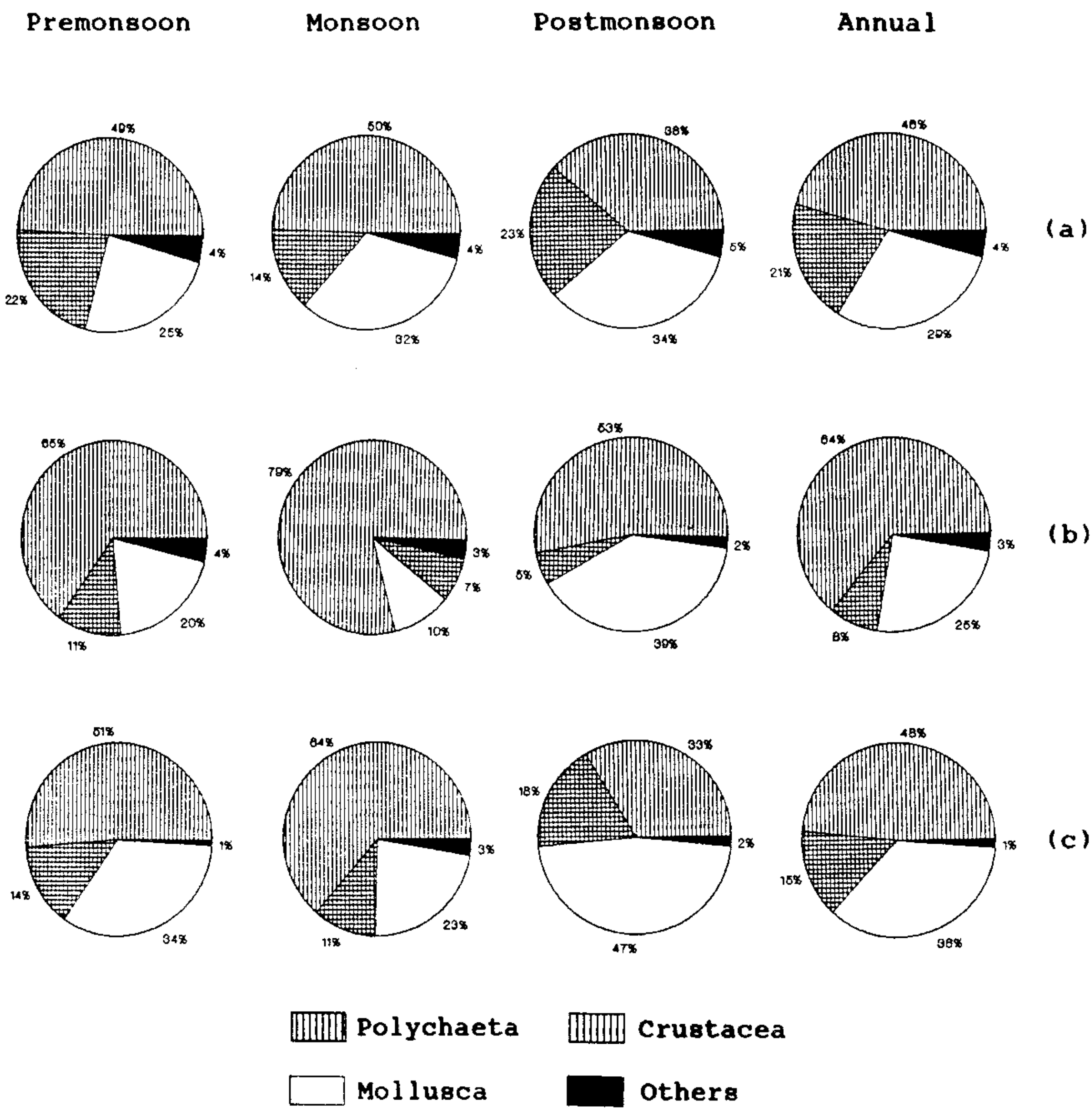
5.7 SPECIES DIVERSITY INDICES

Diversity indices can be used to characterise species abundance relationships in communities. Diversity is composed of two distinct components such as the total number of species and the evenness (how the abundance data are distributed among the species). The concept of species diversity in community ecology has been intensely debated by ecologists over the years. In fact, Hurlbert (1971), went so far as to suggest that diversity was probably best described as a "nonconcept" because of the many sematic, conceptual, and technical problems associated with its use. In spite of debates and numerous cautionary remarks put forth by many regarding their use,

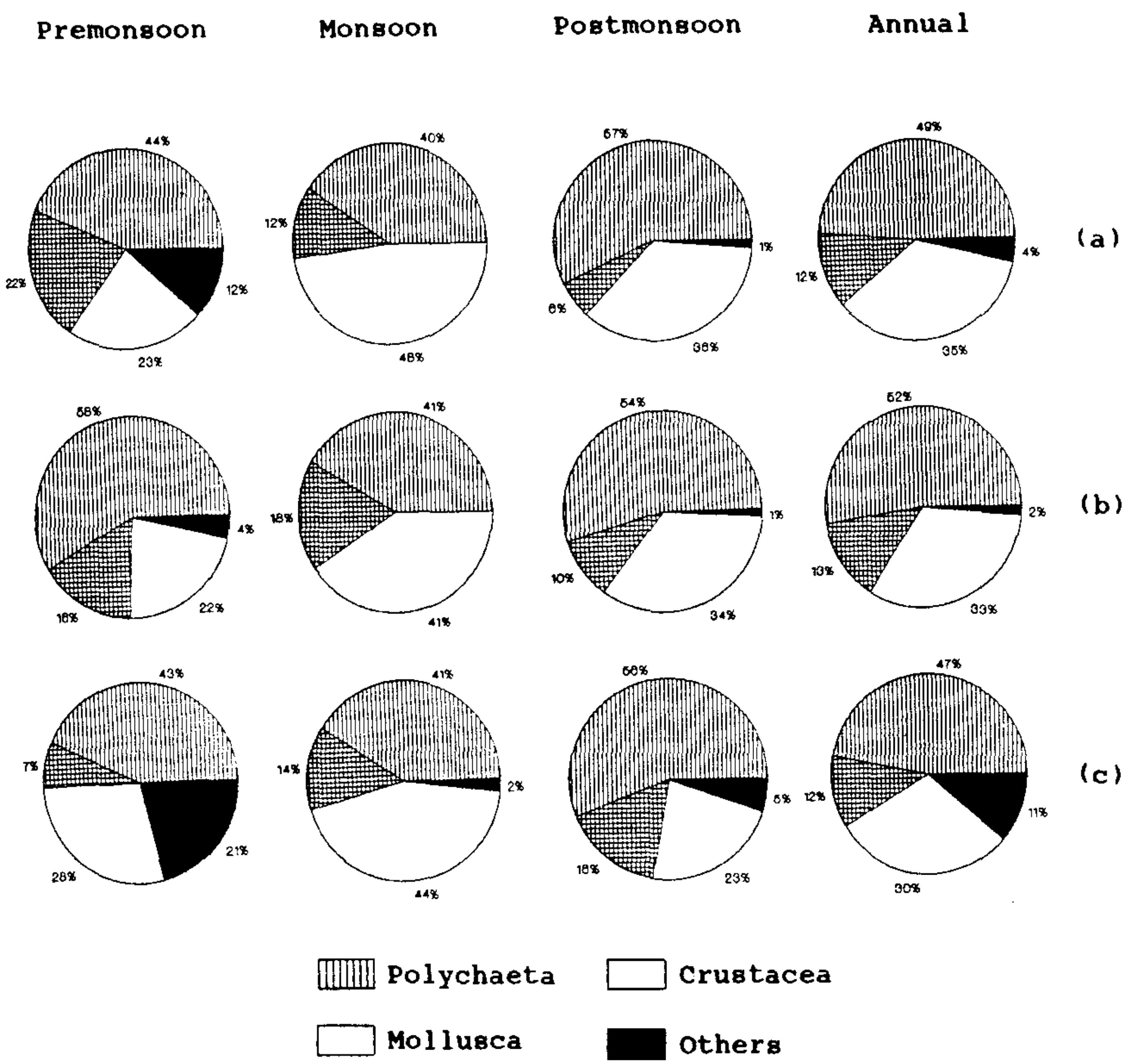


gure 5.4 Percentage occurrence of polychaeta, crustacea, mollusca
d others with respect to total fauna during different seasons
; station 1

) Low tide level (b) Mid tide level (c) High tide level



gure 5.5 Percentage occurrence of polychaeta, crustacea, mollusca
d others with respect to total fauna during different seasons
: station 2
) Low tide level (b) Mid tide level (c) High tide level



igure 5.6 Percentage occurrence of polycheata, crustacea, mollusca nd others with respect to total fauna during different seasons t station 3
a) Low tide level (b) Mid tide level (c) High tide level

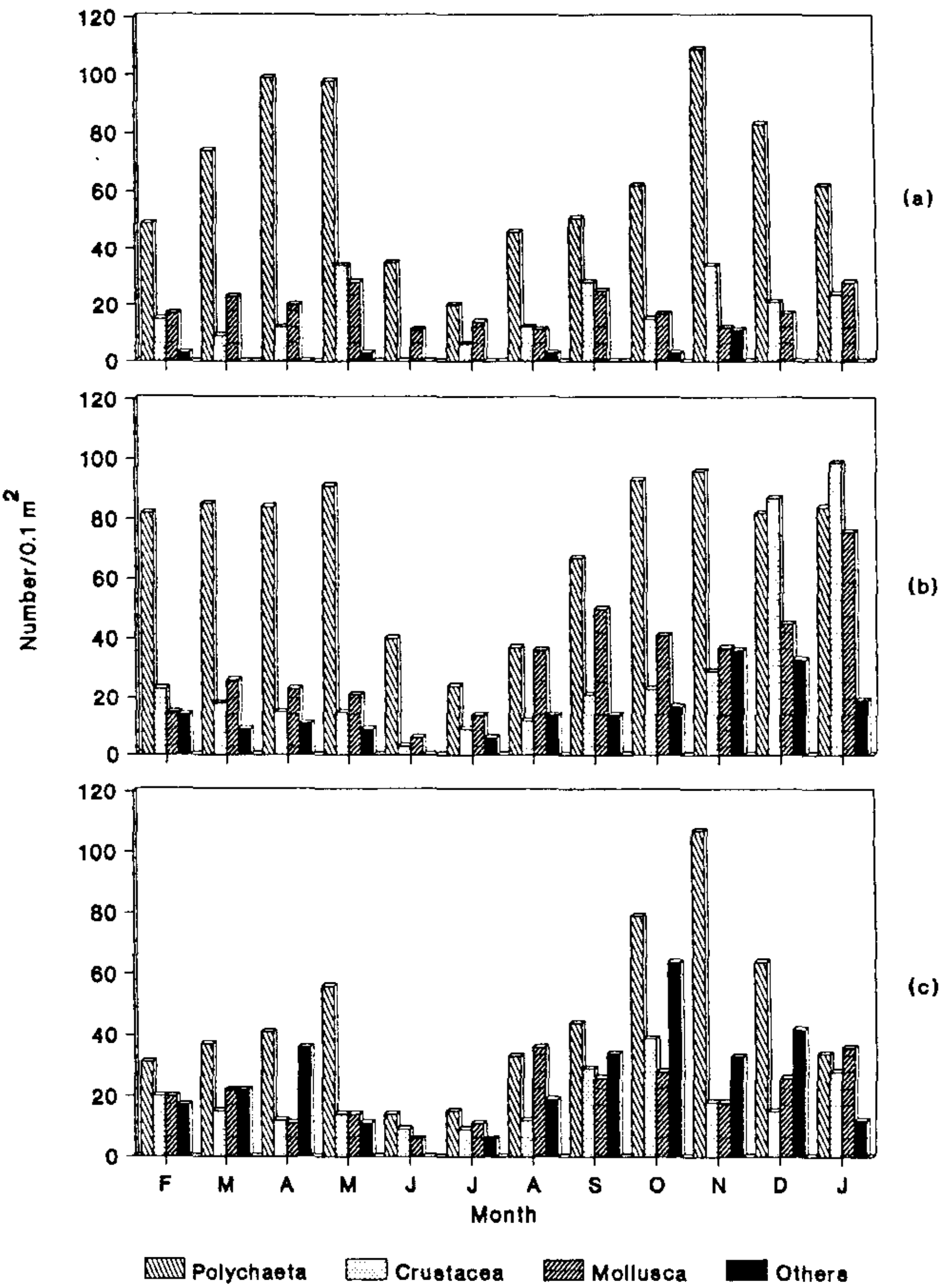


Figure 5.7 Monthly variations (mean values) of major groups of benthos at station 1 during September 1989 to August 1991 (a) Low tide level (b) Mid tide level (c) High tide level

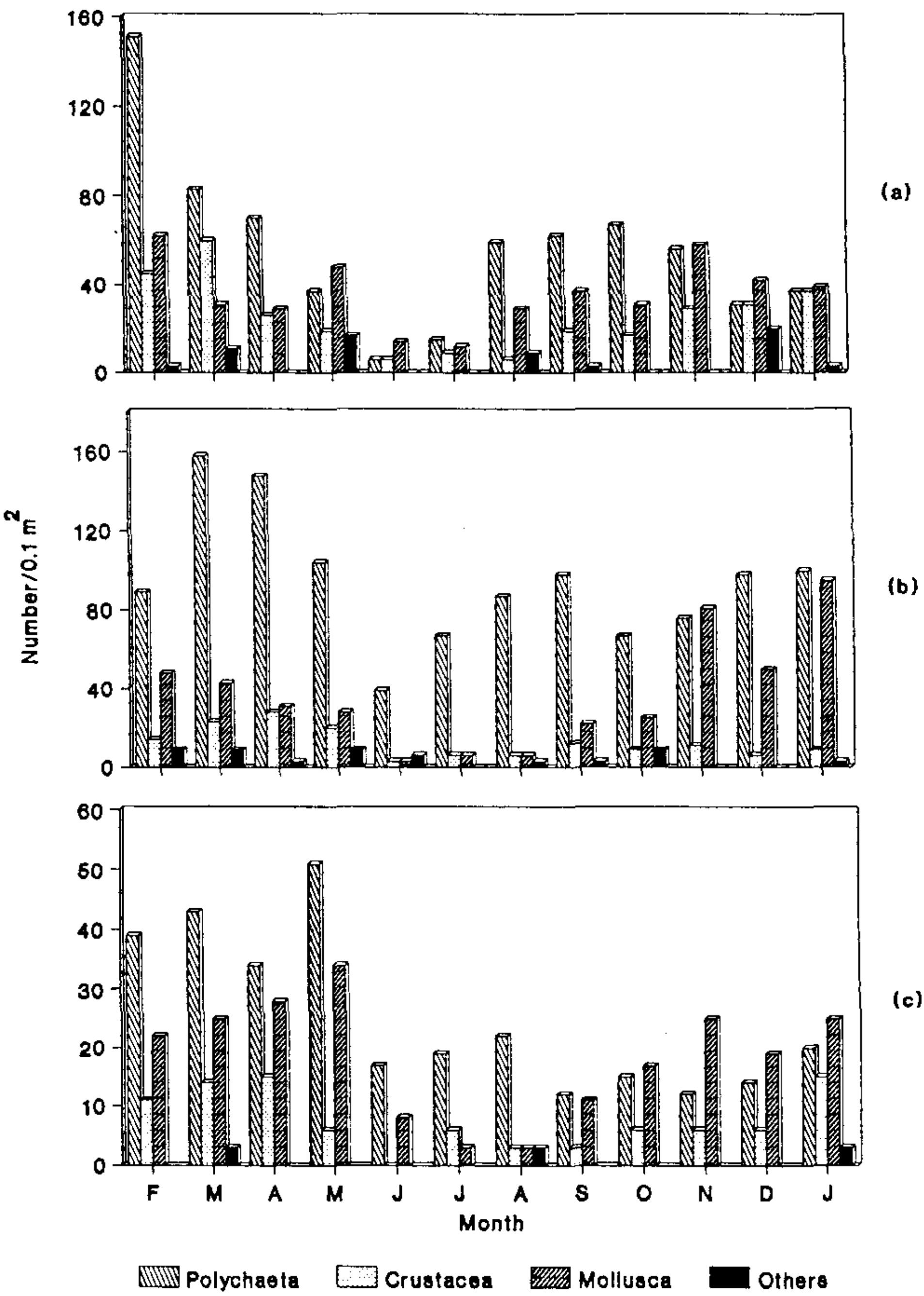


Figure 5.8 Monthly variations (mean values) of major groups of benthos at station 2 during September 1989 to August 1991 (a) Low tide level (b) Mid tide level (c) High tide level

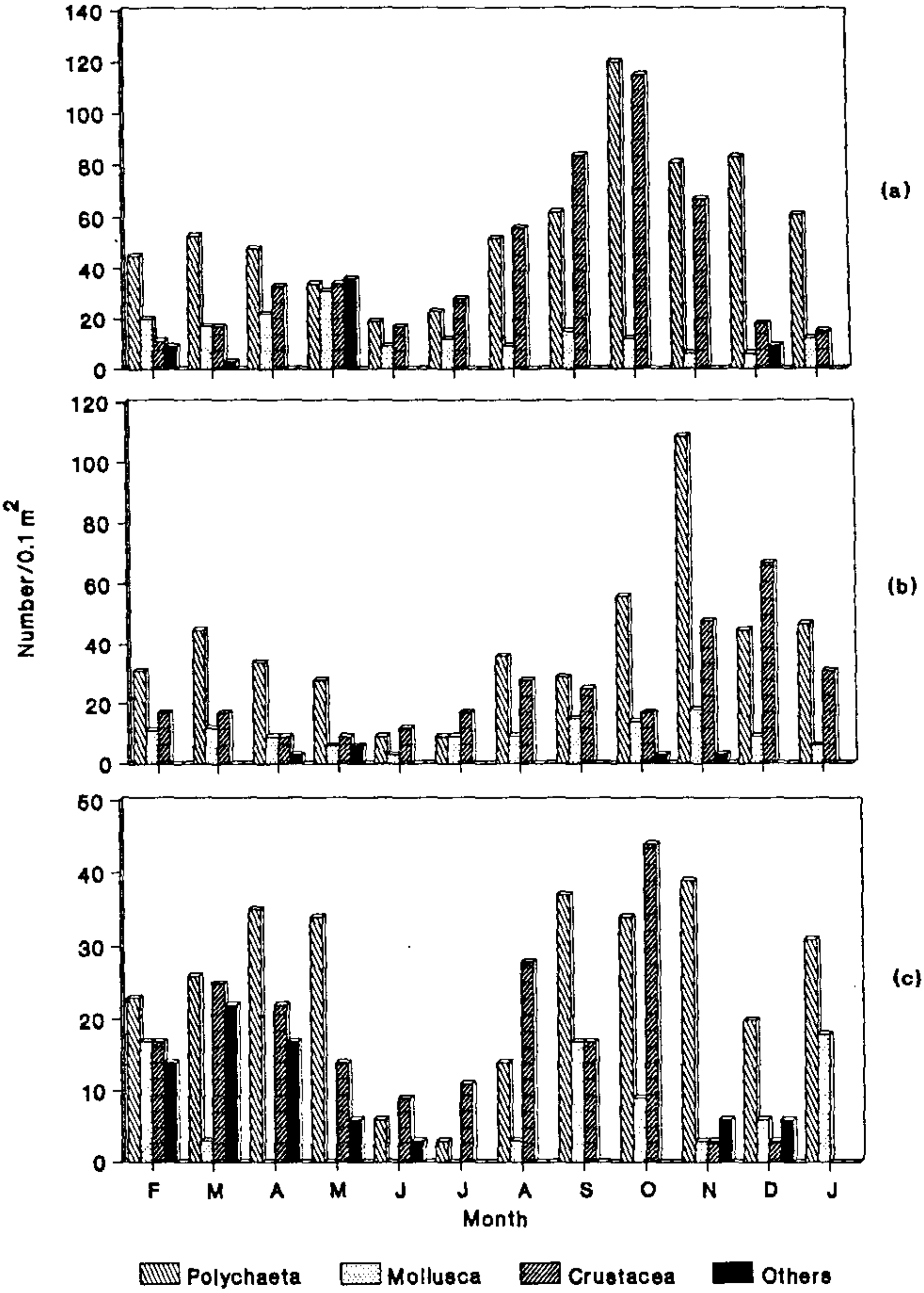


Figure 5.9 Monthly variations (mean values) of major groups of benthos at station 3 during September 1989 to August 1991 (a) Low tide level (b) Mid tide level (c) High tide level

diversity indices have remained very popular with ecologists (Lugwing and Reynolds, 1988).

Species diversity may be thought of as being composed of two components. The first is the number of species in the community, which ecologists often refer to as species richness. The second component is species evenness or equitability. Evenness refers to how the species abundances (eg. the number of individuals, biomass, cover, etc.) are distributed among the species.

Over the years, a number of indices have been proposed for characterising species richness and evenness. Such indices are termed richness indices and evenness indices. Indices that attempt to combine both species richness and evenness into a single value are what we refer to as diversity indices. Species diversity indices here used were worked by using four formula by Margalef (1958), Shannon and Weaver (1958), Hill (1973) and Sheldon (1969) (please refer material and methods).

The diversity indices of benthic fauna together and the polychaete fauna separately were calculated during the present study and they are presented in Tables 5.18-5.20 and 5.21-5.23 respectively. Figs. 5.10-5.15 show monthly variations of the diversity indices of benthic fauna.

Regarding the species diversity indices of benthic fauna, the species richness (R1) values varied from 1.31 during June in the low tide level to 4.5 during March in the mid tide level at station 1. It varied from 0.62 during June in the high tide level to 3.26 during March in the low tide level at station 2 and 0.38 during July in the high tide level to 2.74 during December in the low tide level at station 3. The H' (Shannon's index) value ranged from 1.65 during June in the low tide level to 3.03 during March in the mid tide lvel, 1.07 during June in

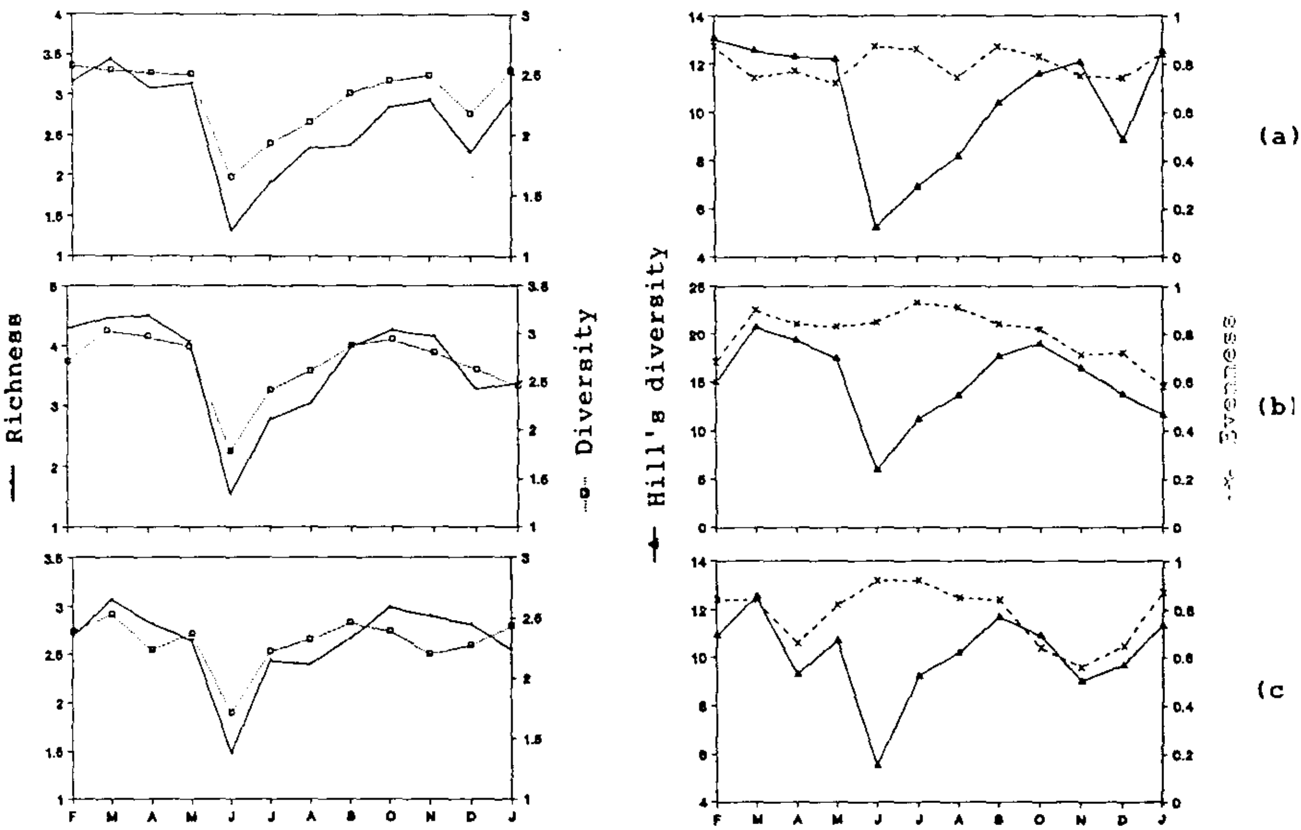


Figure 5.10 Monthly variations in diversity indices of benthic fauna at station 1
(a) Low tide level (b) Mid tide level (c) High tide level

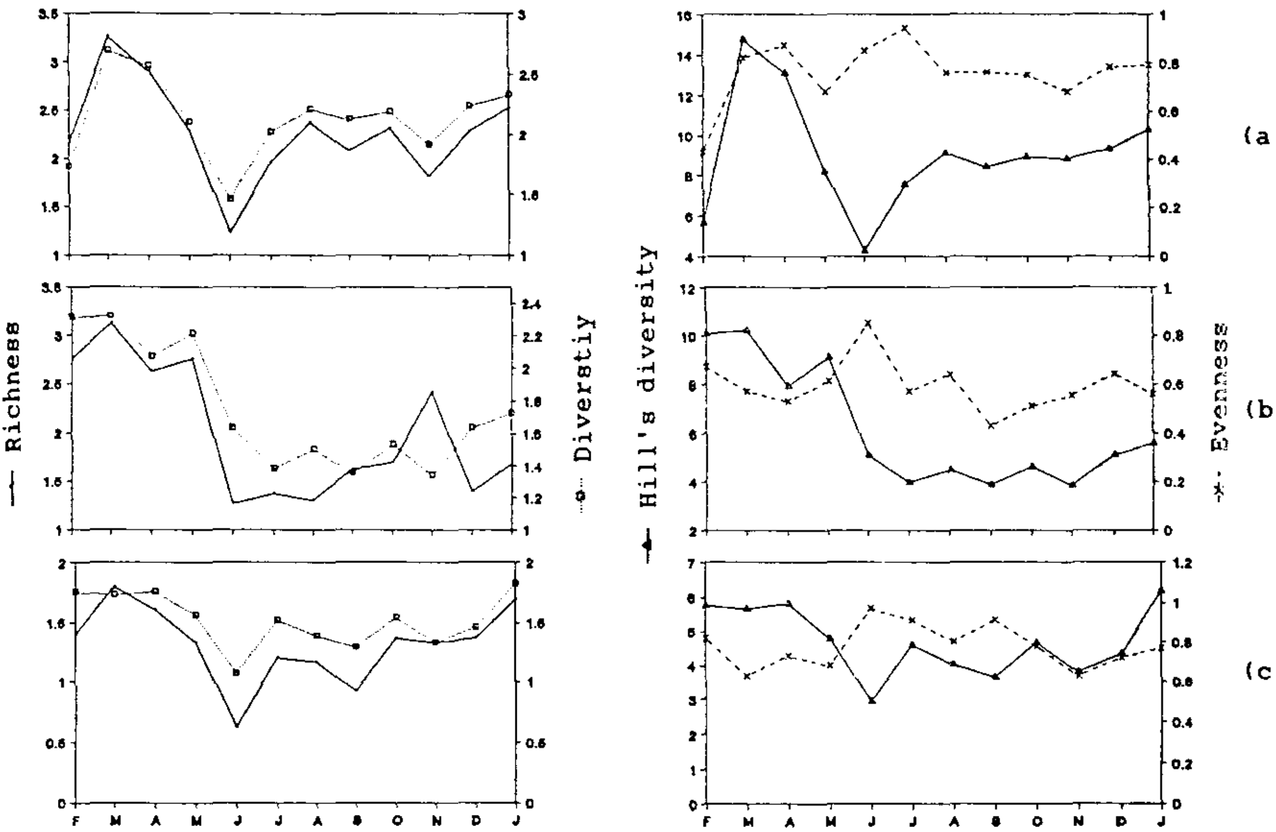


Figure 5.11 Monthly variations in diversity indices of benthic fauna at station 2
(a) Low tide level (b) Mid tide level (c) High tide level

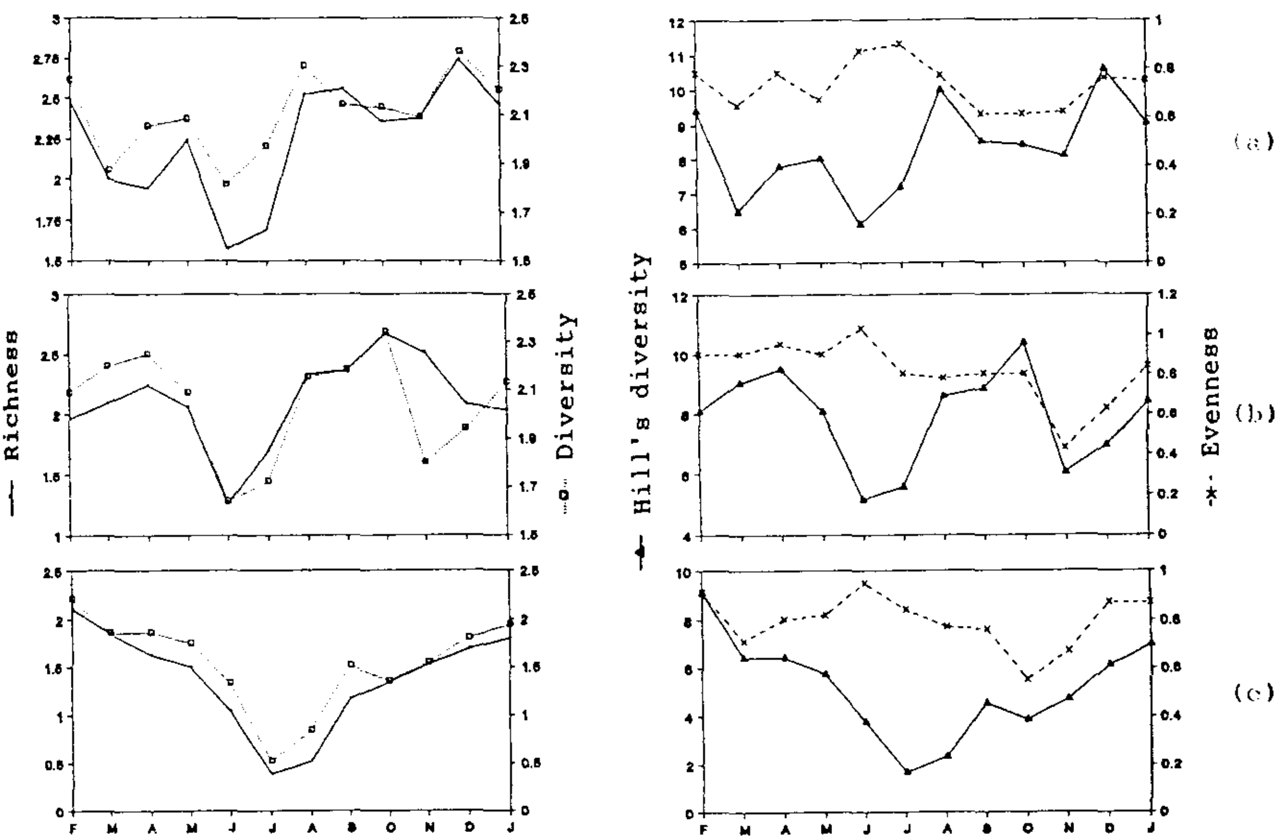


Figure 5.12 Monthly variations in diversity indices of benthic fauna at station 3
(a) Low tide level (b) Mid tide level (c) High tide level

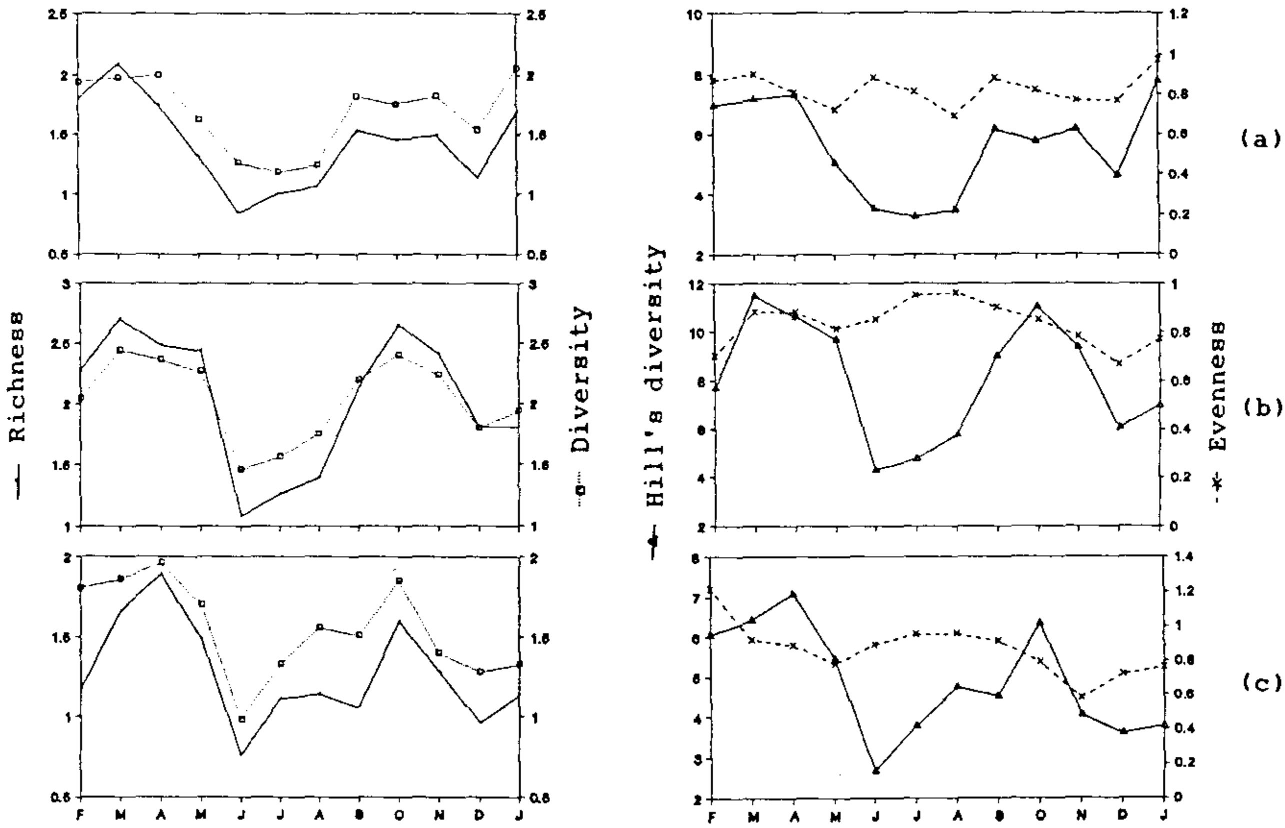


Figure 5.13 Monthly variations in diversity indices of polychaete fauna at station 1
(a) Low tide level (b) Mid tide level (c) High tide level

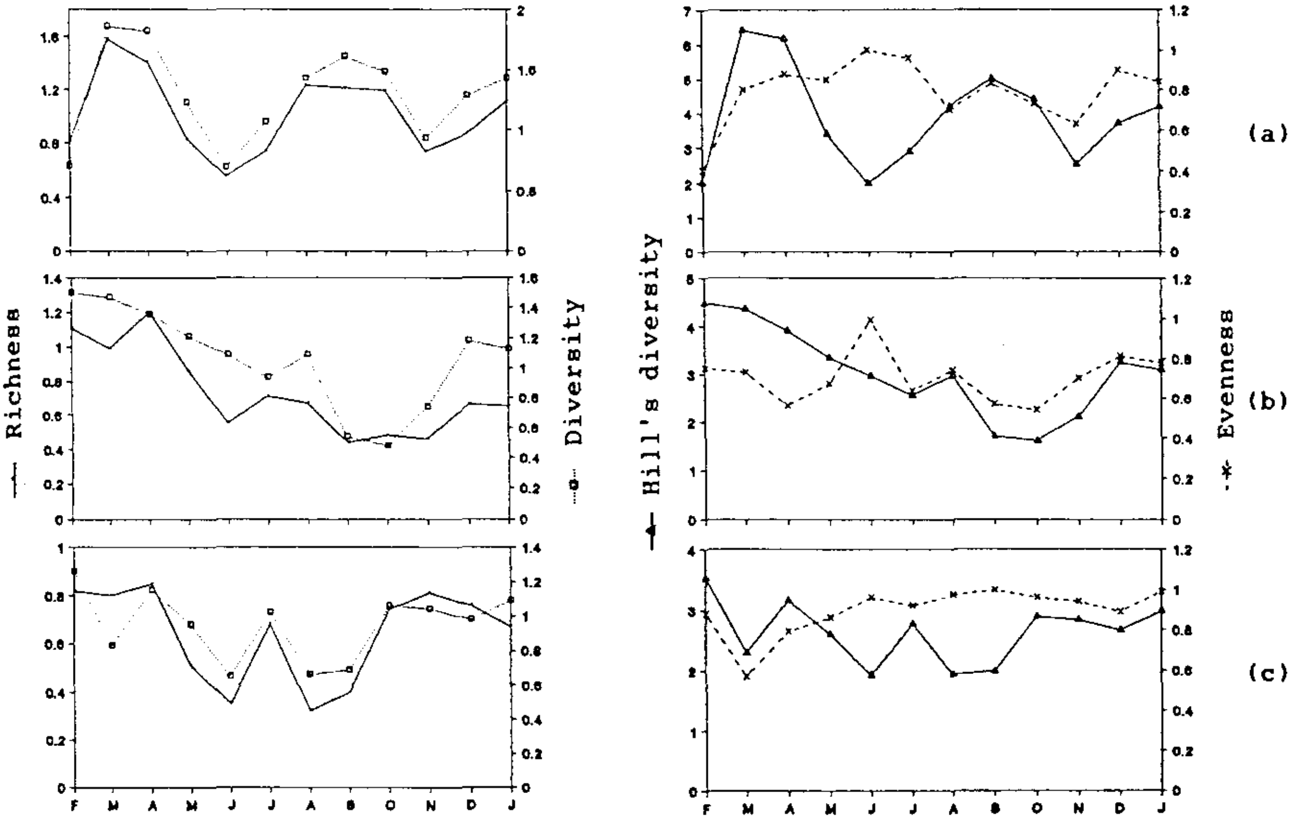


Figure 5.14 Monthly variations in diversity indices of polychaete fauna at station 2
(a) Low tide level (b) Mid tide level (c) High tide level

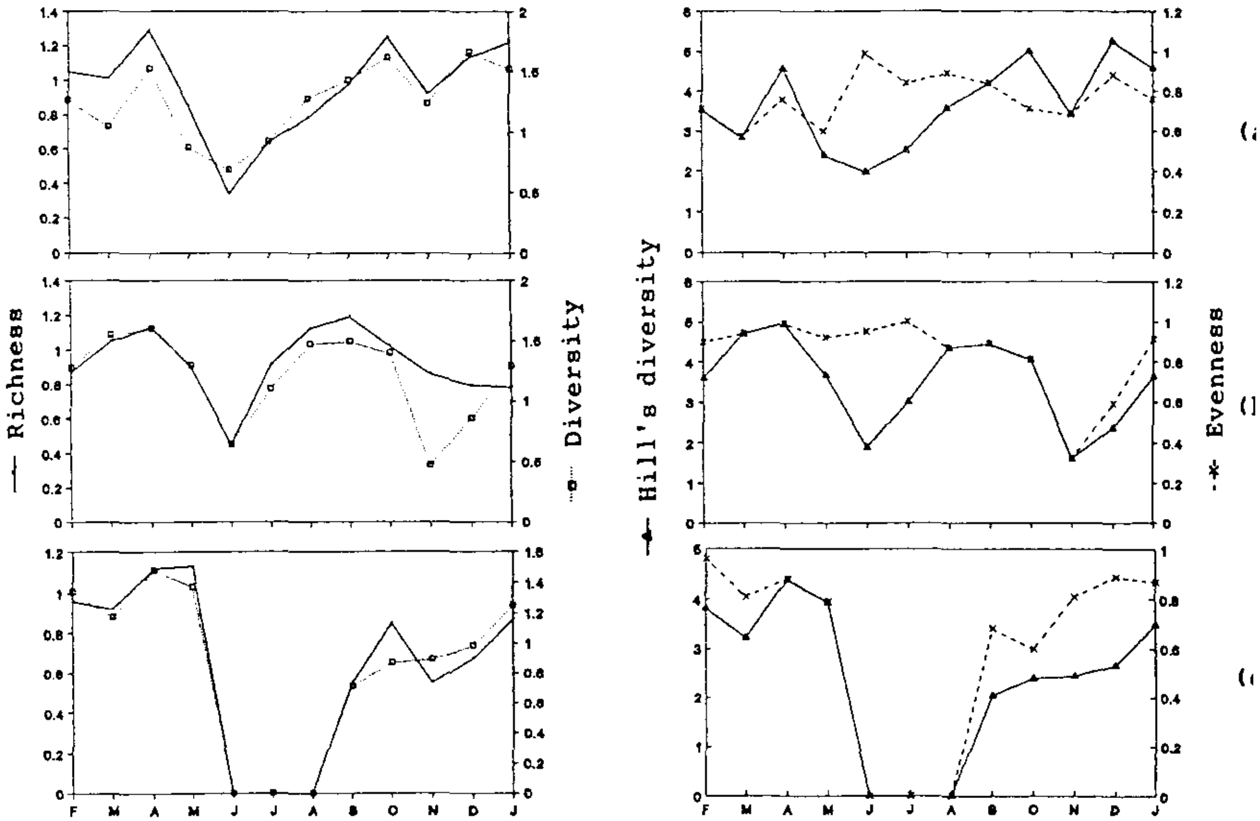


Figure 5.15 Monthly variations in diversity indices of polychaete fauna at station 3

(a) Low tide level (b) Mid tide level (c) High tide level

the high tide level to 2.69 during March in the low tide level and 0.52 during July in the high tide level to 2.34 during October in the mid tide level at stations 1, 2 and 3 respectively. The Hill's diversity number (N1) values varied from 5.21 during June in the low tide level to 20.70 during March in the mid tide level at station 1, 2.92 during June in the high tide level to 14.73 during March in the low tide level at station 2 and 1.68 during July in the high tide level to 10.59 during December in the low tide level at station 3. Although there was some difference in the Evenness (E2) values, they did not vary considerably among the three stations.

Regarding the species diversity indice of polychaete fauna alone, the R1 values ranged from 0.76 during June in the high tide level to 2.70 during March in the mid tide level, 0.32 during August in the high tide level to 1.58 during March in the low tide level and zero during June in the high tide level to 1.29 during April at stations 1, 2 and 3 respectively. The H' values varied from 0.98 during June in the high tide level to 2.44 during March in the mid tide level at station 1. It was varied from 0.66 during August in the high tide level to 1.86 during March in the low tide level at station 2 and zero in the high tide level to 1.60 during April in the mid tide level at station 3. The N1 values varied from 2.66 during June in the high tide level to 11.47 during March in the mid tide level at station 1, 1.62 during October in the mid tide level to 6.42 during March in the low tide level at station 2 and zero in the high tide level to 5.26 during December in the low tide level at station 3. There was slight difference in the E2 values of polychaetes, but in general it did not vary considerably among three stations.

5.8 VARIATIONS IN DIVERSITY INDICES WITH RESPECT TO SEASONS AND TIDE LEVELS

Seasonal variations of the diversity indices of benthic fauna as a whole and polychaete fauna separately were determined, by taking the mean values of three seasons (premonsoon, monsoon and postmonsoon) separately and are given in Table 5.24 and 5.25 respectively.

The diversity indices of benthic faunal groups together and polychaete fauna separately were compared, to study the significance, with respect to seasons and tide levels by using ANOVA technique (Fisher and Yates, 1957 and Snedecor and Cochran, 1968) and presented in Tables 5.26-5.31. The model assumed was,

$$X_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij}$$

where X_{ij} = the diversity index in i^{th} season for the j^{th} tidal level

μ = the overall effect

α_i = the i^{th} season effect

β_j = j^{th} tidal effect

ϵ_{ij} = the random error

The R1, H' and N1 values of benthic fauna were significantly different between seasons and tide levels while E2 values were significantly different only between seasons at station 1 (Table 5.26). At station 2, R1, H' and N1 values were significantly different between seasons and tide levels while E2 values were significantly different only between tide levels (Table 5.27). The R1 and N1 values were only significant between tide levels at station 3 (Table 5.28).

There is significant difference for polychaete fauna between seasons and tide levels for R1, H' and N1 values, but E2 values are not significantly different between seasons and tide levels at station 1 (Table 5.29). At station 2, N1 and E2 values are significantly different between tide levels (Table 5.30). But there is no significant difference between seasons and tide levels for all the diversity indices at station 3 (5.31).

5.9 FAUNAL SIMILARITY

The benthic communities are usually composed of numerous individuals of a few species plus a few individuals of many species. The similarity or affinity of the animals composing these communities can be measured by 'trellis diagram' (Sanders, 1960 and Wieser, 1960). It is one of the best qualitative measurements to demonstrate the relative abundance of species or the degree of similarity between the species components of an array of samples.

This technique used here to illustrate qualitatively the degree of similarity in species composition among the polychaete fauna and the degree of similarity between the major benthic groups with respect to tidal levels and seasons. The results of the analysis are given in Figs. 5.16-5.21. The high abundance of euryhaline polychaete species showed significant similariy of polychaete fauna between months (Figs. 5.16-5.18). The major benthic groups also showed significant similarity and strong association in the three stations with respect to tidal levels and seasons (Fig. 5.19 and 5.20). The high population density of *Paraheteromstus tenuis*, *Nereis glandicincta*, *Marphysa gravelyi*, *Dendronereides heteropoda* and *Dendronereis aestuarina* accounted for strong similarity between the seasons and stations among the polychaete group (Fig. 5.21).

5.10 EFFECT OF ENVIRONMENTAL PARAMETERS ON THE BENTHIC FAUNA

Inorder to study the interdepandancy of the environmental parameters on the distribution and abundance of benthic fauna, Pearson's coefficient of correlation ('r' value) was calculated (Snedecor and Cochran, 1968) using the formula,

$$r = \frac{\sum (x-\bar{x})\ (y-\bar{y})}{n\ \sigma_{\bar{x}}\ \sigma_{y}}$$

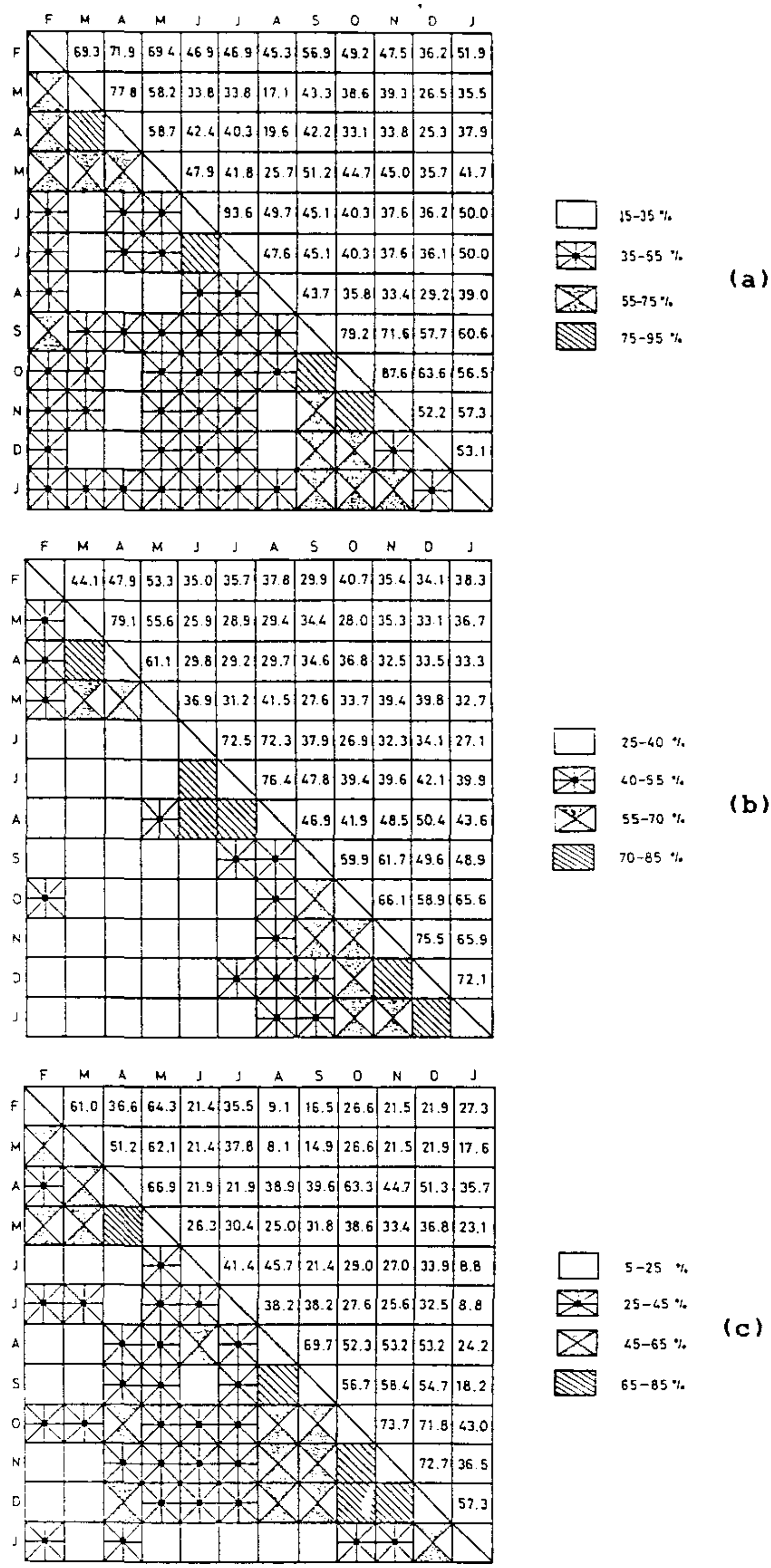


Figure 5.16 Trellis diagram showing the similarity among the polychaete fauna in different months at station 1
(a) Low tide level (b) Mid tide level (c) High tide level

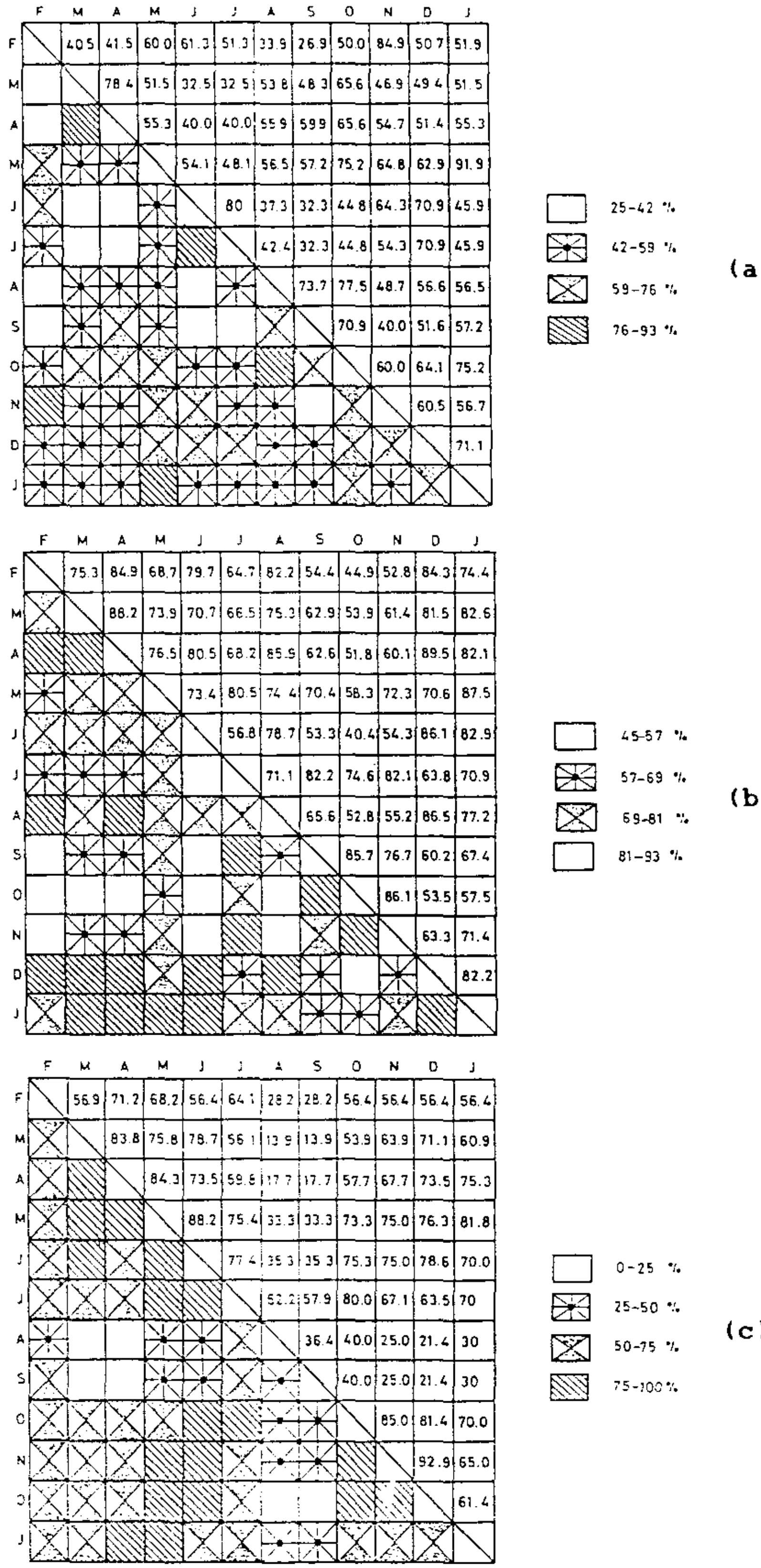


Figure 5.17 Trellis diagram showing the similarity among the polychaete fauna in different months at station 2 (a) Low tide level (b) Mid tide level (c) High tide level

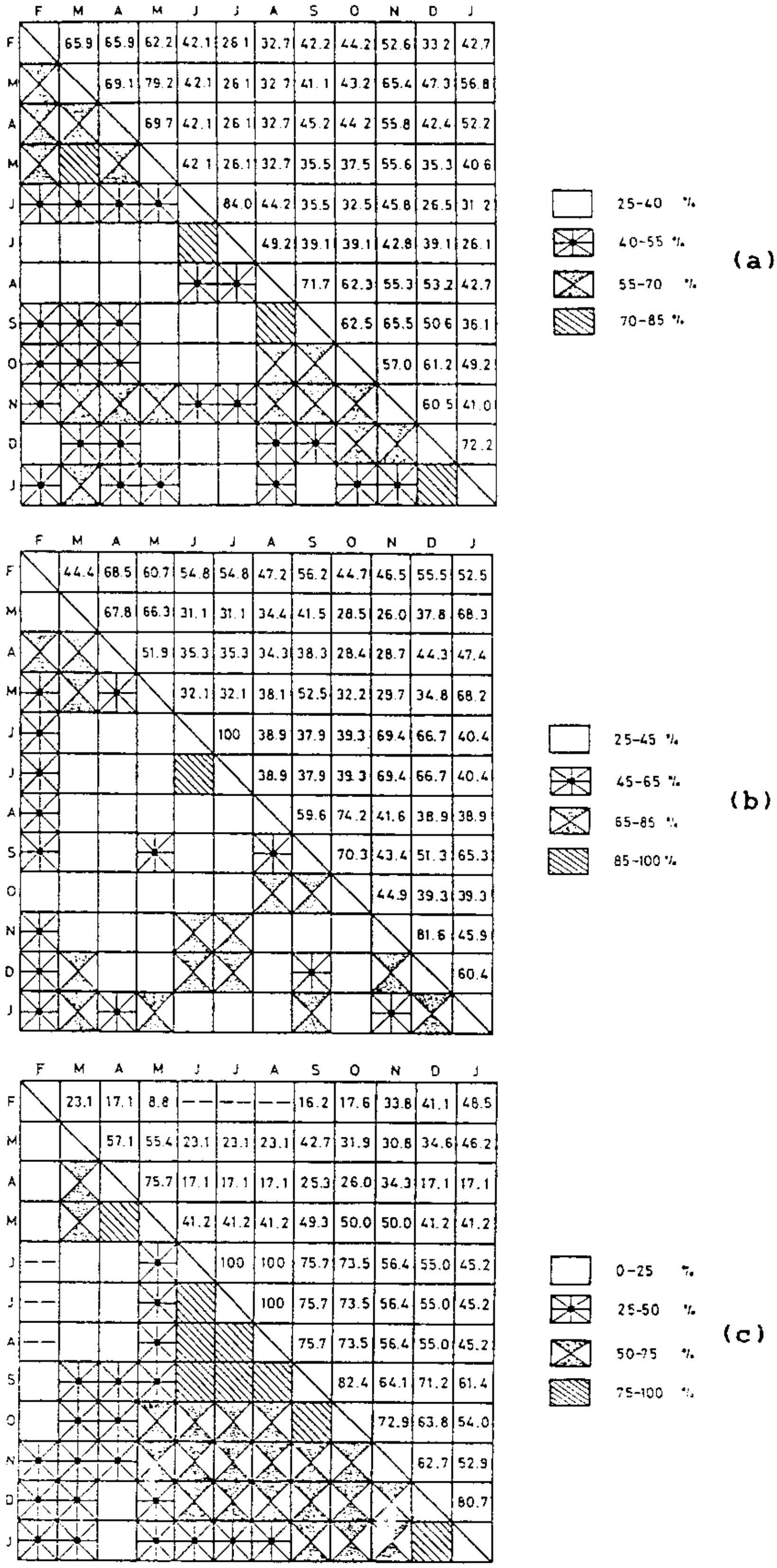


Figure 5.18 Trellis diagram showing the similarity among the polychaete fauna in different months at station 3 (a) Low tide level (b) Mid tide level (c) High tide level

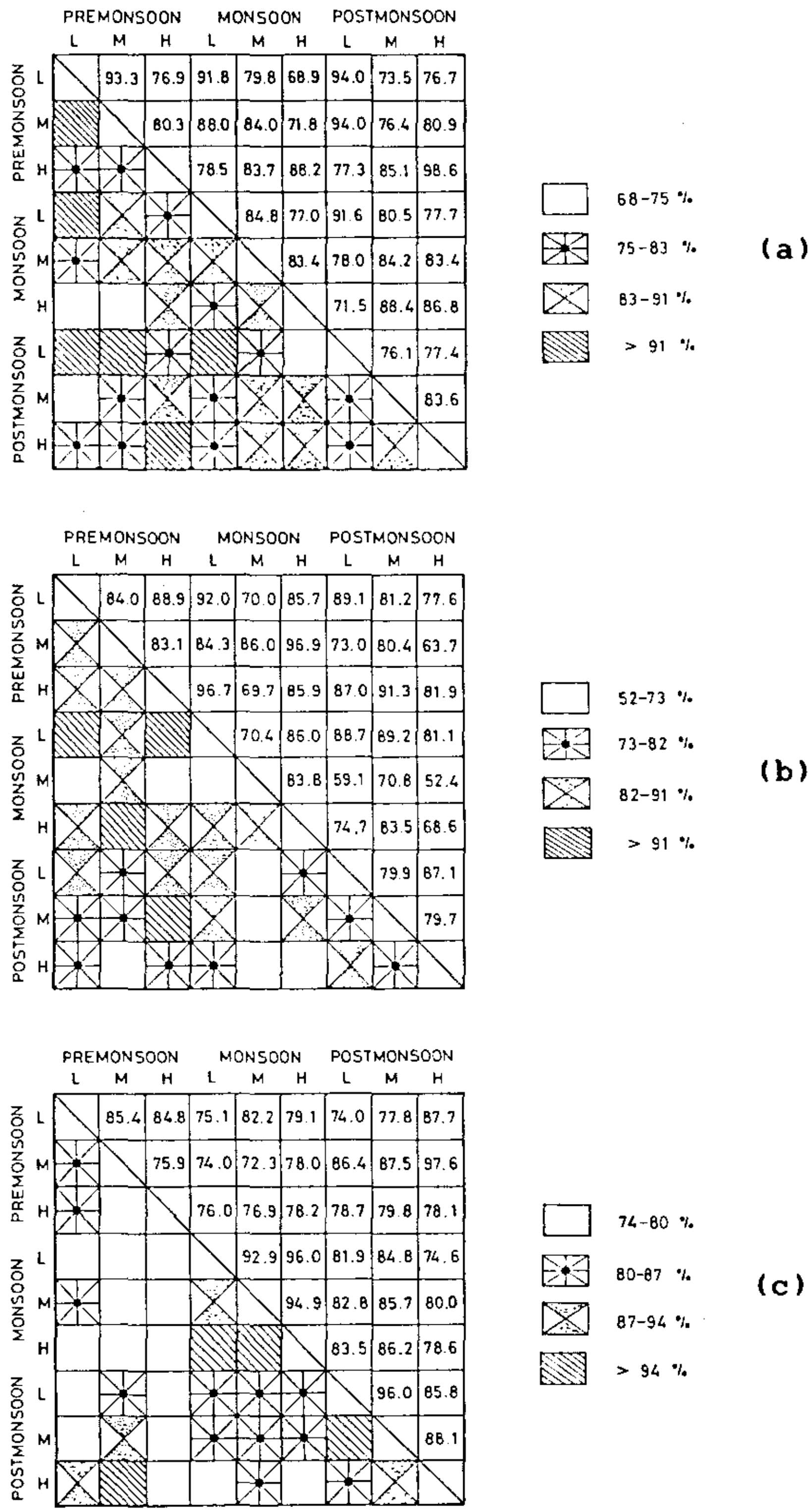


Figure 5.19 Trellis diagram showing the faunal affinity among three tide levels during different seasons (a) Station 1 (b) Station 2 (c) Station 3

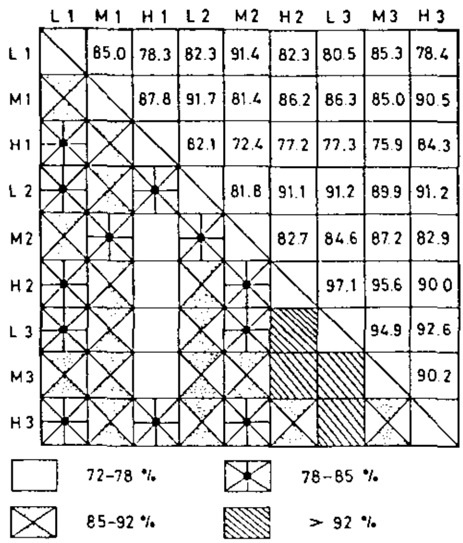


Figure 5.20 Trellis diagram showing the degree of macrofaunal affinity at three stations

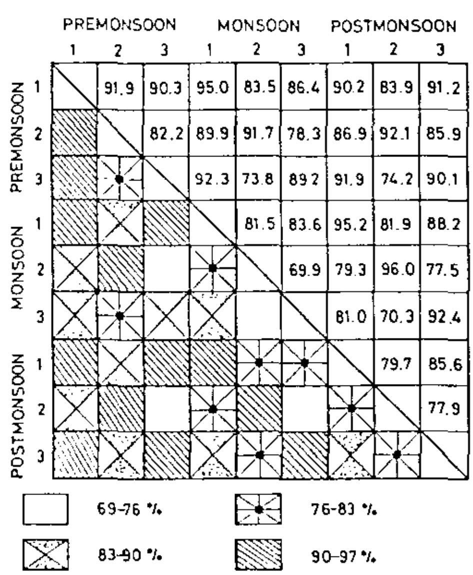


Figure 5.21 Trellis diagram showing the faunal similarity among the polychaete group at three stations

where x and y are the variables under reference. $\bar{x}$ and $\bar{y}$ are their mean values. σ_x and σ_y are their standard deviations and 'n' represents number of pairs. The significance of correlation was tested by using the statistic,

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

where 't' is having degrees of freedom n-2

The results of the analysis are given in Tables 5.32-5.40.

Polychaete fauna is significantly correlated with sediment temperature in all the three tidal levels at station 1, in the low and mid tide levels at station 2 and all the three tidal levels at station 3. Crustacea was found to be significantly correlated with sediment temperature in the low and mid tide levels at station 1, all the three tidal levels at station 2. But there is no significant correlation in the three tidal levels of station 3. Mollusca is significantly positively correlated with sediment temperature in the low tide level of station 1, all the three tidal levels at station 2. The total fauna was significantly correlated in all the three tidal levels of station 1 and 2 and low and high tide level of station 3.

There is significant positive correlation between polychaete fauna and water temperature in the three tidal levels of station 1, low and mid tide levels of station 2 and mid and high tide levels of station 3. Crustacea was found to be significantly correlated with water temperature in the low and mid tide levels of station 1, all the three tidal levels of station 2. Mollusca was correlated with water temperature in the low tide level of station 1 and the three tidal levels of station 2. Total fauna was significantly correlated with water temperature in the three tidal levels of station 1 and 2 and in the high tide level of station 3.

Salinity was significantly correlated with the polychaetes in all the three tidal levels at station 1, low tide and mid tide levels at station 2 and the high tide level at station 3. Crustacea was significantly positively correlated with salinity in the low and mid tide levels at station 1 and in all the tidal levels at station 2. Mollusca was significantly positively correlated with salinity in the low tide level at station 1 and all the three tidal levels at station 2. Total fauna was significantly correlated with all the tidal levels at station 1 and 2. At station 3, only in the high tide level significant positive correlation was observed between total fauna and salinity.

Polychaete fauna was correlated with *p*H of sediment in the mid and high tide levels of station 1 and in the three tidal levels of station 3. Crustacean fauna was correlated with sediment *p*H in the mid and high tide levels at station 1, low and mid tide levels at station 2. Mollusca was correlated with sediment *p*H at station 2 only in all the three tidal levels. Total fauna was correlated with *p*H of sediment in the mid tide level of station 1, low tide level of station 2 and mid tide level of station 3.

Polychaete fauna was significantly and positively correlated with *p*H of water in all the three tidal levels of station 1, low and mid tide levels of stations 2 and 3. Crustacea was correlated with water *p*H in low tide level and mid tide level of station 2 and low and high tide levels at station 1. Mollusca was correlated with *p*H of water only at station 2 in all the three tidal levels. Total fauna was significantly correlated with *p*H of water in all the three tidal levels at stations 1 and 2 and middle level at station 3.

Polychaeta, crustacea and total fauna was not significantly correlated with the dissolved oxygen in all three tidal levels in the three stations. Mollusca was found to be correlated with dissolved oxygen in the mid tide level at station 3.

Regarding the correlation between the total fauna and sediment characteristics, sand was found to be significantly positively correlated with the benthic fauna in the high tide level at station 1, low tide level at station 2 and high tide level at station 3. Clay was found to be significantly correlated in the low and mid tide levels at station 1, low and high tide levels at station 2. Organic matter was found to be significantly positively correlated in the low and high tide levels at station 1 and in the mid tide level at station 2.

Sand was found to be significantly positively correlated with the polychaetes in the high tide level at station 1, low and mid tide levels at station 2 and all the three tidal level at station 3. Clay was found to significantly positively correlated with the polychaete fauna in the low tide level at station 1 and the mid and high tide levels at station 3. Organic matter was found to be significantly correlated with polychaete in the low and mid tide levels at station 1. The crustacean fauna was found to be significantly positively correlated with sand in the low and mid tide levels at station 2. Clay was found to significantly positively correlated with crustacea in the mid tide level at station 3. Sand was found to be significantly positively correlated with mollusca in the low tide level at station 2. Clay was found to be significantly positively correlated with mollusca in the mid tide level at station 1, and all the three tidal levels at station 2. Organic matter was found to be significantly positively correlated with molluscan fauna in the mid and high tide levels at station 2.

5.11 EFFECT OF HYDROLOGICAL FACTORS ON THE BENTHIC BIOMASS

The biomass on various hydrological factors such as salinity, temperature, dissolved oxygen and *p*H was worked out using a multiple regression model of the form,

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6$$

where Y = biomass

x_1 = salinity

x_2 = sediment temperature

x_3 = water temperature

x_4 = dissolved oxygen

x_5 = sediment *p*H

x_6 = water *p*H

The multiple regression equation (Snedecor and Cochran, 1968) was worked out for each station for the three tidal level and they are presented in Tables 5.41-5.49. The significance of the multiple regression was tested using ANOVA table. The fitted multiple regression is significant in the case of station 1 in the high tide level, station 2 in the high tide level and station 3 in the mid tide level.

5.12 VERTICAL DISTRIBUTION OF BENTHIC FAUNA

Most of the benthic studies in the mangrove swamps have been confined to the sediment from the surface to a few cm depth. So information available regarding the depthwise distribution of benthic fauna in the mangrove swamps is scarce. The present study gives the depthwise distribution of of benthos in the mangrove areas of Cochin. Altogether 162 sediment samples were taken to study the vertical distribution of macrobenthos.

.12.1 Percentage composition

The percentage composition of the major groups of benthic fauna together and polychaetes, crustaceans and molluscs separately in the three depth strata are given in Figs. 5.22-5.25.

Station 1

In the low tide level polychaetes (57.93%), Crustaceans (50.68%) and molluscs (56.52%) were found in the upper strata while 31.25% of polychaetes, 24.66% of crustaceans and 27.17% of molluscs were found in the middle strata. In the lower strata 10.82% of polychaetes, 24.66% of crustaceans and 16.31% of molluscs were found. In the mid tide level the composition of polychaetes, crustaceans and molluscs were 65.38%, 72.03% and 73.87%, respectively in the upper strata. In the middle strata 18.03% of polychaetes, 15.26% of crustaceans and 20.10% of molluscs were found. In the lower strata the composition of polychaetes was 16.59%, crustaceans 12.71% and molluscs 6.03%. In the high tide level the percentage of polychaetes, crustaceans and molluscs were 54.12, 80.35 and 74.07, respectively in the upper strata while polychaetes (23.20%), crustaceans (14.75%) and molluscs (18.52%) were observed in the middle strata. In the lower strata the occurrence of these three groups of organisms were comparatively less, with 22.68% of polychaetes, 4.92% of crustaceans and 7.4% of molluscs.

Station 2

In the low tide level polychaetes, crustaceans and molluscs were represented by 81.58%, 53.55% and 60.8%, respectively in the upper strata and 10.90%, 30.6% and 22.4%, respectively in the middle strata. A low composition of polychaetes (7.52%), crustaceans (15.85%) and molluscs (16.8%) were seen in the lower strata. In the mid tide level

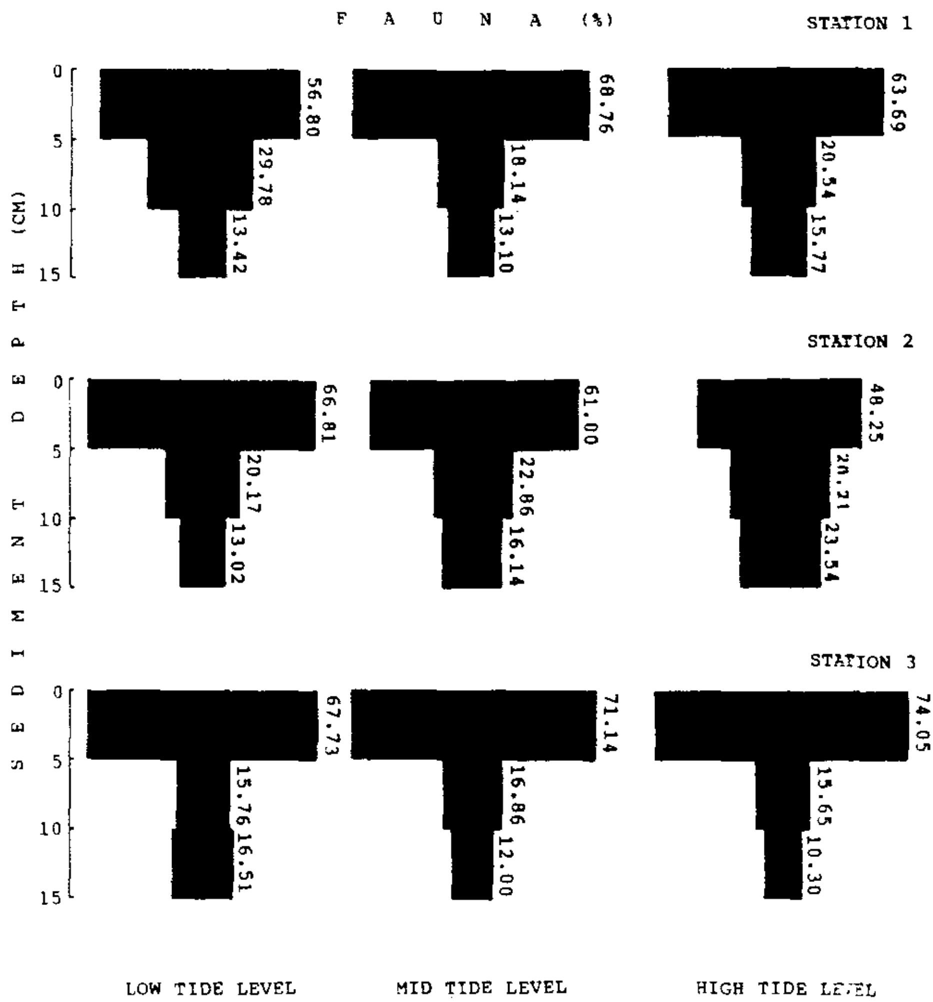


Figure 5.22 Vertical distribution of benthos at three depth levels

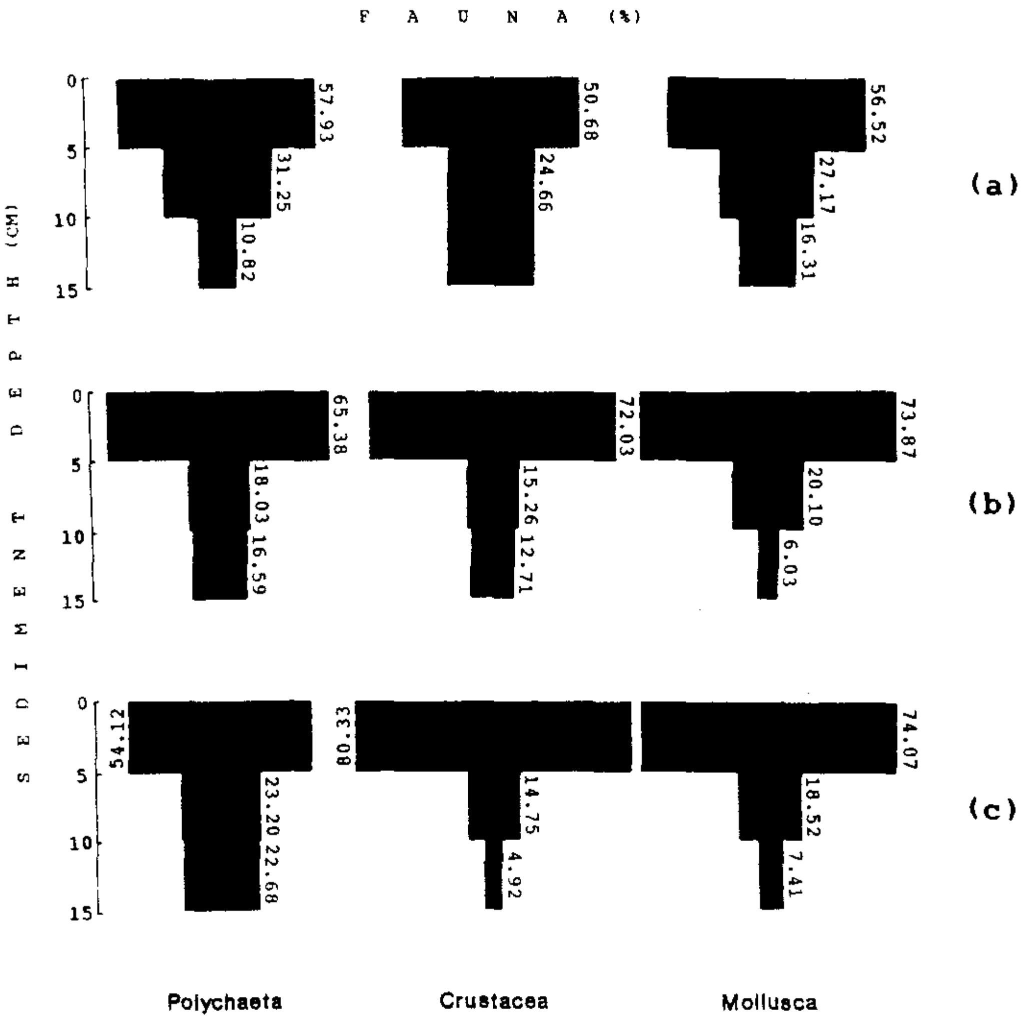


Figure 5.23 Vertical distribution of polychaeta, crustacea and mollusca at three depth levels at station 1
(a) Low tide level (b) Mid tide level (c) High tide level

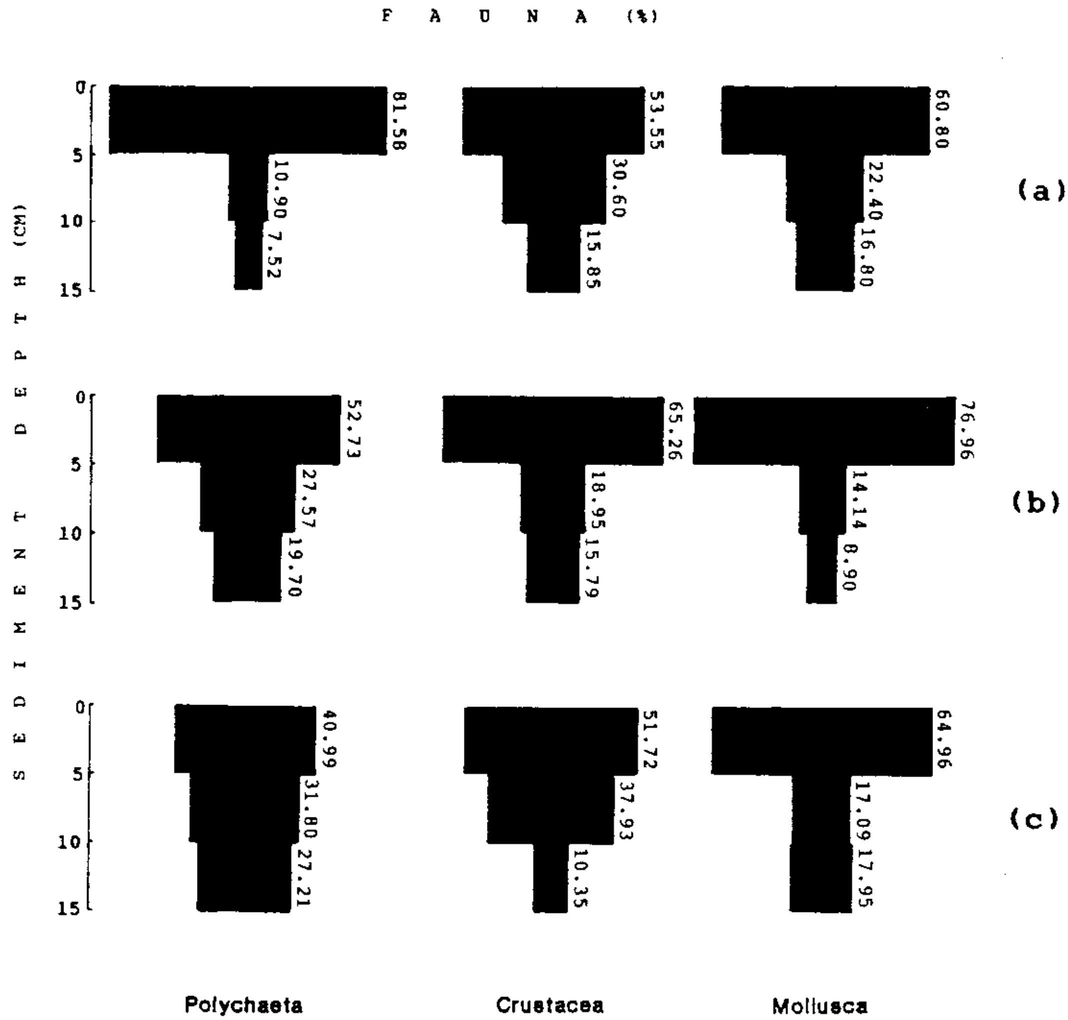


Figure 5.24 Vertical distribution of polychaeta, crustacea and mollusca at three depth levels at station 2
(a) Low tide level (b) Mid tide level (c) High tide level

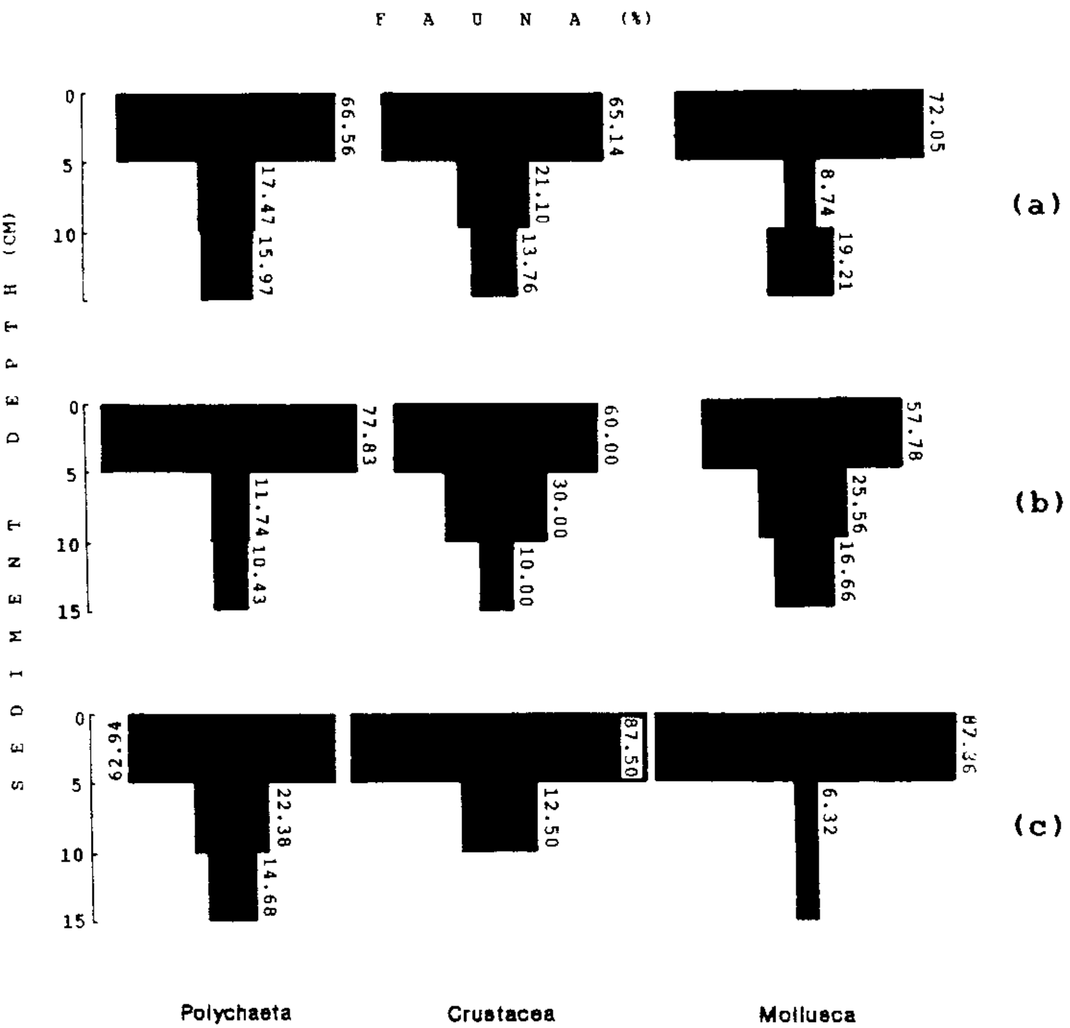


Figure 5.25 Vertical distribution of polychaeta, crustacea and mollusca at three depth levels at station 3
(a) Low tide level (b) Mid tide level (c) High tide level

polychaetes (52.73%), crustaceans (65.26%) and molluscs (76.96%) were found in the upper strata while polychaetes (27.57%), crustaceans (18.95%) and molluscs (14.14%) were found in the middle strata. In the lower strata 19.7% of polychaetes, 15.79% of crustaceans and 8.9% of molluscs were seen. In the high tide level 40.99%, 51.92% and 64.96% of polychaetes, crustaceans and molluscs were found in the upper strata. In the middle strata 31.80% of polychaetes, 37.93% of crustaceans and 17.09% of molluscs were seen. 27.21% of polychaetes, 10.35% of crustaceans and 17.95% of molluscs were found in the lower strata.

Station 3

In the low tide level 66.56%, 65.14% and 72.05% of polychaetes, crustaceans and molluscs were found respectively in the upper strata. In the middle strata polychaetes (17.47%), crustaceans (21.10%) and molluscs (8.74%) were seen while 15.97% of polychaetes, 13.76% of crustaceans and 19.21% of molluscs were seen in the lower strata. In the mid tide level polychaetes, crustaceans and molluscs were represented by 77.83%, 60% and 57.78% respectively in the upper strata; 11.74%, 30% and 25.56% respectively in the middle strata and 10.43%, 10% and 16.66% respectively in the lower strata. In the high tide level polychaetes (62.94%), crustaceans (87.5%) and molluscs (87.36%) were found in the upper strata. Polychaetes (22.38%), crustaceans (12.5%) and molluscs (6.32%) were found in the middle strata. In the lower strata 14.68% of polychaetes and 6.32% of molluscs were found.

From the results obtained it is seen that almost all the species were present in the upper 5 cm depth strata. The species *Glycera alba*, *Phyllodoce* sp., *Lumbriconereis simplex*, *Polydora* sp., *Goniada* sp., *Tapes* sp. and *Uca annulipes* showed preference to the upper strata. They were not found towards deeper layers of the sediment. The species found up to 10 cm depth were *Lumbriconereis latrelli, Pulliella armata, Dotilla* sp., *Metapograpsus messor, Uca* sp. and *Corophium triaenonyx. Ligia* sp. was found only in the lower strata of the substratum. All the other species were found distributed throughout the depth strata (0-15 cm). Though they were found up to 15 cm depth, their population density decreased towards the deeper strata. It was also found that among polychaetes *Marphysa graveli, Dendronereides heteropoda,* and *Dendronereis aestuarina* and the mollusc, *Hydrobia* sp. were seen to penetrate below 15 cm depth.

5.13 VARIATION OF FAUNA IN THE TIDAL ZONES

The edge of the mangrove areas has been selected for the collection of samples. The rise and fall of tides cover and uncover the benthic organisms living at the edges of the mangrove area. So, the organisms at this area are subjected to great environmental extreams than those living in other parts. The tidal area is divided in to three different zones. The high tide zone which receives water at the highest tide; the mid tide zone which is successively covered and uncovered by most of the tides; the low tide zone where there is permanent tidal effect. The total tidal area involved in the mangrove area is governed by the topography and the slope of the shore in each station.

The percentage composition of the fauna in the three tidal levels is given in Fig. 5.26. The population density of organisms in the tidal area shows remarkable variation, based on different tide levels. At station 1, the fauna contributed 28.53%, 41.08% and 30.39% in the low tide, mid tide and high tide level respectively. At station 2, 38.20% was present in the low tide level while 45.81% and 15.99% in the mid tide and high tide level respectively. The low tide level contributed 47.43% whereas the mid tide and high tide level contributed 30.78% and 21.79% respectively at station 3. The distribution

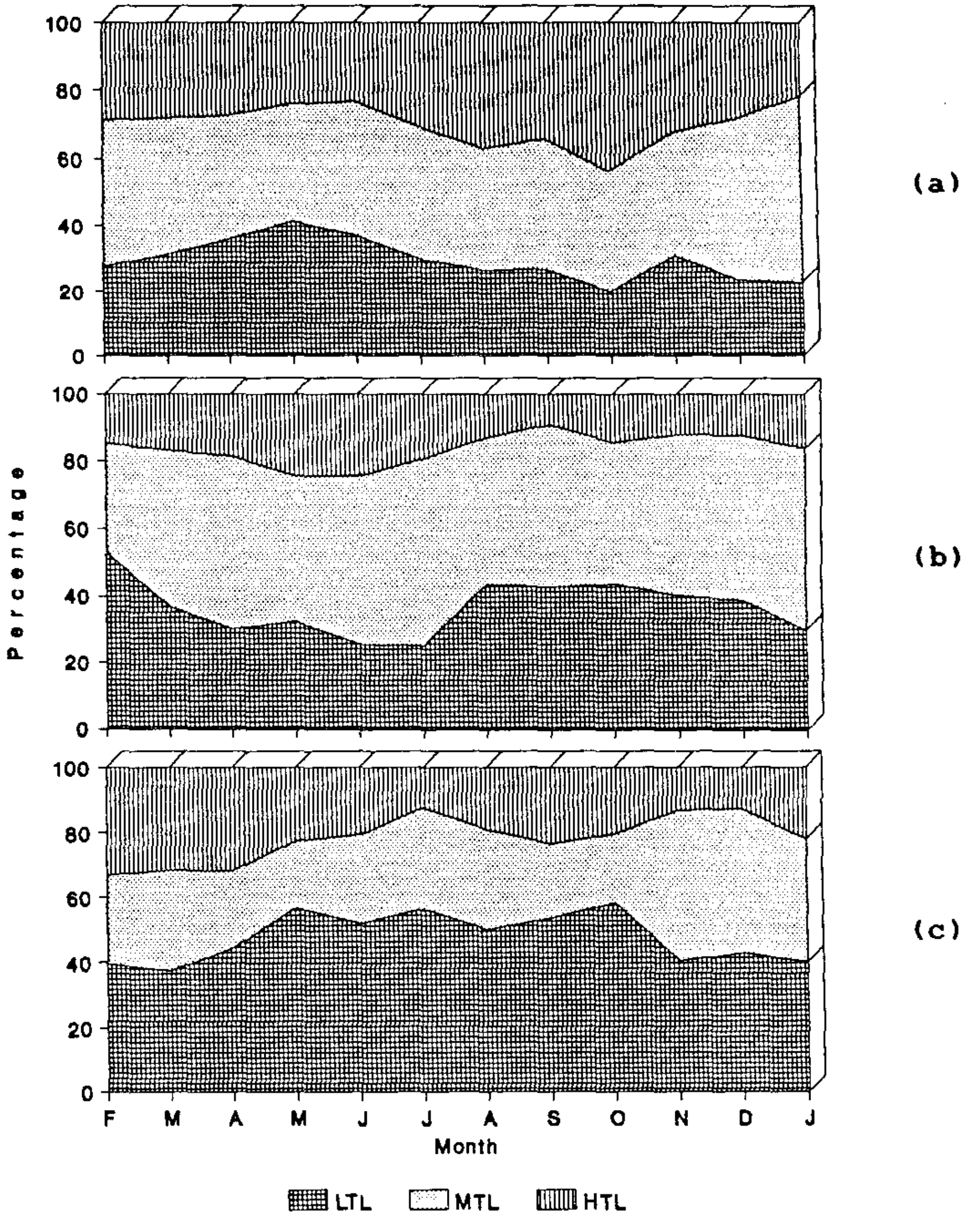


Figure 5.26 Percentage composition (monthly mean values) of benthos in relation to tidal level
(a) Station 1 (b) Station 2 (c) Station 3

of infaunal organisms in each tidal level shows remarkable variation. The population density of polychaetes, crustaceans and molluscs in the three tidal levels is given in Figs. 5.27-5.29. The total population denstiy of benthic fauna in each tidal level is shown in Fig. 5.30. As far as the species composition (including unidentified organisms) is concerned, the highest composition was found in the mid tide and low tide levels. At station 1, 41, 53 and 33 species were found in the low, mid and high tide level respectively. 27 and 24 species were found in the low and mid tide levels of station 2, while 15 species were found in the high tide level. At station 3, 28 species (low tide level), 23 species (mid tide level) and 22 species (high tide level) were recorded.

5.14 RELATIVE DOMINANCE

All the species were not equally distributed in the mangrove area. Of the 54 species recorded, 17 numerically abundant species were taken for the study of the relative dominance of species. Percentage occurrence of these species from their respective groups, out of the total samples collected at each tidal level was calculated and presented with respect to stations in Figs. 5.31-5.33.

Station 1

Among the polychaete population *Paraheteromastus tenuis* contributed 29.57%, 16.65% and 3.06% in the low, mid and high tide level respectively while *Marphysa gravelyi* constituted 7.99%, 13.99% and 12.79%. Among crustaceans *Gammarus* sp. constituted 19.52% in the low tide level, 23.16% in the mid tide level and 20.91% in the high tide level. *Corophium triaenonyx* constituted 13.81%, 30.23% and 18.18% in the low, mid and high tide level respectively. *Musculista* sp. constituted 32.74% in the low tide level, 41.79% in the mid tide level and 23.62% in the high tide level. *Tellina* sp.

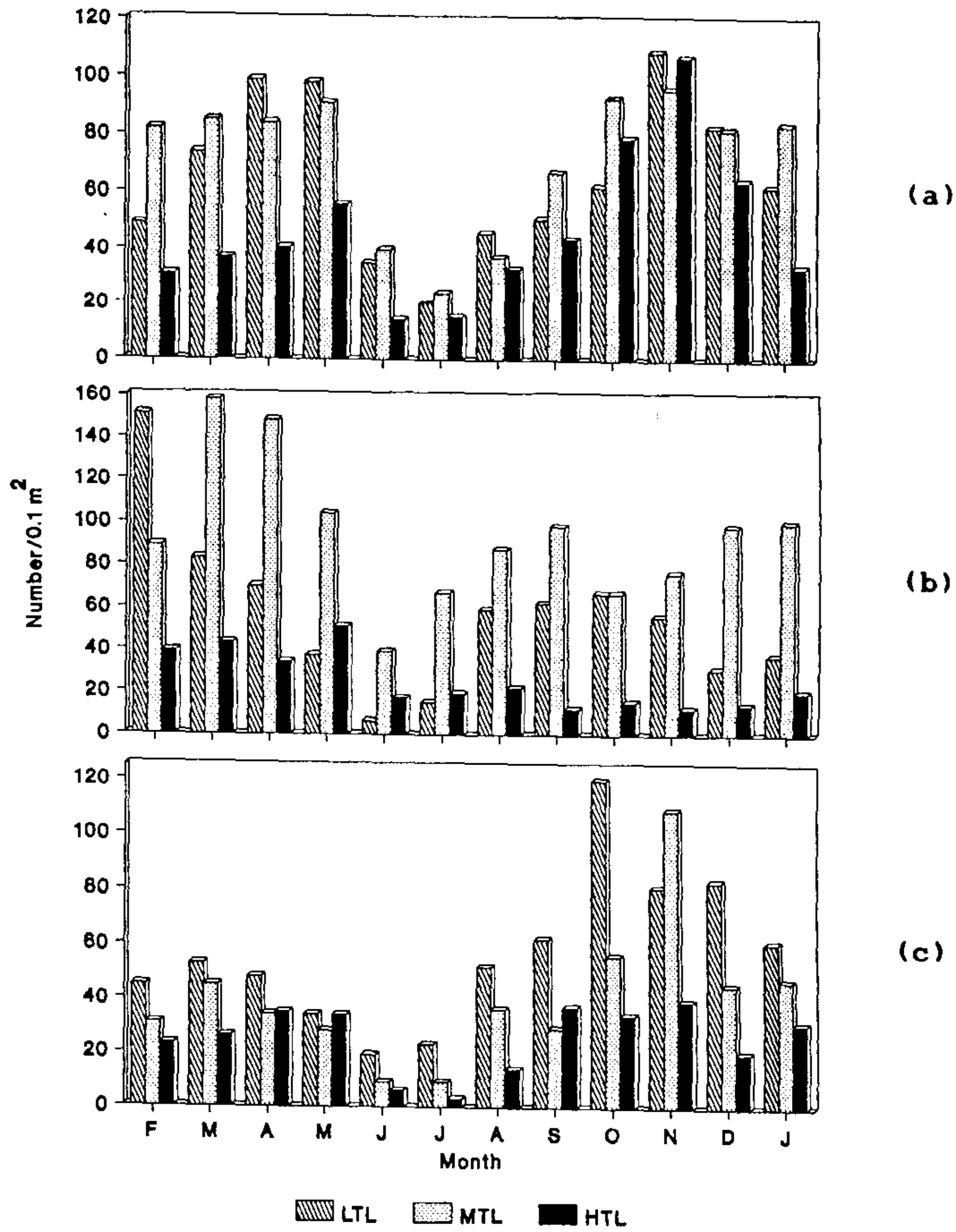


Figure 5.27 Monthly mean values of polychaeta in relation to tidal levels
(a) Station 1 (b) Station 2 (c) Station 3

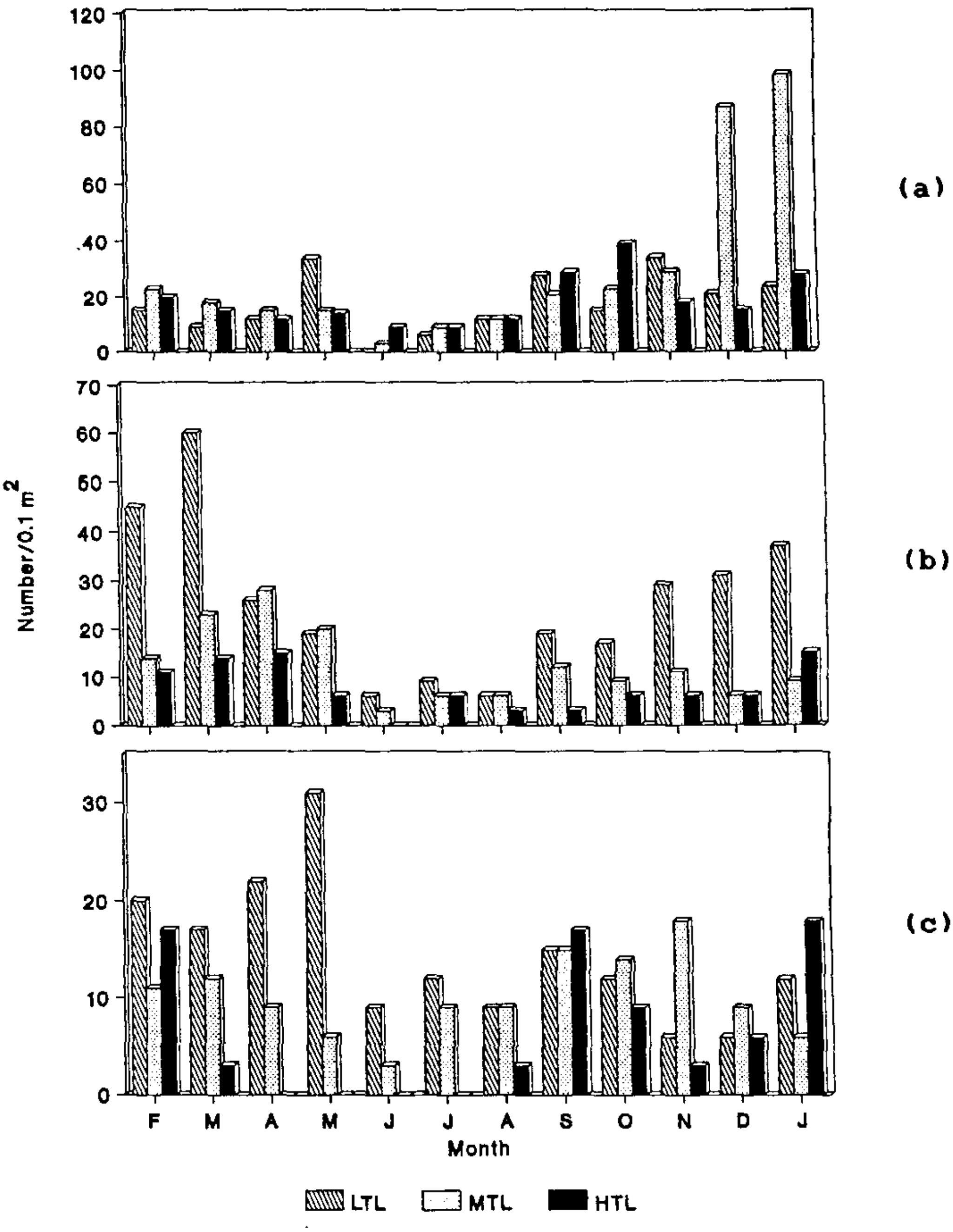


Figure 5.28 Monthly mean values of crustacea in relation to tidal levels
(a) Station 1 (b) Station 2 (c) Station 3

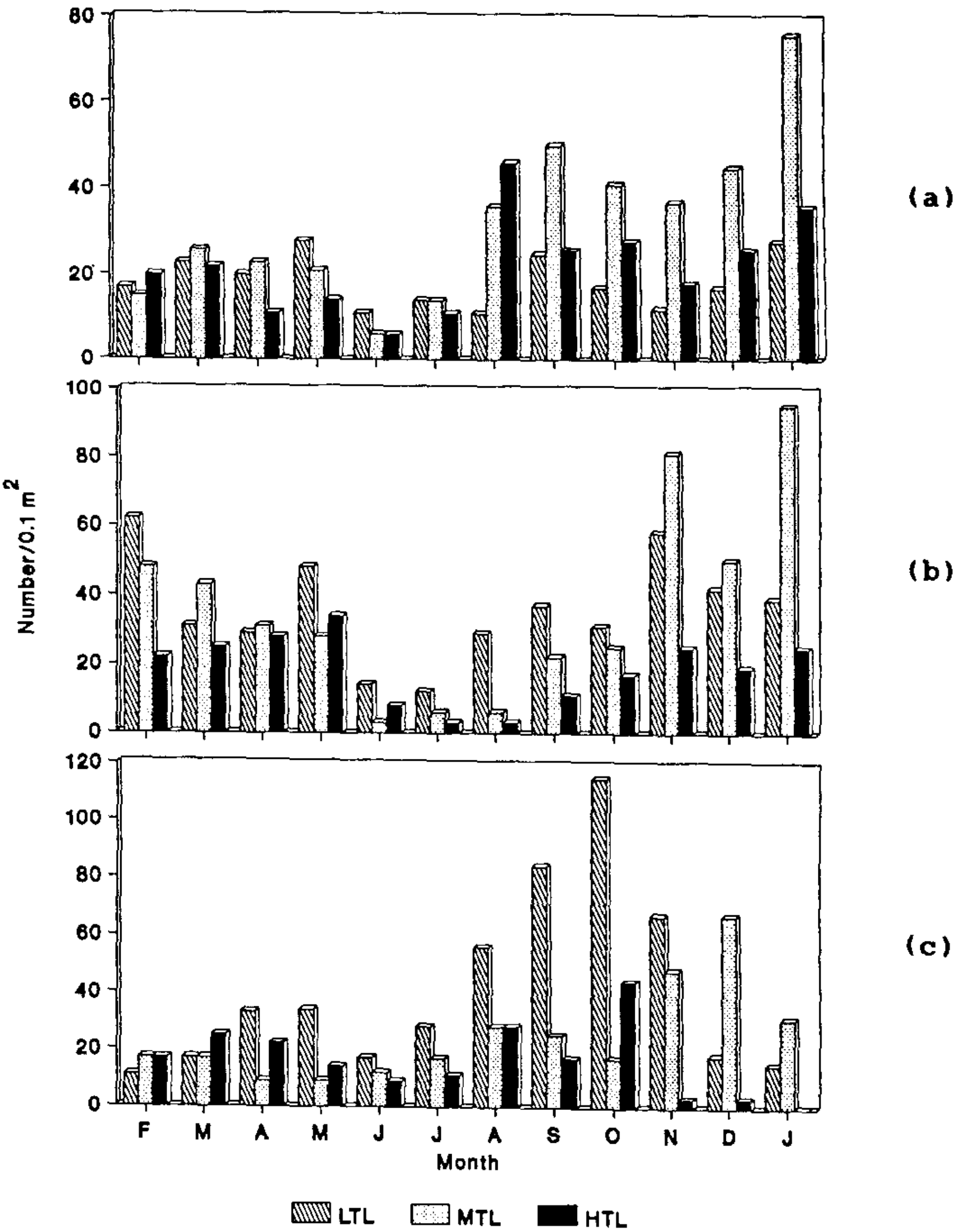


Figure 5.29 Monthly mean values of mollusca in relation to tidal levels
(a) Station 1 (b) Station 2 (c) Station 3

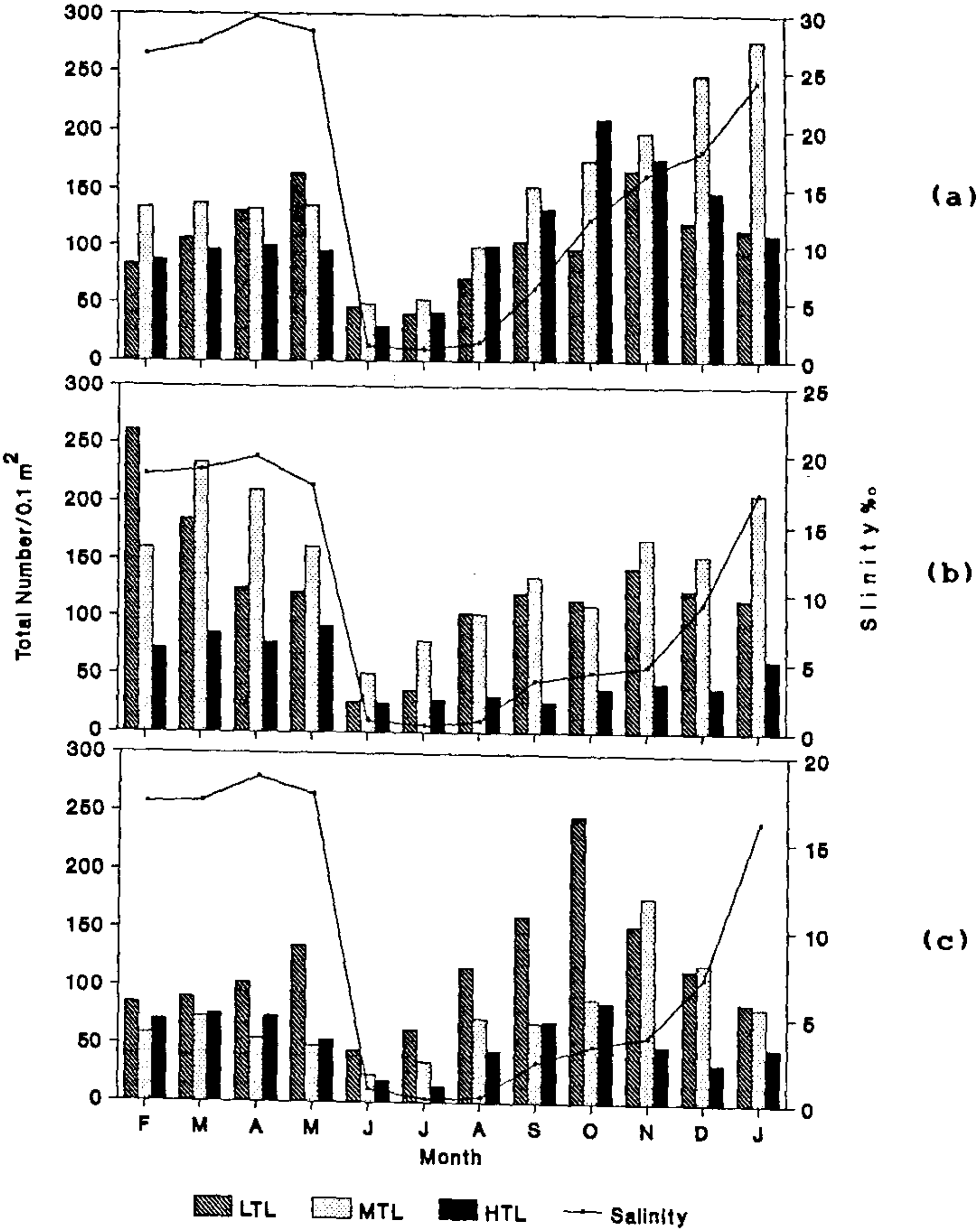


Figure 5.30 Monthly mean values of total organisms at different tidal levels in relation to salinity (a) Station 1 (b) Station 2 (c) Station 3

contributed 15.7%, 14.87% and 12.6% in the three tidal zones respectively.

Station 2

Of the total polychaete population in each tidal level *Dendronereides heteropoda* contributed 20.33%, 54.64% and 46.64% in the low tide, mid tide and high tide level respectively. *Nereis glandicincta* constituted 15.28% in the low tide level 13.97% and 27.85% in the mid and high tide level respectively. *Palaemon* sp. (juvenile) contributed 43.09%, 23.81% and 28.57% of the total crustacean population in the low, mid and high tide level respectively. Among mollusc, *Hydrobia* sp. contributed 70.14% of the total molluscan population in the low tide level while it was 79.91% and 98.64% in the mid and high tide level respectively.

Station 3

In the low, mid and high tide level, *Dendonereis aestuarina* contributed 41.12%, 47.49% and 3.97% respectively of the total polychaete population. Among crustacean, *Gammarus* sp. constituted 47.95% in the low tide level whereas 42.15% and 34.21% in the mid and high tide level respectively. *Villorita cyprinoides* contributed 30.71% and 25.93% in the low and mid tide level respectively. *Hydrobia* sp. constituted 10.91%, 18.86% and 90.67% in the low, mid and high tide level respectively.

5.15 COEXISTENCE OF POLYCHAETE FAUNA

To study the coexistence, relatively dominant polychaete species were taken and matrix of correlation (Snedecor and Cochran, 1968) was formed for the three stations separately by pooling the data of the three tidal levels. Results are given in Table 5.50. Significant positive correlation indicates

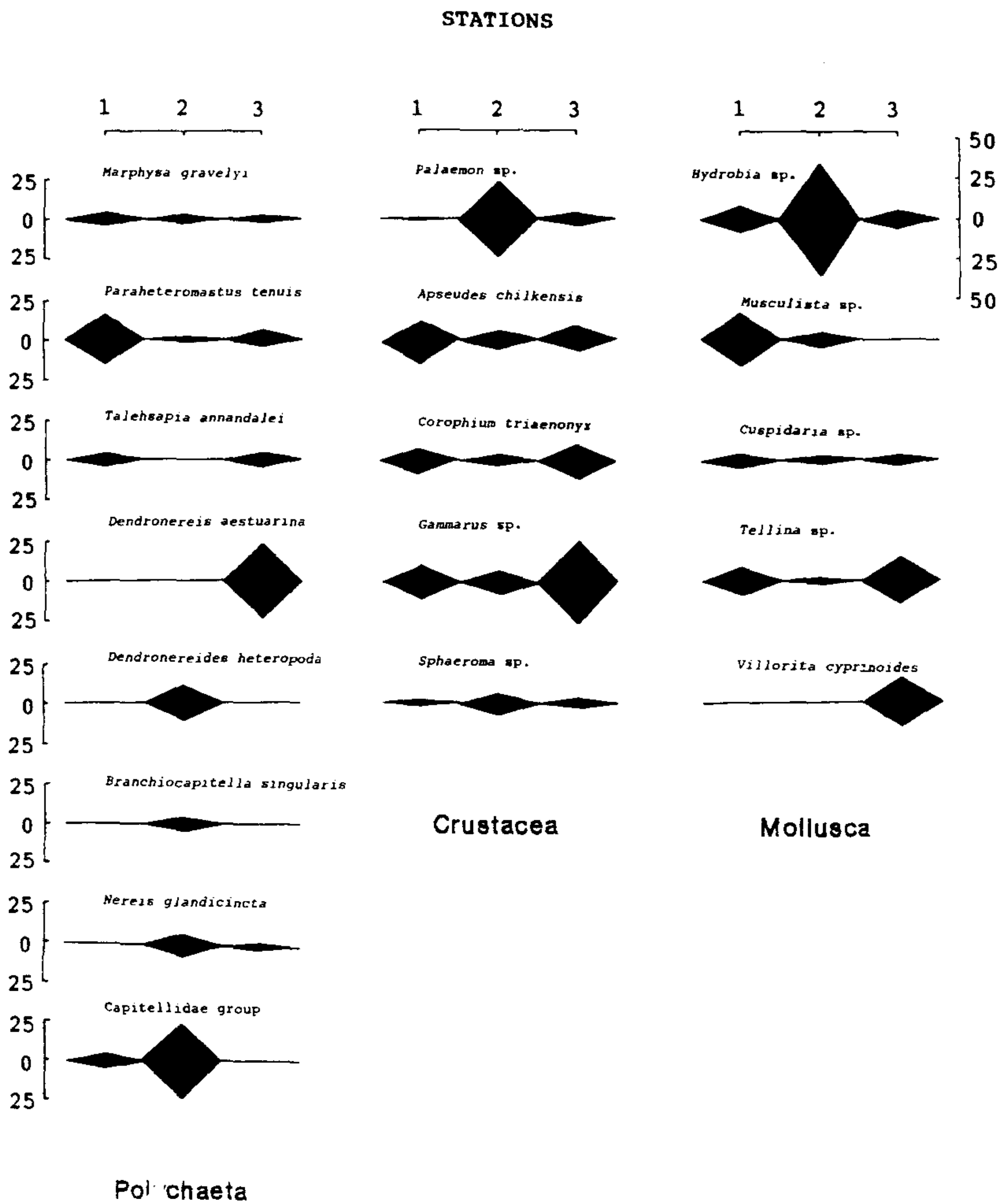


Figure 5.31 Relative abundance (%) of dominant species of polychaeta, crustacea and mollusca at three stations in the low tide level

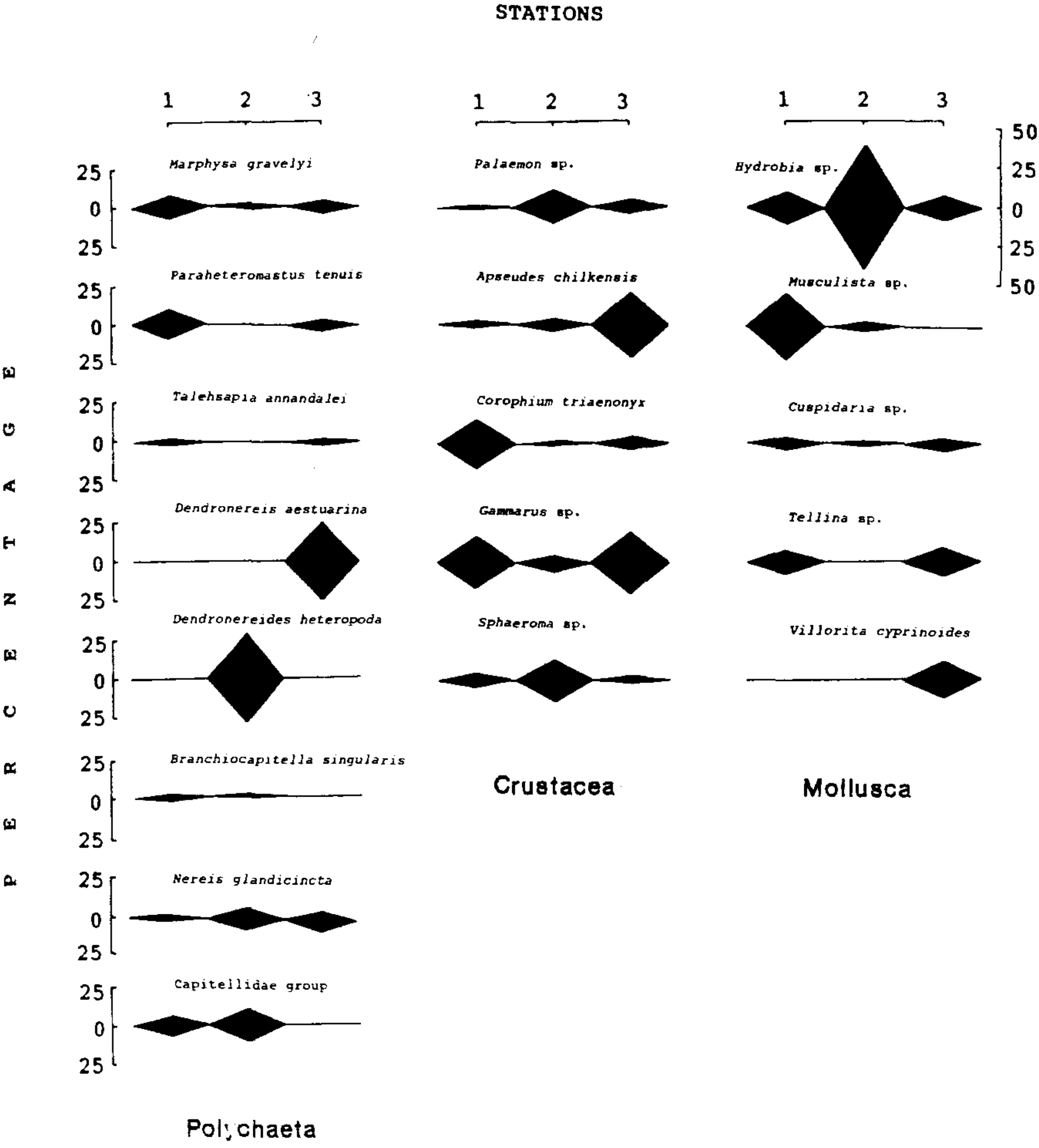


Figure 5.32 Relative abundance (%) of dominant species of polychaeta, crustacea and mollusca at three stations in the mid tide level

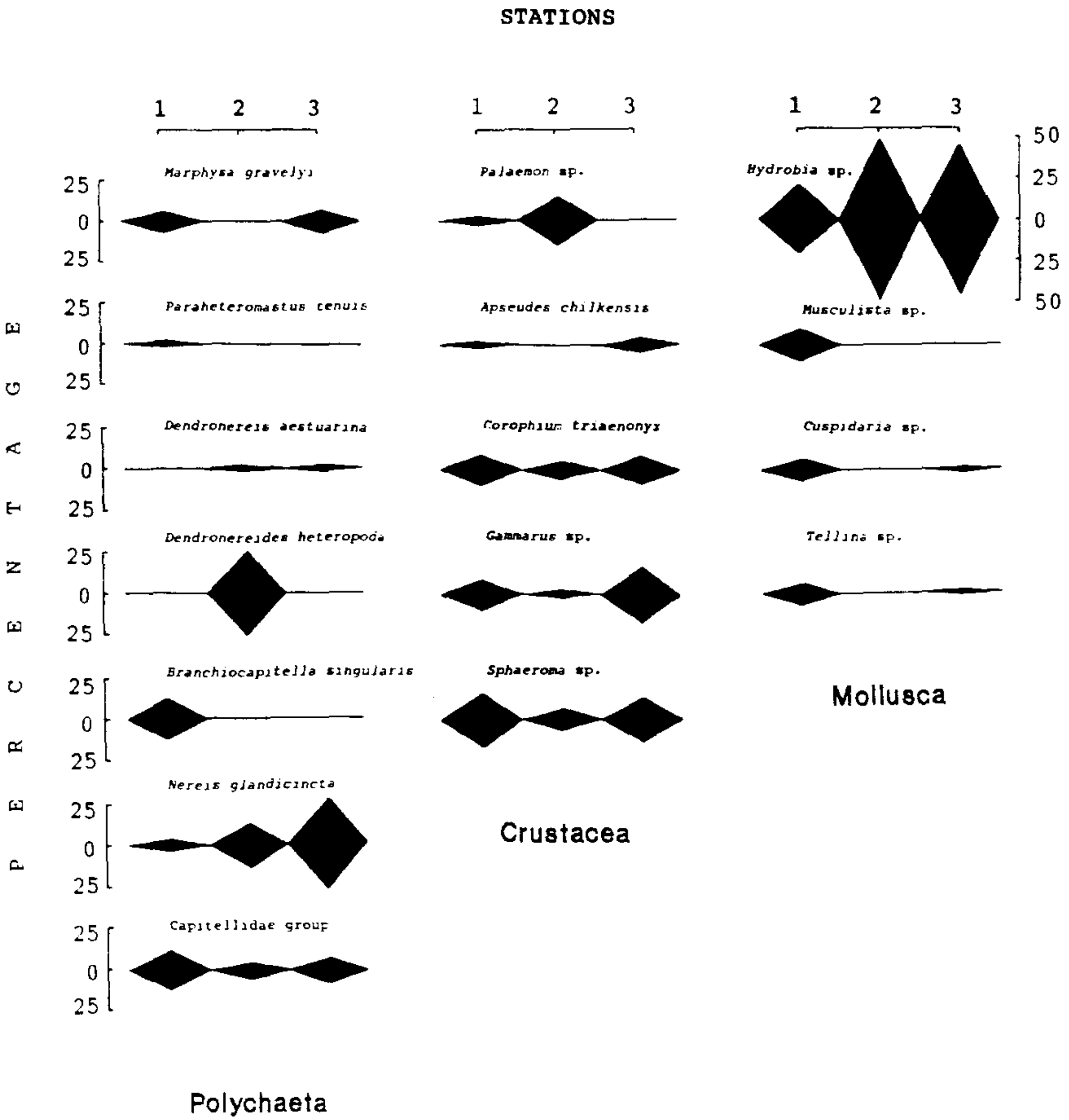


Figure 5.33 Relative abundance (%) of dominant species of polychaeta, crustacea and mollusca at three stations in the high tide level

coexistence among the species and significant negative correlation implies absence of coexistence. At station 1 coexistence was observed between *Eunice tubifex* and *Eunice* sp., *Eunice tubifex* and *Nereis glandicincta, Eunice tubifex* and *Paraheteromastus tenuis, Eunice* sp. and *Marphysa gravelyi, Eunice* sp. and *Nereis glandicincta, Eunice* sp. and *Paraheteromastus tenuis* and *Marphysa gravelyi* with *Paraheteromastus tenuis* and *Nereis glandicincta* with *Paraheteromastus tenuis.* At station 2, coexistence was observed between *Branchiocapitella singularis* and *Dendronereides heteropoda, Branchiocapitella singularis* and *Paraheteromastus tenuis, Dendronereides heteropoda* and *Marphysa gravelyi.* Coexistence was observed between species *Dendronereis aestuarina* and *Marphysa gravelyi, Dendronereis aestuarina* and *Nereis glandicincta, Marphysa gravelyi* and *Nereis glandicincta* and *Paraheteromastus tenuis* and *Talehsapia annandalei* at station 3.

Table 5.1 Systematic list of polychaetes collected from the mangrove areas of Cochin

Family			Ampharetidae Malmgren
	Genus		*Amphicteis* Grube
			Amphicteis gunneri
Family			Capitellidae Grube
	Genus		*Branchiocapitella* Fauvel
			Branchiocapitella singularis
	Genus		*Paraheteromastus* Monro
			Paraheteromastus tenuis
	Genus		*Pulliella* Fauvel
			Pulliella armata
Family			Eunicidae Grube
	Sub Family		Onuphidinae Levinsen
		Genus	*Diopatra* Audouin and Milne-Edwards
			Diopatra neapolitana
	Sub Family		Eunicinae Kinberg
		Genus	*Eunice* Cuvier
			Eunice tubifex
		Genus	*Marphysa* Quatrefages
			Marphysa gravelyi
			Marphysa stragulum
	Sub Family		Lumbriconereinae
		Genus	*Lumbriconereis* Blainville
			Lumbriconereis latreilli
			Lumbriconereis pseudobifilaris
			Lumbriconereis simplex
Family			Nereidae Johnston
		Genus	*Nereis* Cuvier
		Sub Genus	*Nereis*
			Nereis kauderni
			Nereis chilkaensis
			Nereis glandicincta
		Sub Genus	*Ceratonereis* Kingberg
			Ceratonereis costae
		Genus	*Perinereis* Kinberg
			Perinereis cavifrons
		Genus	*Dendronereides* Southern
			Dendronereides heteropoda
		Genus	*Dendronereis* Peters
			Dendronereis aestuarina
			Dendronereis arborifera

Contd.

Family			Glyceridae Grube
	Sub Family		Glycerinae
		Genus	*Glycera* Savigny
			Glycera alba
			Glycera longipinnis
	Sub Family		Goniadinae
		Genus	*Goniada* Aud. & M.- Edwards
Family			Terebellidae Grube
	Sub Family		Amphitritinae Malmgren
		Genus	*Pista* Malmgren
			Pista indica
Family			Serpulidae Burmeister
		Genus	*Mercierella* Fauvel
			Mercierella enigmatica
Family			Hesionidae Grube
		Genus	*Talehsapia* Fauvel
			Talehsapia annandalei
Family			Phyllodocidae Grube
	Sub Family		Phyllodocinae
		Genus	*Phyllodoce* Savigny
Family			Spionidae Sars
		Genus	*Polydora* Bose
		Genus	*Prionospio* Malmgren
			Prionospio pinnata
			Prionospio cirrifera

Table 5.2 Classified list of polychaete species

Family	Errantia	Family	Sedentaria
Eunicidae		Ampharetidae	
	Diopatra neapolitana Delle Chiaje		*Amphicteis gunneri* Sars
	Eunice tubifex Crossland	Capitellidae	
	Eunice spp.		*Branchiocapitella singularis* Fauvel
	Marphysa gravelyi Southern		*Paraheteromastus tenuis* Monro
	Marphysa stragulum (Grube)		*Pulliella armata* Fauvel
	Lubriconereis latreilli Audouin and Milne-Edwards	Teribellidae	
	L. Pseudobifilaris Fauvel		*Pista indica* Fauvel
	L. simplex Southern	Serpulidae	
	Lumbriconeries sp.		*Mercierella enigmatica* Fauvel
Nereidae			
	Nereis glandicincta Southern	Spionidae	
	Nereis chilkaensis Southern		*Prionospio pinnata* Ehlers
	Nereis kauderni Fauvel		*P. cirrifera* Wiren
	Nereis spp.		*Polydora* sp.
	Dendronereides heteropoda Southern		
	Dendronereis aestuarina Southern		
	D. arborifera Peters		
	Perinereis cavifrons Ehlers		
	Perinereis sp.		
	Ceratonereis costae Grube		
Glyceridae			
	Glycera alba Rathke		
	G. longipinnis Grube		
	Goniada sp.		
Hesionidae			
	Talehsapia annandalei Fauvel		
Phyllodocidae			
	Phyllodoce sp.		

Table 5.3 Distribution of benthos in relation to salinity and tide levels

STATION 1

Season	Salinity range (‰)	Species composition Low tide level	 Mid tide level	 High tide level
All seasons	0.97-29.76	Eunice sp. Marphysa gravelyi Paraheteromastus tenuis Talehsapia annandalei Apseudes chilkensis Gammarus sp. Musculista sp. Tellina sp.	Lumbriconereis latreilli Marphysa gravelyi Paraheteromastus tenuis Capitellidae Apseudes chikensis Gammarus sp. Uca annulipes Uca sp. Hydrobia sp. Musculista sp. Tellina sp. Metapograpsus messor	Branchiocapitella singularis Eunice tubifex Marphysa gravelyi Nereis glandicincta Capitellidae Gammarus sp. Uca sp. Sphaeroma sp. Hydrobia sp. Musculista sp.
Premonsoon	26.5-29.76	Diopatra neapolitana Glycera alba Glycera longipinnis Nereis glandicincta Nereis sp. Phyllodoce sp. Corophium triaenonyx Dotilla sp. Bittium sp. Tapes sp.	Amphicteis gunneri Diopatra neapolitana Eunice spp. Glycera alba Glycera longipinnis Goniada sp. Lumbriconereis simplex Nereis kauderni Nereis spp. Perinereis sp. Pulliella armata Polydora sp. Talehsapia annandalei Alpheus sp. Dotilla sp. Bittium sp. Tapes sp.	Diopatra neapolitana Eunice sp. Lumbriconereis latrelli Marphysa stragulum Nereis spp. Perinereis cavifrons Apseudes chilkensis Corophium triaenonyx Bittium sp. Tellina sp.

Contd.

Monsoon	0.97-6.25	Nereis chilkaensis Ceratonereis costae Pulliella armata Capitellidae Cuspidaria sp. Tellina tenuis	Lumbriconereis pseudobifilaris Nereis chilkaensis Mercierella enigmatica Ceratonereis costae Corophium triaenonyx Ligia sp. Cuspidaria sp.	Nereis chilkaensis Perineries cavifrons Ligia sp. Palaemon sp. Cuspidaria sp. Tellina sp.
Postmonsoon	12.26-24.01	Branchiocapitella singularis Ceratonereis costae Lumbriconeries costae Marphysa stragulum Pulliella armata Capitellidae Corophium triaenonyx Dotilla sp. Sphaeroma sp. Palaemon sp.	Amphicteis gunneri Branchiocapitella singularis Ceratonereis costae Eunice spp. Lumbriconereis pseudobifilaris Marphysa stragulum Nereis glandicincta Nereis spp. Perinereis sp. Pulliella armata Lumbriconereis sp. Pista indica Corophium triaenonyx Dotilla sp. Ligia sp. Sphaeroma sp. Palaemon sp.	Lumbriconereis latreilli Lumbriconereis sp. Marphya stragulam Pulliella armata Corophium triaenonyx Cuspidaria sp.

Table 5.4 Distribution of benthos in relation to salinity and tide levels

STATION 2

Season	Salinity range (‰)	Species composition Low tide level	 Mid tide level	 High tide level
All seasons	0.48-19.85	Branchiocapitella singularis Dendronereides heteropoda Marphysa gravelyi Nereis glandicincta Perinereis sp. Capitellidae Gammarus sp. Sphaeroma sp. Palaemon sp. Hydrobia sp.	Dendronereis heteropoda Nereis glandicincta Capitellidae Hydrobia sp. Palaemon sp. Apseudes chilkensis Cuspidaria sp.	Dendronereides heteropoda Nereis glandicincta Hydrobia sp.
Premonsoon	18.59-19.85	Paraheteromastus tenuis Apseudes chilkensis Corophium triaenonyx Uca sp. Bittium sp. Cupidaria sp. Musculista sp.	Branchiocapitella singularis Eunice spp. Marphysa gravelyi Marphysa stragulum Pista indica Corophium triaenonyx Gammarus sp. Uca sp. Sphaeroma sp. Bittium sp. Musculista sp. Tellina sp.	Pista indica Polydora sp. Capitellidae Corophium triaenonyx Metapograpsus messor Sphaeroma sp.
Monsoon	0.48-3.69	Nereis chilkaensis Cuspidaria sp. Tellina sp.	Pista indica	Pista indica
Postmonsoon	4.29-17.31	Eunice sp. Apseudes chilkensis Uca sp. Bittium sp. Musculista sp. Villorita cyprinoides	Marphysa gravelyi Gammarus sp. Uca sp. Sphaeroma sp. Musculista sp.	Dendronereis aestuarina Gammarus sp. Uca sp. Metapograpsus messor Sphaeroma sp.

Table 5.5 Distribution of benthos in relation to salinity and tide levels

STATION 3

Season	Salinity range (‰)	Species composition Low tide level	 Mid tide level	 High tide level
All seasons	0.19-18.64	Dendronereis aestuarina Perinereis sp. Apseudes chilkensis Corophium triaenonyx Gammarus sp. Palaemon sp. Hydrobia sp. Villorita cyprinoides	Dendronereis aestuarina Marphysa gravelyi Nereis glandicincta Prionospio cirrifera Apseudes chilkensis Gammarus sp. Palaemon sp. Tellina sp. Villorita cyprinoides	Marphysa gravelyi Nereis glandicincta Hydrobia sp.
Premonsoon	17.13-18.64	Dendronereis arborifera Eunice tubifex Marphysa gravelyi Nereis glandicinta Nereis sp.	Dendronereis arborifera Perinereis sp. Hydrobia sp.	Dendronereis aestuarina Eunice sp. Perinereis sp. Nereis sp. Capitellidae Apseudes chilkensis Gammarurs sp. Palaemon sp.
Monsoon	0.19-2.31	Nereis chilkaensis Branchiocapitella singularis Paraheteromastus tenuis Talehsapia annandalei Tellina tenuis Tellina sp.	Nereis chilkaensis Paraheteromastus tenuis Talehsapia annandalei Tellina tenuis Cuspidaria sp.	Corophium triaenonyx Sphaeroma sp. Cuspidaria sp.
Postmonsoon	3.3-16.16	Branchiocapitella singularis Dendronereis arborifera Marphysa gravelyi Nereis chilkaensis Nereis glandicincta Paraheteromastus tenuis Prionospio cirrifera Talehsapia annandalei Prionospio pinnata Sphaeroma sp. Tellina sp. Cuspidaria sp.	Dendronereis arborifera Nereis chilkaensis Paraheteromastus tenuis Perinereis sp. Talehsapia annandalei Corophium triaenonyx Sphaeroma sp. Hydrobia sp. Cuspidaria sp.	Branchiocapitella singularis Dendronereis aestuarina Prinospio cirrifera Perinereis sp. Apseudes chilkensis Gammarus sp. Sphaeroma sp. Corophium triaenonyx Tellina sp.

Table 5.6 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

LOW TIDE LEVEL - STATION 1

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Branchiocapitella singularis	--	--	--	--	--	--	--	--	--	--	3	3	6
Ceratonereis costae	--	--	--	--	--	--	3	8	11	28	--	--	50
Diopatra neapolitana	6	14	17	--	--	--	--	--	--	--	--	--	37
Eunice tubifex	3	3	3	--	--	--	--	--	6	11	--	8	34
Eunice spp.	6	14	11	17	--	--	--	6	3	6	--	--	63
Glycera alba	3	3	--	--	--	--	--	--	--	--	--	--	6
Glycera longipinnis	--	3	6	3	--	--	--	--	--	--	--	--	12
Lumbriconereis latreilli	--	--	--	3	--	--	--	--	3	6	25	--	37
Marphysa gravelyi	6	--	--	6	6	3	6	6	6	8	8	8	63
Marphysa stragulum	--	--	--	--	--	--	--	--	--	--	3	6	9
Nereis Chilkaensis	--	--	--	--	6	3	25	--	--	--	--	--	34
Nereis glandicincta	--	6	6	--	--	--	--	--	--	--	--	--	12
Nereis sp.	8	3	11	28	--	--	--	--	--	--	--	--	50
Paraheteromastus tenuis	14	22	25	33	17	11	6	14	19	33	22	17	233
Pulliella armata	--	--	--	--	--	--	--	3	--	3	--	8	14
Phyllodoce sp.	--	3	3	--	--	--	--	--	--	--	--	--	6
Talehsapia annandalei	3	3	17	8	6	3	3	3	--	--	--	6	52
Capitellidae	--	--	--	--	--	--	3	11	14	14	22	6	70
TOTAL	49	74	99	98	35	20	46	51	62	109	83	62	788
CRUSTACEA													
Apseudes chilkensis	3	3	--	--	--	6	6	11	6	6	9	6	56
Corophium triaenonyx	6	--	--	--	--	--	--	--	6	8	6	3	29
Dotilla sp.	--	3	3	--	--	--	--	--	3	--	--	--	9
Gammarus sp.	--	--	3	6	--	--	6	14	--	3	3	6	41
Uca annulipes	--	--	6	8	--	--	--	--	--	--	--	--	14
Uca sp.	6	3	--	17	--	--	--	--	--	--	--	--	26
Sphaeroma sp.	--	--	--	--	--	--	--	--	--	--	3	6	9
Palaemon sp.	--	--	--	--	--	--	--	--	--	--	--	3	3
Penaid sp.	--	--	--	--	--	--	--	3	--	17	--	--	20
Amphipod	--	--	--	3	--	--	--	--	--	--	--	--	3
TOTAL	15	9	12	34	--	6	12	28	15	34	21	24	210

Contd.

MOLLUSCA													
Bittium sp.	3	3	--	--	--	--	--	--	--	--	--	--	6
Cuspidaria sp.	--	--	--	--	--	--	--	17	6	--	--	--	23
Hydrobia sp.	--	11	8	8	--	--	8	--	--	--	--	--	35
Musculista sp.	11	3	3	3	--	8	3	--	3	3	14	22	73
Nerita sp.	--	--	--	--	--	--	--	--	--	3	--	--	3
Tellina tenuis	--	--	--	--	--	3	--	--	--	--	--	--	3
Tellina sp.	--	6	6	6	8	3	--	--	--	--	--	6	35
Tapes sp.	--	--	--	8	--	--	--	--	--	--	--	--	8
Bivalve	3	--	--	--	--	--	--	8	8	6	3	--	28
Gastropod	--	--	3	3	3	--	--	--	--	--	--	--	9
TOTAL	17	23	20	28	11	14	11	25	17	12	17	28	223
OTHER GROUPS													
Sipunculoidea	--	--	--	--	--	--	3	--	3	--	--	--	6
Gobioid fish	3	--	--	3	--	--	--	--	--	--	--	--	6
Sea anemone	--	--	--	--	--	--	--	--	--	11	--	--	11
TOTAL	3	--	--	3	--	--	3	--	3	11	--	--	23
GRAND TOTAL	84	106	131	163	46	40	72	104	97	166	121	114	1244

Table 5.7 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

MID TIDE LEVEL - STATION 1

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Amphicteis gunneri	3	--	--	--	--	--	--	--	6	--	--	--	9
Branchiocapitella singularis	--	--	--	--	--	--	--	11	8	11	6	3	39
Ceratonereis costae	--	--	--	--	--	--	--	3	--	3	--	--	6
Diopatra neapolitana	19	6	3	3	--	--	--	--	--	--	--	--	31
Dendronereis aestuarina	--	--	--	--	--	--	--	--	3	--	--	--	3
Eunice tubifex	--	11	14	--	--	--	--	6	8	--	--	--	39
Eunice spp.	6	12	8	6	--	--	--	--	3	6	3	8	52
Glycera alba	--	8	6	6	--	--	--	--	--	--	--	--	20
Glycera longipinnis	3	8	8	6	--	--	--	--	--	--	--	--	25
Goniada sp.	3	--	--	3	--	--	--	--	--	--	--	--	6
Lumbriconereis latreilli	--	--	--	6	3	--	6	--	--	3	3	--	21
Lumbriconereis pseudobifilaris	--	--	--	--	--	--	--	6	3	6	--	--	15
Lumbriconereis simplex	--	3	6	--	--	--	--	--	--	--	--	--	9
Lumbriconereis sp.	--	--	--	--	--	--	--	--	--	3	--	--	3
Marphysa gravelyi	17	11	11	19	6	3	6	6	11	14	11	6	121
Marphysa stragulum	3	--	--	--	--	--	--	--	11	--	--	11	25
Mercierella enigmatica	--	--	--	--	--	--	--	3	--	--	--	--	3
Nereis kauderni	3	--	3	--	--	--	--	--	--	--	--	--	3
Nereis chilkaensis	--	--	--	--	17	6	8	--	--	--	--	--	31
Nereis glandicincta	--	--	--	--	--	--	--	6	6	8	6	8	34
Nereis spp.	--	3	8	17	--	--	--	--	--	--	3	3	34
Paraheteromastus tenuis	19	8	11	11	8	6	8	14	14	14	14	17	144
Perinereis sp.	3	--	--	8	--	--	--	--	3	--	--	--	14
Pulliella armata	--	3	--	--	--	--	--	--	3	3	--	3	12
Pista indica	--	--	--	--	--	--	--	--	--	3	3	--	6
Polydora sp.	3	6	3	--	--	--	--	--	--	--	--	--	3
Talehsapia annandalei	--	3	3	3	6	6	3	6	--	--	--	--	30
Capitellidae	--	3	--	3	--	3	6	6	14	22	33	25	115
TOTAL	82	85	84	91	40	24	37	67	93	96	82	84	865

Contd.

CRUSTACEA													
Apseudes chilkensis	3	3	--	--	--	--	6	--	--	--	--	6	18
Alpheus sp.	--	--	3	3	--	--	--	--	--	--	--	--	6
Corophium triaenonyx	--	--	--	--	--	--	3	--	6	--	42	56	107
Dotilla sp.	--	3	3	3	--	--	--	--	--	--	--	3	12
Gammarus sp.	8	6	3	3	--	3	--	3	3	6	25	22	82
Ligia sp.	--	--	--	--	--	--	--	3	--	3	--	--	6
Metapograpsus messor	3	--	--	--	--	--	--	6	3	--	--	--	12
Sphaeroma sp.	--	--	--	--	--	--	--	--	8	11	11	3	33
Uca annulipes	3	6	3	--	--	--	--	6	3	3	6	--	30
Uca sp.	3	--	3	6	3	3	3	3	--	3	3	3	33
Palaemon sp.	--	--	--	--	--	3	--	--	--	3	--	--	6
Penaid sp.	3	--	--	--	--	--	--	--	--	--	--	6	9
TOTAL	23	18	15	15	3	9	12	21	23	29	87	99	354
MOLLUSCA													
Bittium sp.	--	6	3	--	--	--	--	--	--	--	--	--	9
Cuspidaria sp.	--	--	--	--	--	3	14	11	--	--	--	--	28
Hydrobia sp.	--	6	3	6	--	--	11	22	22	--	--	6	76
Musculista sp.	6	--	--	6	--	3	8	14	11	17	31	67	163
Nerita sp.	--	--	--	--	--	--	--	--	--	3	--	--	3
Tellina sp.	6	6	14	9	6	8	3	3	--	--	--	3	58
Tapes sp.	3	8	3	--	--	--	--	--	--	--	--	--	
Bivalve	--	--	--	--	--	--	--	--	8	17	11	--	36
Gastropod	--	--	--	--	--	--	--	--	--	--	3	--	3
TOTAL	15	26	23	21	6	14	36	50	41	37	45	76	390
OTHER GROUPS													
Nemertines	3	3	3	--	--	--	--	--	3	--	--	--	12
Gobioid fish	--	--	--	3	--	--	--	--	--	--	--	--	3
Sea anemone	11	6	8	6	--	6	6	8	14	33	25	19	142
Insect larvae	--	--	--	--	--	--	8	6	--	3	8	--	25
TOTAL	14	9	11	9	--	6	14	14	17	36	33	19	182
GRAND TOTAL	134	138	133	136	49	53	99	152	174	198	247	278	1791

Table 5.8 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

HIGH TIDE LEVL - STATION 1

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Branchiocapitella singularis	--	--	3	3	3	3	8	14	22	56	22	--	134
Diopatra neapolitana	--	3	3	6	--	--	--	--	--	--	--	--	12
Eunice tubifex	11	8	6	19	--	--	--	3	6	3	--	--	56
Eunice spp.	3	6	--	--	--	--	--	--	6	8	3	3	29
Lumbriconereis latreilli	--	--	6	--	--	--	--	--	8	--	--	--	14
Lumbriconereis sp.	--	--	--	--	--	--	--	--	--	--	--	3	3
Marphysa gravelyi	11	8	6	14	3	6	--	--	6	6	8	3	71
Marphysa stragulum	3	--	--	--	--	--	--	--	--	--	--	8	11
Nereis chilkaensis	--	--	--	--	8	--	8	--	--	--	--	--	16
Nereis glandicincta	3	3	3	3	--	--	3	11	3	6	3	--	38
Nereis spp.	--	3	3	3	--	--	--	--	--	--	--	--	9
Paraheteromastus tenuis	--	--	--	--	--	3	6	8	--	--	--	--	17
Perinereis cavifrons	--	6	--	--	--	3	--	--	--	--	--	--	9
Pulliella armata	--	--	--	--	--	--	--	--	6	3	--	--	9
Capitellidae	--	--	11	8	--	--	8	8	22	25	28	17	127
TOTAL	31	37	41	56	14	15	33	44	79	107	64	34	555
CRUSTACEA													
Apseudes chilkensis	--	6	3	3	--	--	--	--	--	--	--	--	12
Corophium triaenonyx	11	3	--	--	--	--	--	--	3	3	6	14	40
Gammarus sp.	6	--	3	--	--	--	3	6	11	3	6	8	46
Uca annulipes	--	--	--	--	--	--	--	6	3	--	--	--	9
Uca sp.	--	--	6	8	3	3	3	3	3	6	--	--	35
Ligia sp.	--	--	--	--	--	3	--	--	--	--	--	--	3
Sphaeroma sp.	3	6	--	3	--	--	6	14	19	6	3	6	66
Palaemon sp.	--	--	--	--	6	3	--	--	--	--	--	--	9
TOTAL	20	15	12	14	9	9	12	29	39	18	15	28	220

Contd.

CRUSTACEA													
Apseudes chilkensis	--	6	3	3	--	--	--	--	--	--	--	--	12
Corophium triaenonyx	11	3	--	--	--	--	--	--	3	3	6	14	40
Gammarus sp.	6	--	3	--	--	--	3	6	11	3	6	8	46
Uca annulipes	--	--	--	--	--	--	--	6	3	--	--	--	9
Uca sp.	--	--	6	8	3	3	3	3	3	6	--	--	35
Ligia sp.	--	--	--	--	--	3	--	--	--	--	--	--	3
Sphaeroma sp.	3	6	--	3	--	--	6	14	19	6	3	6	66
Palaemon sp.	--	--	--	--	6	3	--	--	--	--	--	--	9
TOTAL	20	15	12	14	9	9	12	29	39	18	15	28	220
MOLLUSCA													
Bittium sp.	--	8	--	--	--	--	--	--	--	--	--	--	8
Cuspidaria sp.	--	--	--	--	--	--	11	6	--	--	6	8	31
Hydrobia sp.	11	--	8	8	--	8	8	14	14	6	8	14	99
Musculista sp.	6	3	--	--	--	--	17	6	8	6	6	8	60
Nerita sp.	--	--	--	--	--	--	--	--	--	3	3	6	12
Tellina spp.	3	11	3	6	6	3	--	--	--	--	--	--	32
Bivalve	--	--	--	--	--	--	--	--	6	3	3	--	12
TOTAL	20	22	11	14	6	11	36	26	28	18	26	36	254
OTHER GROUPS													
Sipunculoidea	3	--	--	--	--	--	--	--	--	--	3	--	6
Sea anemone	14	19	36	11	--	6	19	28	64	33	39	12	281
Insect larvae	--	3	--	--	--	--	--	6	--	--	--	--	9
TOTAL	17	22	36	11	--	6	19	34	64	33	42	12	296
GRAND TOTAL	88	96	100	95	29	41	100	133	210	176	147	110	1325

Table 5.9 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

LOW TIDE LEVEL - STATION 2

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Branchiocapitella singularis	--	19	17	--	--	--	3	3	6	--	--	--	48
Dendronereides heteropoda	6	14	8	11	--	--	28	22	25	6	6	11	137
Eunice sp.	--	--	--	--	--	--	--	--	--	--	3	3	6
Marphysa gravelyi	3	3	8	6	--	--	--	6	3	--	--	6	35
Nereis glandicincta	17	8	11	3	3	6	11	14	8	8	11	3	103
Nereis chilkaensis	--	--	--	--	--	3	3	--	--	--	--	--	6
Paraheteromastus tenuis	--	14	3	--	--	--	--	--	--	--	--	--	17
Perinereis sp.	--	3	6	--	--	--	3	11	3	3	--	--	29
Pista indica	3	3	--	--	--	--	--	--	--	--	--	--	6
Capitellidae	122	19	17	17	3	6	11	6	22	39	11	14	287
TOTAL	151	83	70	37	6	15	59	62	67	56	31	37	674
CRUSTACEA													
Apseudes chilkensis	8	11	--	--	--	--	--	--	--	--	6	11	36
Corophium triaenonyx	6	11	3	--	--	--	--	--	--	--	--	--	20
Gammarus sp.	6	8	11	8	--	3	--	--	--	--	--	6	42
Sphaeroma sp.	--	19	6	8	--	--	6	--	--	6	--	--	45
Uca sp.	3	--	6	3	--	--	--	--	3	6	6	3	30
Palaemon sp.	22	11	--	--	6	6	--	19	14	17	19	17	131
TOTAL	45	60	26	19	6	9	6	19	17	29	31	37	304

Contd.

MOLLUSCA													
Bittium sp.	6	3	6	3	--	--	--	--	--	--	--	3	21
Cuspidaria sp.	--	3	6	3	3	6	--	--	--	--	--	--	21
Hydrobia sp.	56	22	14	39	11	--	17	28	17	44	33	22	303
Musculista sp.	--	3	3	3	--	--	--	--	3	6	6	14	38
Tellina sp.	--	--	--	--	--	3	6	3	--	--	--	--	12
Villorita cyprinoides var cochinensis	--	--	--	--	--	--	--	--	3	--	--	--	3
Bivalve	--	--	--	--	--	3	6	6	8	8	--	--	31
Gastropod	--	--	--	--	--	--	--	--	--	--	3	--	3
TOTAL	62	31	29	48	14	12	29	37	31	58	42	39	432
OTHER GROUPS													
Nemertines	--	11	--	17	--	--	6	--	--	--	14	--	48
Gobioid fish	3	--	--	--	--	--	--	--	--	--	6	3	12
Insect larvae	--	--	--	--	--	--	3	3	--	--	--	--	6
TOTAL	3	11	--	17	--	--	9	3	--	--	20	3	66
GRAND TOTAL	261	185	125	121	26	36	103	121	115	143	124	116	1476

Table 5.10 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

MID TIDE LEVEL - STATION 2

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Branchiocapitella singularis	--	17	6	3	--	--	--	--	--	--	--	--	26
Dendronereides heteropoda	33	72	67	56	14	47	42	81	58	56	42	50	618
Eunice sp.	--	8	3	--	--	--	--	--	--	--	--	--	11
Marphysa gravelyi	3	6	3	--	--	--	--	--	6	6	6	3	33
Marphysa stragulum	8	--	--	--	--	--	--	--	--	--	--	--	8
Nereis glandicincta	11	19	19	25	11	8	6	3	3	14	14	25	158
Pista indica	6	--	3	6	--	6	6	--	--	--	--	--	27
Capitellidae	28	36	47	14	14	6	33	14	--	--	36	22	250
TOTAL	89	158	148	104	39	67	87	98	67	76	98	100	1131
CRUSTACEA													
Apseudes chilkensis	--	--	--	3	--	--	--	6	3	--	--	--	12
Corophium triaenonyx	--	3	--	--	--	--	--	--	--	--	--	--	3
Gammarus sp.	--	6	3	8	--	--	--	--	--	3	--	--	20
Uca sp.	3	3	6	3	--	--	--	--	6	8	3	--	32
Sphaeroma sp.	3	11	19	6	--	--	--	--	--	--	3	3	45
Palaemon sp.	8	--	--	--	3	6	6	6	--	--	--	6	35
TOTAL	14	23	28	20	3	6	6	12	9	11	6	9	147

Contd.

MOLLUSCA													
Bittium sp.	6	6	--	3	--	--	--	--	--	--	--	--	15
Cuspidaria sp.	--	3	--	--	--	3	--	--	--	--	--	6	12
Hydrobia sp.	33	25	22	11	3	3	6	19	22	78	47	81	350
Musculista sp.	6	3	3	6	--	--	--	--	--	--	--	8	26
Tellina sp.	--	3	--	--	--	--	--	--	--	--	--	--	3
Bivalve	3	3	3	8	--	--	--	3	3	3	3	--	29
Gastropod	--	--	3	--	--	--	--	--	--	--	--	--	3
TOTAL	48	43	31	28	3	6	6	22	25	81	50	95	438
OTHER GROUPS													
Nemertines	6	--	--	3	--	--	--	--	6	--	--	3	18
Gobioid fish	--	3	--	--	--	--	--	--	--	--	--	--	3
Insect larvae	3	6	3	6	6	--	3	3	3	--	--	--	33
TOTAL	9	9	3	9	6	--	3	3	9	--	--	3	54
GRAND TOTAL	160	233	210	161	51	79	102	135	110	168	154	207	1770

Table 5.11 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

HIGH TIDE LEVEL - STATION 2

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Dendronereides heteropoda	14	31	19	28	11	8	--	--	6	6	8	8	139
Dendronereis aestuarina	--	--	--	--	--	--	--	--	3	3	3	--	9
Nereis glandicincta	8	6	6	17	6	8	8	6	6	3	3	6	83
Pista indica	3	--	--	--	--	3	14	6	--	--	--	--	26
Polydora sp.	--	3	3	--	--	--	--	--	--	--	--	--	6
Capitellidae	14	3	6	6	--	--	--	--	--	--	--	6	35
TOTAL	39	43	34	51	17	19	22	12	15	12	14	20	298
CRUSTACEA													
Corophium triaenonyx	--	--	6	3	--	--	--	3	--	--	--	--	12
Gammarus sp.	--	--	--	--	--	--	--	--	--	--	3	3	6
Uca sp.	--	--	--	--	--	--	--	--	3	3	--	--	6
Metapograpsus messor	3	3	6	3	--	--	--	--	--	3	3	6	27
Sphaeroma sp.	--	8	3	--	--	--	--	--	3	--	--	--	14
Palaemon sp.	8	3	--	--	--	6	3	--	--	--	--	6	26
TOTAL	11	14	15	6	--	6	3	3	6	6	6	15	91
MOLLUSCA													
Hydrobia sp.	22	25	28	31	8	3	3	11	17	25	19	25	217
Bivalve	--	--	--	3	--	--	--	--	--	--	--	--	3
TOTAL	22	25	28	34	8	3	3	11	17	25	19	25	220
OTHER GROUPS													
Insect larvae	--	3	--	--	--	--	3	--	--	--	--	3	9
GRAND TOTAL	72	85	77	91	25	28	31	26	38	43	39	63	618

Table 5.12 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

LOW TIDE LEVEL - STATION 3

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Branchiocapitella singularis	--	--	--	--	--	--	--	3	3	--	--	--	6
Dendronereis aestuarina	22	36	22	25	8	6	17	22	39	42	22	19	280
Dendronereis arborifera	--	8	3	--	--	--	--	--	--	8	19	22	60
Eunice tubifex	14	--	--	--	--	--	--	--	--	--	--	--	14
Marphysa gravelyi	3	3	6	3	--	--	--	--	6	3	--	--	24
Nereis chilkaensis	--	--	--	--	11	14	6	--	--	3	--	--	34
Nereis glandicincta	3	3	6	3	--	--	--	--	--	--	8	6	29
Nereis sp.	--	--	3	3	--	--	--	--	--	--	--	--	6
Paraheteromastus tenuis	--	--	--	--	--	3	6	14	17	19	17	--	76
Perinereis sp.	3	3	8	--	--	--	--	6	8	--	--	3	31
Prionospio pinnata	--	--	--	--	--	--	--	--	--	--	--	3	3
Prionospio cirrifera	--	--	--	--	--	--	6	--	39	--	14	8	67
Talehsapia annandalei	--	--	--	--	--	--	17	17	8	6	3	--	51
TOTAL	45	53	48	34	19	23	52	62	120	81	83	61	681
CRUSTACEA													
Apseudes chilkensis	6	3	--	--	3	6	3	3	--	--	--	6	30
Corophium triaenonyx	--	--	3	17	--	--	--	3	6	3	3	--	35
Gammarus sp.	8	14	19	11	6	6	6	6	--	--	--	6	82
Sphaeroma sp.	--	--	--	--	--	--	--	--	3	3	3	--	9
Palaemon sp.	6	--	--	3	--	--	--	3	3	--	--	--	15
TOTAL	20	17	22	31	9	12	9	15	12	6	6	12	171

Contd.

MOLLUSCA													
Cuspidaria sp.	--	--	--	--	3	6	3	3	3	8	3	--	29
Hydrobia sp.	8	11	11	3	--	--	3	--	6	3	6	3	54
Tellina tenuis	--	--	--	--	3	--	3	3	--	--	--	--	9
Tellina sp.	--	--	--	--	--	--	19	56	50	6	6	--	137
Villorita cyprinoides var cochinensis	3	--	--	6	11	14	6	11	56	39	3	3	152
Gastropod	--	--	22	--	--	8	22	11	--	11	--	3	77
Bivalve	--	6	--	25	--	--	--	--	--	--	--	6	37
TOTAL	11	17	33	34	17	28	56	84	115	67	18	15	495
OTHER GROUPS													
Nemertines	--	3	--	--	--	--	--	--	--	--	3	--	6
Sea anemone	3	--	--	33	--	--	--	--	--	--	--	--	36
Insect larvae	6	--	--	3	--	--	--	--	--	--	6	--	15
TOTAL	9	3	--	36	--	--	--	--	--	--	9	--	57
GRAND TOTAL	85	90	103	135	45	63	117	161	247	154	116	88	1404

Table 5.13 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

MID TIDE LEVEL - STATION 3

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Dendronereis aestuarina	11	8	6	6	6	3	11	11	19	94	33	19	227
Dendronereis arborifera	--	14	8	--	--	--	--	--	--	--	3	6	31
Marphysa gravelyi	6	6	6	3	3	3	3	--	3	3	--	--	36
Nereis chilkaensis	--	--	--	--	--	3	11	--	6	3	--	--	23
Nereis glandicincta	11	6	8	8	--	--	3	6	3	6	6	8	65
Paraheteromastus tenuis	--	--	--	--	--	--	8	6	14	--	--	--	28
Perinereis sp.	3	--	6	--	--	--	--	--	--	3	3	--	15
Prionospio cirrifera	--	11	--	11	--	--	--	3	--	--	--	14	39
Talehsapia annandalei	--	--	--	--	--	--	--	3	11	--	--	--	14
TOTAL	31	45	34	28	9	9	36	29	56	109	45	47	478
CRUSTACEA													
Apseudes chilkensis	8	6	3	--	--	6	3	6	8	6	--	--	46
Corophium triaenonyx	--	--	--	--	--	--	--	--	--	6	3	--	9
Gammarus sp.	3	6	6	3	3	3	6	6	3	3	6	3	51
Sphaeroma sp.	--	--	--	--	--	--	--	--	3	3	--	--	6
Palaemon sp.	--	--	--	3	--	--	--	3	--	--	--	3	9
TOTAL	11	12	9	6	3	9	9	15	14	18	9	6	121

Contd.

MOLLUSCA													
Cuspidaria sp.	--	--	--	--	6	--	3	3	--	11	3	--	26
Hydrobia sp.	8	3	3	3	--	--	--	--	8	14	14	3	56
Tellina tenuis	--	--	--	--	--	--	3	--	--	--	--	--	3
Tellina sp.	3	3	--	--	6	14	19	--	--	6	3	--	54
Villorita cyprinoides var cochinensis	6	11	6	6	--	--	--	3	6	17	11	11	77
Bivalve	--	--	--	--	--	3	--	--	3	--	--	6	12
Gastropod	--	--	--	--	--	--	3	19	--	--	36	11	69
TOTAL	17	17	9	9	12	17	28	25	17	48	67	31	297
OTHER GROUPS													
Nemertines	--	--	--	--	--	--	--	--	3	3	--	--	6
Sea anemone	--	--	3	6	--	--	--	--	--	--	--	--	9
TOTAL	--	--	3	6	--	--	--	--	3	3	--	--	15
GRAND TOTAL	59	74	55	49	24	35	73	69	90	178	121	84	911

Table 5.14 Monthly occurrence (mean values) of organisms in 0.1 m^2 area during September 1989 to August 1991

HIGH TIDE LEVEL - STATION 3

NAME	F	M	A	M	J	J	A	S	O	N	D	J	TOTAL
POLYCHAETA													
Branchiocapitella singularis	--	--	--	--	--	--	--	--	3	--	--	--	3
Dendronereis aestuarina	3	3	--	--	--	--	--	--	--	--	--	6	12
Eunice sp.	--	--	6	3	--	--	--	--	--	--	--	--	9
Marphysa gravelyi	6	3	--	--	--	--	--	6	3	3	6	8	35
Nereis glandicincta	8	6	6	14	6	3	14	28	25	22	11	14	157
Prionospio cirrifera	--	--	--	--	--	--	--	--	--	--	3	3	6
Perinereis sp.	6	--	6	3	--	--	--	--	3	14	--	--	32
Nereis sp.	--	--	3	3	--	--	--	--	--	--	--	--	6
Capitellidae	--	14	14	11	--	--	--	3	--	--	--	--	42
TOTAL	23	26	35	34	6	3	14	37	34	39	20	31	302
CRUSTACEA													
Apseudes chilkensis	--	3	--	--	--	--	--	--	--	--	3	3	9
Corophium triaenonyx	--	--	--	--	--	--	--	3	--	--	3	6	12
Gammarus sp.	11	--	--	--	--	--	--	--	6	3	--	6	26
Sphaeroma sp.	--	--	--	--	--	--	3	14	3	--	--	--	20
Palaemon sp.	6	--	--	--	--	--	--	--	--	--	--	3	9
TOTAL	17	3	--	--	--	--	3	17	9	3	6	18	76

Contd.

MOLLUSCA													
Cuspidaria sp.	--	3	--	--	3	--	--	--	--	--	--	--	6
Hydrobia sp.	14	19	22	14	6	11	28	17	44	--	--	--	175
Tellina sp.	--	--	--	--	--	--	--	--	--	3	3	--	6
Gastropod	--	3	--	--	--	--	--	--	--	--	--	--	3
Bivalve	3	--	--	--	--	--	--	--	--	--	--	--	3
TOTAL	17	25	22	14	9	11	28	17	44	3	3	--	193
OTHER GROUPS													
Sea anemone	8	22	14	6	3	--	--	--	--	3	6	--	62
Gobioid fish	6	--	--	--	--	--	--	--	--	3	--	--	9
Insect larvae	--	--	3	--	--	--	--	--	--	--	--	--	3
TOTAL	14	22	17	6	3	--	--	--	--	6	6	--	74
GRAND TOTAL	71	76	74	54	18	14	45	71	87	51	35	49	645

Table 5.15 Biomass of organisms (monthly mean values) in 0.1 m^2 area at station 1 during September 1989 to August 1991

MONTH	Low tide level						Mid tide level						High tide level					
	WET WEIGHT			DRY WEIGHT			WET WEIGHT			DRY WEIGHT			WET WEIGHT			DRY WEIGHT		
	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total
FEB	2.4194	0.5131	2.9325	0.2649	0.1304	0.3953	2.7401	1.4508	4.1909	0.2332	0.2642	0.4974	3.4411	0.0694	3.5105	0.3908	0.0192	0.4100
MAR	2.0314	0.2396	2.2710	0.2196	0.1279	0.3475	2.4469	0.1988	2.6457	0.3879	0.0957	0.4836	3.3907	0.2272	3.9179	0.4701	0.0454	0.5155
APR	2.8869	0.5661	3.4530	0.1889	0.3322	0.5211	3.4589	0.1469	3.6058	0.4320	0.0464	0.4784	0.8597	0.2169	1.0766	0.1040	0.0692	0.1732
MAY	1.6751	2.1229	3.7980	0.1194	0.5126	0.6320	2.6256	5.4688	8.0944	0.3088	1.0347	1.3435	1.1258	0.2369	1.3627	0.1124	0.0478	0.1602
JUN	0.4121	0.3210	0.7331	0.0649	0.0430	0.1079	0.8594	0.2931	1.1525	0.0982	0.0585	0.1567	0.4632	0.1914	0.6546	0.0625	0.0433	0.1058
JUL	0.1149	0.6368	0.7517	0.0151	0.1506	0.1657	0.3379	2.2196	2.5575	0.0322	0.5292	0.5614	0.6125	0.8625	1.4750	0.0642	0.1275	0.1917
AUG	0.3444	0.8624	1.2068	0.0464	0.1649	0.2113	1.2146	2.1824	3.3970	0.1325	0.5285	0.6610	0.1994	0.3885	0.5879	0.0315	0.0711	0.1026
SEP	0.7386	0.3572	1.0958	0.0406	0.0808	0.1214	6.7854	4.3588	11.1442	0.8081	0.7664	1.5745	4.5942	3.6722	8.2664	0.6233	0.8185	1.4418
OCT	2.2572	0.3039	2.5611	0.1939	0.1319	0.3258	8.0441	0.8464	8.8905	0.5803	0.8614	1.4417	5.8372	1.1192	6.9564	0.6486	0.1025	0.7511
NOV	3.8162	0.4600	4.2762	0.4181	0.1542	0.5723	10.8331	1.1243	11.9574	1.2025	0.1372	1.3397	5.7856	0.1035	5.8891	0.7071	0.0418	0.7489
DEC	1.6614	0.3061	1.9675	0.1833	0.0375	0.2208	11.8986	1.0697	12.9683	1.3586	0.1689	1.5275	3.1131	0.0875	3.2006	0.5933	0.0783	0.6716
JAN	2.3408	0.3535	2.6943	0.3007	0.0822	0.3829	9.8417	3.0580	12.8997	1.0420	0.4353	1.4773	0.3090	0.3393	0.6483	0.0351	0.0874	0.1225
TOTAL	20.6984	7.0426	27.7410	2.0558	1.9482	4.0040	61.0863	22.4176	83.5039	6.6163	4.9264	11.5427	30.0315	7.5145	37.5460	3.8429	1.5520	5.3949
Grand total of the three tidal levels													11.8162	36.9747	148.79	12.5150	8.4266	20.9416

Table 5.16 Biomass of organisms (monthly mean values) in 0.1 m^2 area at station 2 during September 1989 to August 1991

	Low tide level						Mid tide level						High tide level					
MONTH	WET WEIGHT			DRY WEIGHT			WET WEIGHT			DRY WEIGHT			WET WEIGHT			DRY WEIGHT		
	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total
FEB	0.6364	3.4207	4.0571	0.0703	0.7304	0.8007	1.1801	0.9054	2.0855	0.1464	0.2526	0.3990	0.3547	2.5642	2.9189	0.0463	0.5292	0.5755
MAR	0.8528	1.2726	2.1254	0.0794	0.2886	0.3680	3.8724	0.5867	4.4591	0.5764	0.1563	0.7327	0.5013	2.0293	2.5306	0.0829	0.3289	0.4118
APR	0.7650	0.5960	1.3610	0.0713	0.2531	0.3244	2.1033	1.8322	3.9355	0.1208	0.3319	0.4527	0.2850	0.5654	0.8504	0.0510	0.2231	0.2741
MAY	0.2213	0.1808	0.4021	0.0278	0.1358	0.1636	2.0276	0.4603	2.4879	0.2322	0.0999	0.3321	0.6033	0.2896	0.8929	0.0842	0.1450	0.2292
JUN	0.0167	0.2072	0.2239	0.0061	0.0613	0.0674	0.7925	0.1311	0.9236	0.1110	0.0707	0.1817	0.3909	0.0145	0.4054	0.0397	0.0046	0.0443
JUL	0.1388	1.4146	1.5534	0.0201	0.0822	0.1023	1.7667	0.8025	2.5692	0.1594	0.1311	0.2905	0.4604	0.4643	0.9247	0.0514	0.0758	0.1272
AUG	0.7443	0.1169	0.8612	0.1047	0.0240	0.1287	1.7667	2.5657	4.3324	0.2104	0.0192	0.2296	0.6981	0.2288	0.9269	0.0900	0.0321	0.1221
SEP	2.0157	0.3025	2.3182	0.1960	0.0325	0.2285	0.6128	0.8024	1.4152	0.3188	0.1610	0.4798	0.1275	0.0235	0.1510	0.0101	0.0068	0.0169
OCT	1.4839	0.6394	2.1233	0.1508	0.0506	0.2014	5.9736	1.2106	7.1842	0.8042	0.1153	0.9195	0.1256	0.2172	0.3428	0.0181	0.0663	0.0844
NOV	0.3229	0.2450	0.5679	0.0476	0.0542	0.1018	5.6879	0.4006	6.0885	0.7038	0.2344	0.9382	0.1076	0.8732	0.9808	0.0132	0.2103	0.2235
DEC	0.3783	5.3572	5.7355	0.0600	0.9058	0.9658	4.5844	0.2089	4.7933	0.4297	0.1058	0.5355	0.1078	1.1169	1.2247	0.0128	0.3325	0.3453
JAN	0.6622	1.1826	1.8448	0.1089	0.2040	0.3129	4.2929	0.8706	5.1635	0.4527	0.1571	0.6098	0.1753	1.4269	1.6022	0.0260	0.3839	0.4099
TOTAL	8.2383	14.9355	23.1738	0.9430	2.8225	3.7655	34.6609	10.7770	45.4379	4.2658	1.8353	6.1011	3.9375	9.8138	13.7513	0.5257	2.3385	2.8642
Grand total of three tidal levels													46.8367	35.5263	82.3630	5.7345	6.9963	12.7308

Table 5.17 Biomass of organisms (monthly mean values) in 0.1 m^2 area at station 3 during September 1989 to August 1991

MONTH	Low tide level						Mid tide level						High tide level					
	WET WEIGHT			DRY WEIGHT			WET WEIGHT			DRY WEIGHT			WET WEIGHT			DRY WEIGHT		
	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total	Polychaeta	Others	Total
FEB	2.1254	3.3257	5.4511	0.1919	0.5581	0.7500	0.9296	0.0708	1.0004	0.1064	0.0492	0.1556	1.3853	2.5689	3.9542	0.1303	0.3986	0.5289
MAR	1.0200	0.0567	1.0767	0.1268	0.0467	0.1735	1.4542	0.8214	2.2756	0.2213	0.1258	0.3471	0.3949	0.6917	1.0866	0.0654	0.0951	0.1605
APR	1.1486	0.0508	1.1994	0.1119	0.0264	0.1383	1.4486	0.2850	1.7336	0.1717	0.0236	0.1953	0.3688	0.2044	0.5732	0.0796	0.0685	0.1481
MAY	1.0185	1.3833	2.4018	0.1060	0.2278	0.3338	1.0868	0.1797	1.2665	0.1103	0.0194	0.1297	0.4610	0.3419	0.8029	0.0682	0.0425	0.1107
JUN	0.1989	0.8251	1.0240	0.0117	0.1769	0.1886	0.2561	0.1508	0.4069	0.0214	0.0251	0.0465	0.1581	0.0303	0.1884	0.0132	0.0100	0.0232
JUL	0.4657	0.7653	1.2310	0.0635	0.1100	0.1735	0.2736	0.6303	0.9039	0.0353	0.1497	0.1850	0.1350	0.0375	0.1725	0.0112	0.0063	0.0175
AUG	0.8928	0.9654	1.8582	0.1186	0.3329	0.4515	0.5871	0.7540	1.3411	0.1028	0.1022	0.2050	0.2385	0.1122	0.3507	0.0403	0.0181	0.0584
SEP	1.5078	0.8272	2.3350	0.1951	0.2842	0.4793	0.4028	0.6346	1.0374	0.1000	0.0703	0.1703	0.6963	0.3825	1.0788	0.0749	0.1794	0.2543
OCT	2.1276	1.0410	3.1686	0.2743	0.4485	0.7228	0.8860	0.3378	1.2238	0.1054	0.0603	0.1657	0.5250	1.2430	1.7680	0.0353	0.2130	0.2483
NOV	0.9985	1.3829	2.3814	0.1199	0.3135	0.4334	0.9286	0.5165	1.4451	0.1128	0.1428	0.2556	0.5508	0.2492	0.8000	0.0460	0.2148	0.2608
DEB	1.3108	0.4522	1.7630	0.1621	0.0994	0.2615	0.3494	0.5108	0.8602	0.0578	0.1300	0.1878	0.4811	0.2462	0.7273	0.0522	0.2019	0.2541
JAN	1.2365	0.1443	1.3808	0.1392	0.1003	0.2395	0.6876	0.6022	1.2898	0.0746	0.0919	0.1665	1.3004	0.1297	1.4301	0.1581	0.0224	0.1805
TOTAL	14.0511	11.2199	25.2710	1.6210	2.7247	4.3457	9.2904	5.4939	14.7843	1.2198	0.9903	2.2101	6.6952	6.2375	12.9327	0.7747	1.4706	2.2453
Grand total of the three tidal levels													30.0367	22.9513	52.9880	3.6155	5.1856	8.8011

Table 5.18 Diversity indices of benthic fauna at station 1

	Low tide level				Mid tide level				High tide level			
Month	R1	H'	N1	E2	R1	H'	N1	E2	R1	H'	N1	E2
Feb	3.16	2.57	13.07	0.87	4.29	2.71	15.03	0.68	2.68	2.39	10.91	0.84
Mar	3.43	2.53	12.55	0.74	4.46	3.03	20.70	0.90	3.07	2.53	12.55	0.84
Apr	3.07	2.51	12.30	0.77	4.50	2.96	19.30	0.84	2.82	2.23	9.30	0.66
May	3.14	2.50	12.18	0.72	4.07	2.86	17.46	0.83	2.64	2.37	10.70	0.82
Jun	1.31	1.65	5.21	0.87	1.54	1.78	5.93	0.85	1.48	1.71	5.53	0.92
Jul	1.90	1.93	6.89	0.86	2.77	2.41	11.13	0.93	2.43	2.22	9.31	0.92
Aug	2.34	2.10	8.17	0.74	3.04	2.61	13.60	0.91	2.39	2.32	10.18	0.85
Sep	2.37	2.34	10.38	0.87	3.98	2.87	17.64	0.84	2.66	2.46	11.70	0.84
Oct	2.84	2.45	11.59	0.83	4.26	2.94	18.92	0.82	2.99	2.39	10.91	0.64
Nov	2.94	2.49	12.06	0.75	4.16	2.80	16.44	0.71	2.90	2.20	9.03	0.56
Dec	2.29	2.18	8.85	0.74	3.27	2.62	13.74	0.72	2.81	2.27	9.68	0.65
Jan	2.95	2.53	12.55	0.84	3.37	2.45	11.59	0.58	2.55	2.43	11.36	0.87

R1 = Species richness N1 = Hill's diversity index

H' = Species diversity E2 = Evenness

Table 5.19 Diversity indices of benthic fauna at station 2

	Low tide level				Mid tide level				High tide level			
Month	R1	H'	N1	E2	R1	H'	N1	E2	R1	H'	N1	E2
Feb	2.16	1.73	5.64	0.43	2.76	2.31	10.07	0.67	1.40	1.75	5.75	0.82
Mar	3.26	2.69	14.73	0.82	3.12	2.32	10.18	0.57	1.80	1.73	5.64	0.63
Apr	2.90	2.57	13.07	0.87	2.63	2.07	7.92	0.53	1.61	1.76	5.81	0.73
May	2.29	2.10	8.17	0.68	2.76	2.21	9.12	0.61	1.33	1.56	4.76	0.68
Jun	1.23	1.45	4.26	0.85	1.27	1.63	5.10	0.85	0.62	1.07	2.92	0.97
Jul	1.96	2.02	7.54	0.94	1.37	1.38	3.97	0.57	1.20	1.52	4.57	0.91
Aug	2.38	2.21	9.12	0.76	1.30	1.50	4.48	0.64	1.17	1.39	4.01	0.80
Sep	2.08	2.13	8.41	0.76	1.63	1.35	3.86	0.43	0.92	1.29	3.63	0.91
Oct	2.32	2.19	8.94	0.75	1.70	1.53	4.62	0.51	1.37	1.54	4.66	0.78
Nov	1.81	1.92	8.82	0.68	2.42	1.34	3.82	0.55	1.33	1.33	3.78	0.63
Dec	2.28	2.23	9.30	0.78	1.39	1.63	5.10	0.64	1.37	1.46	4.31	0.72
Jan	2.53	2.33	10.28	0.79	1.69	1.72	5.58	0.56	1.69	1.82	6.17	0.77

R1 = Species richness N1 = Hill's diversity index
H' = Species diversity E2 = Evenness

Table 5.20 Diversity indices of benthic fauna at station 3

	Low tide level				Mid tide level				High tide level			
Month	R1	H'	N1	E2	R1	H'	N1	E2	R1	H'	N1	E2
Feb	2.48	2.24	9.39	0.78	1.96	2.09	8.08	0.90	2.11	2.21	9.12	0.91
Mar	2.00	1.87	6.49	0.65	2.09	2.20	9.03	0.90	1.85	1.86	6.42	0.71
Apr	1.94	2.05	7.77	0.78	2.24	2.25	9.49	0.95	1.63	1.86	6.42	0.80
May	2.24	2.08	8.00	0.67	2.06	2.09	8.08	0.90	1.50	1.75	5.75	0.82
Jun	1.57	1.81	6.11	0.87	1.26	1.64	5.16	1.03	1.04	1.33	3.78	0.95
Jul	1.69	1.97	7.17	0.90	1.69	1.72	5.58	0.80	0.38	0.52	1.68	0.84
Aug	2.52	2.30	9.97	0.77	2.33	2.15	8.58	0.78	0.52	0.84	2.32	0.77
Sep	2.56	2.14	8.50	0.61	2.36	2.18	8.85	0.80	1.17	1.51	4.53	0.76
Oct	2.36	2.13	8.41	0.61	2.67	2.34	10.38	0.80	1.34	1.35	3.86	0.55
Nov	2.38	2.09	8.08	0.62	2.51	1.80	6.05	0.43	1.53	1.55	4.71	0.67
Dec	2.74	2.36	10.59	0.76	2.08	1.94	6.96	0.63	1.69	1.81	6.11	0.87
Jan	2.46	2.20	9.03	0.75	2.03	2.13	8.41	0.84	1.80	1.94	6.96	0.87

R1 = Species richness N1 = Hill's diversity index
H' = Species diversity E2 = Evenness

Table 5.21 Diversity indices of polychaete fauna at station 1

Month	Low tide level				Mid tide level				High tide level			
	R1	H'	N1	E2	R1	H'	N1	E2	R1	H'	N1	E2
Feb	1.80	1.94	6.96	0.87	2.27	2.04	7.69	0.70	1.17	1.80	6.05	1.21
Mar	2.09	1.97	7.17	0.90	2.70	2.44	11.47	0.88	1.66	1.86	6.42	0.92
Apr	1.74	1.99	7.32	0.81	2.48	2.36	10.59	0.88	1.89	1.96	7.10	0.89
May	1.31	1.62	5.05	0.72	2.44	2.27	9.68	0.81	1.49	1.70	5.47	0.78
Jun	0.84	1.26	3.53	0.88	1.08	1.45	4.26	0.85	0.76	0.98	2.66	0.89
Jul	1.00	1.18	3.25	0.81	1.26	1.56	4.76	0.95	1.11	1.33	3.78	0.95
Aug	1.06	1.24	3.46	0.69	1.39	1.75	5.75	0.96	1.14	1.56	4.76	0.95
Sep	1.53	1.82	6.17	0.88	2.14	2.20	9.03	0.90	1.06	1.51	4.53	0.91
Oct	1.45	1.75	5.75	0.82	2.65	2.40	11.02	0.85	1.60	1.85	6.34	0.79
Nov	1.49	1.82	6.17	0.77	2.41	2.24	9.39	0.78	1.28	1.40	4.06	0.58
Dec	1.13	1.53	4.62	0.77	1.81	1.80	6.05	0.67	0.96	1.28	3.60	0.72
Jan	1.69	2.05	7.77	0.97	1.81	1.94	6.96	0.77	1.13	1.33	3.78	0.76

R1 = Species richness   N1 = Hill's diversity index
H' = Species diversity   E2 = Evenness

Table 5.22 Diversity indices of polychaete fauna at station 2

	Low tide level				Mid tide level				High tide level			
Month	R1	H'	N1	E2	R1	H'	N1	E2	R1	H'	N1	E2
Feb	0.80	0.70	2.01	0.40	1.11	1.50	4.48	0.75	0.82	1.26	3.53	0.88
Mar	1.58	1.86	6.42	0.80	0.99	1.47	4.35	0.73	0.80	0.83	2.29	0.57
Apr	1.41	1.82	6.17	0.88	1.20	1.36	3.90	0.56	0.85	1.15	3.16	0.79
May	0.83	1.22	3.39	0.85	0.86	1.21	3.35	0.67	0.51	0.95	2.59	0.86
Jun	0.56	0.69	1.99	1.00	0.55	1.09	2.97	0.99	0.35	0.65	1.92	0.96
Jul	0.74	1.06	2.89	0.96	0.71	0.94	2.56	0.64	0.68	1.02	2.77	0.92
Aug	1.23	1.43	4.18	0.70	0.67	1.09	2.97	0.74	0.32	0.66	1.93	0.97
Sep	1.21	1.61	5.00	0.83	0.44	0.54	1.72	0.57	0.40	0.69	1.99	1.00
Oct	1.19	1.48	4.39	0.73	0.48	0.48	1.62	0.54	0.74	1.06	2.89	0.96
Nov	0.74	0.93	2.53	0.63	0.46	0.74	2.10	0.70	0.81	1.04	2.83	0.94
Dec	0.87	1.28	3.60	0.90	0.66	1.18	3.25	0.81	0.76	0.98	2.66	0.89
Jan	1.11	1.43	4.18	0.84	0.65	1.13	3.10	0.78	0.67	1.09	2.97	0.99

R1 = Species richness N1 = Hill's diversity index
H' = Species diversity E2 = Evenness

Table 5.23 Diversity indices of polychaete fauna at station 3

	Low tide level				Mid tide level				High tide level			
Month	R1	H'	N1	E2	R1	H'	N1	E2	R1	H'	N1	E2
Feb	1.05	1.26	3.53	0.71	0.87	1.28	3.60	0.90	0.96	1.34	3.82	0.96
Mar	1.01	1.04	2.83	0.57	1.05	1.55	4.71	0.94	0.92	1.17	3.22	0.81
Apr	1.29	1.52	4.57	0.76	1.13	1.60	4.95	0.99	1.12	1.48	4.39	0.88
May	0.85	0.87	2.39	0.60	0.90	1.30	3.67	0.92	1.13	1.37	3.94	0.79
Jun	0.34	0.68	1.97	0.99	0.45	0.64	1.90	0.95	--	--	--	--
Jul	0.64	0.92	2.51	0.84	0.91	1.10	3.00	1.00	--	--	--	--
Aug	0.78	1.27	3.56	0.89	1.12	1.47	4.35	0.87	--	--	--	--
Sep	0.97	1.43	4.18	0.84	1.19	1.49	4.44	0.89	0.55	0.71	2.03	0.68
Oct	1.25	1.61	5.00	0.71	1.02	1.40	4.06	0.81	0.85	0.87	2.39	0.60
Nov	0.92	1.23	3.42	0.68	0.86	0.47	1.60	0.32	0.55	0.89	2.44	0.81
Dec	1.13	1.66	5.26	0.88	0.79	0.86	2.36	0.59	0.67	0.98	2.66	0.89
Jan	1.22	1.52	4.57	0.76	0.78	1.29	3.63	0.91	0.87	1.25	3.49	0.87

R1 = Species richness   N1 = Hill's diversity index

H' = Species diversity   E2 = Evenness

Table 5.24 Diversity indices of benthos in different seasons

	Station 1				Station 2				Station 3			
Seasons	R1	H'	N1	E2	R1	H'	N1	E2	R1	H'	N1	E2
	Low tide level											
Premonsoon	3.20	2.53	12.53	0.78	2.65	2.27	10.40	0.70	2.17	2.06	7.91	0.72
Monsoon	1.9	2.01	7.66	0.83	1.91	1.95	7.33	0.83	2.09	2.06	7.94	0.79
Postmonsoon	2.76	2.41	11.26	0.79	2.24	2.17	8.84	0.75	2.49	2.20	9.03	0.69
	Mid tide level											
Premonsoon	4.33	2.89	18.12	0.81	2.82	2.23	9.32	0.60	2.09	2.16	8.67	0.91
Monsoon	2.83	2.42	12.08	0.88	1.39	1.47	4.35	0.62	1.91	1.92	7.04	0.85
Postmonsoon	3.77	2.70	15.17	0.71	1.80	1.56	4.78	0.57	2.32	2.05	7.95	0.68
	High tide level											
Premonsoon	2.80	2.38	10.87	0.79	1.54	1.70	5.49	0.72	1.77	1.92	6.93	0.81
Monsoon	2.24	2.18	9.15	0.88	0.98	1.32	3.78	0.90	0.78	1.05	3.08	0.83
Postmonsoon	2.81	2.32	10.25	0.68	1.44	1.54	4.73	0.73	1.59	1.66	5.41	0.74

R1 = Species richness N1 = Hill's diversity index
E2 = Species diversity E2 = Evenness

Table 5.25 Diversity indices of polychaete fauna in different seasons

	Station 1				Station 2				Station 3			
Seasons	R1	H'	N1	E2	R1	H'	N1	E2	R1	H'	N1	E2
Low tide level												
Premonsoon	1.74	1.88	6.63	0.83	1.16	1.40	4.50	0.73	1.05	1.17	3.33	0.66
Monsoon	1.11	1.38	4.10	0.82	0.94	1.20	3.52	0.87	0.68	1.08	3.06	0.89
Postmonsoon	1.44	1.79	6.08	0.83	0.98	1.28	3.68	0.78	1.13	1.51	4.56	0.76
Mid tide level												
Premonsoon	2.47	2.28	9.86	0.82	1.04	1.39	4.02	0.68	0.99	1.43	4.23	0.94
Monsoon	1.47	1.74	5.95	0.92	0.59	0.92	2.56	0.74	0.92	1.18	3.42	0.93
Postmonsoon	2.17	2.10	8.36	0.77	0.56	0.88	2.52	0.71	0.86	1.06	2.91	0.66
High tide level												
Premonsoon	1.55	1.83	6.26	0.95	0.75	1.05	2.89	0.78	1.08	1.34	3.84	0.86
Monsoon	1.02	1.35	3.93	0.93	0.44	0.76	2.15	0.96	0.14	0.18	0.51	0.17
Postmonsoon	1.24	1.47	4.45	0.71	0.75	1.04	2.84	0.95	0.74	1.00	2.75	0.79

R1 = Species richness   N1 = Hill's diversity index

E2 = Species diversity   E2 = Evenness

Table 5.26 Anova table showing the significance of the diversity indices of benthos in different seasons and tide levels at station 1

Source	Sum of Squares	D.F.	Mean Square	F ratio
			Richness (R1)	
Between seasons	1.89	2	0.94	15.827*
Between tide levels	2.05	2	1.02	17.180*
Error	0.24	4	0.06	
Total	4.17	8		
			Diversity (H')	
Between seasons	0.25	2	0.12	14.601*
Between tide levels	0.27	2	0.13	15.782*
Error	0.03	4	0.01	
Total	0.55	8		
			Hill's diversity number (N1)	
Between seasons	27.02	2	13.51	9.860*
Between tide levels	46.98	2	23.49	17.141*
Error	5.48	4	1.37	
Total	79.49	8		
			Evenness (E2)	
Between seasons	0.03	2	0.01	6.966*
Between tide levels	0.00	2	0.00	0.138
Error	0.01	4	0.00	
Total	0.04	8		

* - Significant at 5% level ($P<0.05$)

Table 5. 27 Anova table showing the significance of the diveristy indices of benthos in different seasons and tide levels at station 2

Source	Sum of Squares	D.F.	Mean Square	F ratio
				Richness (R1)
Between seasons	1.25	2	0.62	8.622*
Between tide levels	1.43	2	0.72	9.895*
Error	0.29	4	0.07	
Total	2.97	8		
				Diversity (H')
Between seasons	0.39	2	0.20	7.887*
Between tide levels	0.69	2	0.34	13.919*
Error	0.10	4	0.02	
Total	1.18	8		
				Hill's diversity number (N1)
Between seasons	16.72	2	8.36	7.226*
Between tide levels	27.08	2	13.54	11.705*
Error	4.63	4	1.16	
Total	48.43	8		
				Evenness (E2)
Between seasons	0.02	2	0.01	5.459
Between tide levels	0.06	2	0.03	15.262*
Error	0.01	4	0.00	
Total	0.09	8		

* - Significant at 5% level (*P*<0.05)

Table 5.28 Anova table showing the significance of the diversity indices of benthos in different seasons and tide levels at station 3

Source	Sum of Squares	D.F.	Mean Square	F ratio
				Richness (R1)
Between seasons	0.48	2	0.24	3.846
Between tide levels	1.31	2	0.63	10.450*
Error	0.25	4	0.06	
Total	2.04	8		
				Diversity (H')
Between seasons	0.23	2	0.11	2.159
Between tide levels	0.57	2	0.29	5.391
Error	0.21	4	0.05	
Total	1.01	8		
				Hill's diversity number (N1)
Between seasons	5.52	2	2.76	2.664
Between tide levels	17.65	2	8.83	8.515*
Error	4.15	4	1.04	
Total	27.32	8		
				Evenness (E2)
Between seasons	0.03	2	0.01	4.585
Between tide levels	0.01	2	0.01	1.793
Error	0.01	4	0.00	
Total	0.05	8		

* - Significant at 5% level ($P<0.05$)

Table 5.29 Anova table showing the significance of the diversity indices of polychaete fauna in different seasons and tide levels at station 1

Source	Sum of Squares	D.F.	Mean Square	F ratio
				Richness (R1)
Between seasons	0.78	2	0.39	18.883*
Between tide levels	0.98	2	0.49	23.637*
Error	0.08	4	0.02	
Total	1.85	8		
				Diversity (H')
Between seasons	0.39	2	0.08	26.595*
Between tide levels	0.39	2	0.09	26.340*
Error	0.03	4	0.02	
Total	0.80	8		
				Hill's diversity number (N1)
Between seasons	12.88	2	0.91	17.950*
Between tide levels	16.63	2	1.27	23.181*
Error	1.44	4	0.13	
Total	30.95	8		
				Evenness (E2)
Between seasons	0.02	2	0.01	2.120
Between tide levels	0.01	2	0.03	0.188
Error	0.02	4	0.00	
Total	0.05	8		

* - Significant at 5% level (P<0.05)

Table 5.30 Anova table showing the significance of the diversity indices of polychaete fauna in different seasons and tide levels at station 2

Source	Sum of Squares	D.F.	Mean Square	F ratio
			Richness (R1)	
Between seasons	0.17	2	0.08	4.781
Between tide levels	0.24	2	0.12	6.874
Error	0.07	4	0.02	
Total	0.48	8		
			Diversity (H')	
Between seasons	0.16	2	0.08	4.189
Between tide levels	0.18	2	0.09	4.829
Error	0.08	4	0.02	
Total	0.42	8		
	Hill's diversity number (N1)			
Between seasons	1.82	2	0.91	6.802*
Between tide levels	2.54	2	1.27	9.482*
Error	0.54	4	0.13	
Total	4.89	8		
			Evenness (E2)	
Between seasons	0.02	2	0.01	6.660*
Between tide levels	0.05	2	0.03	14.053*
Error	0.01	4	0.00	
Total	0.08	8		

* - Significant at 5% level ($P<0.05$)

Table 5.31 Anova table showing the significance of the diversity indices of polychaete fauna in different seasons and tide levels at station 3

Source	Sum of Squares	D.F.	Mean Square	F ratio
			Richness (R1)	
Between seasons	0.34	2	0.17	2.819
Between tide levels	0.16	2	0.08	1.368
Error	0.24	4	0.06	
Total	0.74	8		
			Diversity (H')	
Between seasons	0.41	2	0.20	1.702
Between tide levels	0.32	2	0.16	1.333
Error	0.48	4	0.12	
Total	1.20	8		
	Hill's diversity number (N1)			
Between seasons	3.47	2	1.74	1.560
Between tide levels	2.99	2	1.50	1.344
Error	4.45	4	1.11	
Total	10.92	8		
			Evenness (E2)	
Between seasons	0.04	2	0.02	0.224
Between tide levels	0.09	2	0.04	0.536
Error	0.33	4	0.08	
Total	0.45	8		

fauna and environmental parameters

Station 1 - Low tide level

	Salin-ity	Sediment temp.	Water temp.	Dissolved oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polych-aeta	Crusta-cea	Mollusca
Salinity	#1.0000													
S-temp.	#0.9723	#1.0000												
W-temp.	#0.9756	#0.9569	#1.0000											
D-oxygen	-0.5420	-0.6585	-0.5752	#1.0000										
S-pH	#0.6926	*0.6165	*0.6121	-0.2529	#1.0000									
W-pH	#0.9118	#0.8675	#0.8566	-0.4291	#0.8961	#1.0000								
Sand%	-0.6590	-0.6575	-0.6390	0.5530	-0.7480	-0.8139	#1.0000							
Silt%	-0.4953	-0.5507	-0.4933	0.2230	-0.0029	-0.2518	-0.2314	#1.0000						
Clay%	#0.9043	#0.9306	#0.8837	-0.6597	#0.7386	#0.9321	-0.8651	-0.2872	#1.0000					
O-matter%	#0.9163	#0.9454	#0.8961	-0.6606	#0.7256	#0.9298	-0.8363	-0.3390	#0.9985	#1.0000				
T-fauna	#0.8565	#0.8392	#0.8559	-0.6283	0.5189	#0.7194	-0.6348	-0.2497	#0.7539	#0.7547	#1.0000			
Polychaeta	#0.8347	#0.8565	#0.8028	-0.7348	0.4742	#0.6901	-0.6335	-0.2963	#0.7768	#0.7798	#0.9567	#1.0000		
Crustacea	*0.6347	*0.5743	*0.6772	-0.2811	0.488	*0.6004	-0.5178	-0.038	0.5298	0.5225	#0.7979	*0.6098	#1.0000	
Mollusca	*0.6622	*0.5642	#0.7010	-0.0697	0.4215	0.5115	-0.2147	-0.4024	0.4189	0.4344	0.5384	0.3956	0.5238	#1.0000

"*" - 5% Significance ($P < 0.05$)
"#" - 1% Significance ($P < 0.01$)
Degrees of freedom = 11

fauna and environmental parameters

Station 1 - Mid tide level

	Salin-ity	Sediment temp.	Water temp.	Dissolved Oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polych-aeta	Crusta-cea	Mollusca
Salinity	#1.0000													
S-temp.	#0.9828	#1.0000												
W-temp.	#0.9756	#0.9731	#1.0000											
D-oxygen	-0.5420	-0.5787	-0.5752	#1.0000										
S-pH	#0.7753	#0.7137	#0.6942	-0.1411	#1.0000									
W-pH	#0.9118	#0.8905	#0.8566	-0.4291	#0.8778	#1.0000								
Sand%	0.2604	0.2663	0.2639	-0.0456	-0.0858	-0.0026	#1.0000							
Silt%	-0.8877	-0.8608	-0.8607	*0.6563	-0.7890	-0.9314	0.0447	#1.0000						
Clay%	0.2099	0.1914	0.1966	-0.2804	0.4559	0.4545	-0.8749	-0.5244	#1.0000					
O-matter%	-0.2040	-0.2120	-0.2090	0.0046	0.1332	0.0594	-0.9988	-0.1064	#0.9024	#1.0000				
T-fauna	#0.7843	#0.7793	#0.7365	-0.3477	#0.7702	#0.8471	-0.3101	-0.7757	*0.6414	0.3565	#1.0000			
Polychaeta	#0.9371	#0.9012	#0.9163	-0.5778	#0.7570	#0.8333	0.0622	-0.8616	0.3660	-0.0085	#0.8237	#1.0000		
Crustacea	*0.6391	*0.6462	*0.5891	-0.1507	#0.7224	#0.8175	-0.4002	-0.6827	*0.6729	0.4403	#0.9262	*0.6019	#1.0000	
Mollusca	0.4256	0.4452	0.3927	-0.0790	0.4967	0.5021	-0.4743	-0.4118	*0.6042	0.4972	#0.8482	0.4761	#0.8340	#1.0000

"*" - 5% Significance ($P<0.05$)
"#" - 1% Significance ($P<0.01$)
Degress of freedom = 11

	Salin-ity	Sediment temp.	Water temp.	Dissolved oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polych-aeta	Crusta-cea	Mollusca
Salinity	#1.0000													
S-temp.	#0.9819	#1.0000												
W-temp.	#0.9756	#0.9666	#1.0000											
D-oxygen	-0.5420	-0.5481	-0.5752	#1.0000										
S-pH	#0.8541	#0.7777	#0.8580	-0.3880	#1.0000									
W-pH	#0.9118	#0.8634	#0.8566	-0.4291	#0.8697	#1.0000								
Sand%	0.3482	0.3109	0.3323	-0.3694	0.5519	*0.5741	#1.0000							
Silt%	#0.9349	#0.9080	#0.9168	-0.6347	#0.7826	#0.8751	0.3072	#1.0000						
Clay%	-0.5480	-0.5096	-0.5294	0.4906	-0.6890	-0.7347	-0.9697	-0.5278	#1.0000					
O-matter%	#0.8850	#0.8491	#0.8643	-0.6556	#0.8475	#0.9310	*0.6560	#0.9197	-0.8189	#1.0000				
T-fauna	*0.6197	*0.6681	*0.6107	-0.3922	0.5228	*0.6001	*0.6278	0.4707	-0.6800	*0.6324	#1.0000			
Polychaeta	*0.6411	#0.6896	*0.6592	-0.5814	*0.5773	*0.5742	*0.6290	0.5408	-0.6988	#0.6885	#0.9301	#1.0000		
Crustacea	0.4762	0.4408	0.4981	-0.0519	*0.5924	0.4892	0.5492	0.2815	-0.5619	0.4500	#0.7495	*0.5813	#1.0000	
Mollusca	0.2973	0.3289	0.2324	0.1907	0.1998	0.4115	0.4251	0.1374	-0.4145	0.2845	#0.7522	0.5191	*0.6621	#1.0000

"*" - 5% Significance ($P < 0.05$)
"#" - 1% Significance ($P < 0.01$)
Degrees of freedom = 11

fauna and environmental parameters

Station 2 - Low tide level

	Salin- ity	Sediment temp.	Water temp.	Dissolved oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polych- aeta	Crusta- cea	Mollusca
Salinity	#1.0000													
S-temp.	#0.9690	#1.0000												
W-temp.	#0.9551	#0.9780	#1.0000											
D-oxygen	-0.3271	-0.4099	-0.2983	#1.0000										
S-pH	#0.6841	*0.6326	0.5412	-0.3037	#1.0000									
W-pH	#0.8397	#0.8191	#0.7236	-0.3726	#0.9097	#1.0000								
Sand%	#0.8949	#0.9169	#0.9055	-0.4770	0.4750	#0.6987	#1.0000							
Silt%	-0.8186	-0.8676	-0.7844	*0.6605	-0.8058	-0.8574	-0.8021	#1.0000						
Clay%	#0.8227	#0.8713	#0.7891	-0.6596	#0.8027	#0.8575	#0.8082	-1.0000	#1.0000					
O-matter%	-0.6760	-0.6678	-0.7230	0.1645	-0.0356	-0.3375	-0.8542	0.3733	-0.3829	#1.0000				
T-fauna	#0.7745	#0.8057	#0.7557	-0.1756	*0.5680	#0.7697	#0.6971	-0.6577	*0.6606	-0.5093	#1.0000			
Polychaeta	*0.6003	*0.6720	*0.6253	-0.0591	0.3296	*0.5696	*0.5788	-0.4796	0.4829	-0.4807	#0.9368	#1.0000		
Crustacea	#0.8834	#0.8782	#0.8441	-0.2191	#0.7442	#0.8977	#0.7702	-0.7857	#0.7881	-0.5111	#0.7954	*0.6399	#1.0000	
Mollusca	#0.7180	#0.7056	*0.6192	-0.3613	*0.6394	#0.7572	*0.5834	-0.6717	*0.6724	-0.3202	#0.8836	#0.7310	*0.6795	#1.0000

"*" - 5% Significance ($P<0.05$)
"#" - 1% Significance ($P<0.01$)
Degrees of freedom = 11

fauna and environmental parameters

Station 2 - Mid tide level

	Salin- ity	Sediment temp.	Water temp.	Dissolved oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polych- aeta	Crusta- cea	Mollusca
Salinity	#1.0000													
S-temp.	#0.9369	#1.0000												
W-temp.	#0.9551	#0.9806	#1.0000											
D-oxygen	-0.3271	-0.3324	-0.2983	#1.0000										
S-pH	0.3714	0.4205	0.3507	-0.4079	#1.0000									
W-pH	#0.8397	#0.7237	#0.7236	-0.3726	*0.6657	#1.0000								
Sand%	0.5247	0.5312	*0.5824	-0.0186	-0.4581	0.1560	#1.0000							
Silt%	-0.8486	-0.8374	-0.8725	0.3832	-0.0480	-0.5952	-0.833	#1.0000						
Clay%	0.4448	0.4149	0.3803	-0.5929	#0.9031	#0.6940	-0.4299	-0.1384	#1.0000					
O-matter%	*0.6365	*0.6056	*0.5826	-0.6517	#0.8515	#0.8011	-0.1803	-0.3916	#0.9655	#1.0000				
T-fauna	#0.8740	#0.8963	#0.8740	-0.2357	0.5133	#0.8445	0.3988	-0.7052	0.4368	*0.5912	#1.0000			
Polychaeta	#0.7162	#0.7936	#0.7992	-0.0014	0.2259	*0.5826	*0.5543	-0.6629	0.0879	0.2561	#0.8923	#1.0000		
Crustacea	#0.7693	#0.8937	#0.8598	-0.1932	0.1151	0.4784	#0.7297	-0.8315	0.0486	0.2639	#0.8217	#0.8423	#1.0000	
Mollusca	#0.8359	#0.8085	#0.7620	-0.4182	#0.7576	#0.9346	0.0942	-0.5511	#0.7318	#0.8248	#0.8849	*0.5976	*0.5901	#1.0000

*" - 5% Significance ($P<0.05$)
#" - 1% Significance ($P<0.01$)
Degrees of freedom = 11

fauna and environmental parameters

Station 2 - High tide level

	Salin-ity	Sediment temp.	Water temp.	Dissolved oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polych-aeta	Crusta-cea	Mollusca
Salinity	#1.0000													
S-temp.	#0.8912	#1.0000												
W-temp.	#0.9551	#0.9717	#1.0000											
D-oxygen	-0.3271	-0.2393	-0.2983	#1.0000										
S-pH	*0.6396	0.3506	0.4798	-0.3867	#1.0000									
W-pH	#0.8397	*0.6052	#0.7236	-0.3726	#0.9336	#1.0000								
Sand%	-0.2401	-0.0442	-0.1690	0.5021	-0.7048	-0.5516	#1.0000							
Silt%	-0.8547	-0.8481	-0.8773	0.3935	-0.3369	-0.6068	-0.0855	#1.0000						
Clay%	#0.8685	#0.7419	#0.8442	-0.6403	#0.7170	#0.8507	-0.5414	-0.7912	#1.0000					
O-matter%	*0.5796	0.3904	0.5220	-0.6378	#0.8066	#0.7729	-0.9111	-0.3310	#0.8390	#1.0000				
T-fauna	#0.8745	#0.8148	#0.8695	-0.4317	0.4611	*0.6828	-0.0016	-0.9520	#0.8042	0.3939	#1.0000			
Polychaeta	0.5135	0.5474	0.5498	-0.179	-0.0355	0.2166	0.5112	-0.8090	0.3687	-0.1508	#0.8115	#1.0000		
Crustacea	#0.7413	#0.7008	#0.7480	-0.3797	*0.6531	#0.7681	-0.2459	-0.7085	#0.7487	0.5249	#0.7840	0.4738	#1.0000	
Mollusca	#0.9272	#0.8020	#0.8830	-0.4400	*0.5846	#0.7573	-0.3825	-0.7707	#0.8852	*0.6800	#0.7685	0.3394	*0.5695	#1.0000

"*" - 5% Significance ($P<0.05$)
"#" - 1% significance ($P<0.01$)
Degrees of freedom = 11

fauna and environmental parameters

Station 3 - Low tide level

	Salin-tiy	Sediment temp.	Water temp.	Dissolved oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polych-aeta	Crusta-cea	Mollusca
Salinity	#1.0000													
S-temp.	#0.9432	#1.0000												
W-temp.	#0.9485	#0.9823	#1.0000											
D-oxygen	-0.7243	-0.6226	-0.6152	#1.0000										
S-pH	#0.6932	*0.6697	*0.6231	-0.3081	#1.0000									
W-pH	#0.7421	#0.7343	#0.7404	-0.2273	#0.9110	#1.0000								
Sand%	#0.7253	#0.8045	#0.7816	-0.3552	#0.8151	#0.8460	#1.0000							
Silt%	-0.8774	-0.8876	-0.9214	*0.6467	-0.4020	-0.5690	-0.6077	#1.0000						
Clay%	#0.9052	#0.9315	#0.9553	-0.6277	0.5219	*0.6695	#0.7459	-0.9835	#1.0000					
O-matter%	-0.7466	-0.7257	-0.7751	*0.6243	-0.1416	-0.3297	-0.2935	#0.9410	-0.8644	#1.0000				
T-fauna	0.2259	0.4656	0.3591	-0.1736	0.2665	0.1690	0.4629	-0.1477	0.2274	0.0147	#1.0000			
Polychaeta	0.3532	*0.5575	0.4667	-0.0654	*0.6295	*0.5621	#0.7007	-0.1809	0.3078	0.0730	#0.8369	#1.0000		
Crustacea	0.4695	0.4030	0.4631	-0.6848	-0.1622	-0.0879	-0.1015	-0.6060	0.4930	-0.7632	0.0109	-0.2747	#1.0000	
Mollusca	-0.3320	-0.0900	-0.1918	0.1340	-0.2509	-0.4123	-0.0674	0.3398	-0.3037	0.3769	#0.7681	0.4640	-0.1331	#1.0000

"*" - 5% Significance ($P<0.05$)
"#" - 1% Significance ($P<0.01$)
Degrees of freedom = 11

fauna and environmental parameters

Station 3 - Mid tide level

	Salin-ity	Sediment temp.	Water temp.	Dissolved oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polych-aeta	Crusta-cea	Mollusca
Salinity	#1.0000													
S-temp.	#0.9541	#1.0000												
W-temp.	#0.9485	#0.9760	#1.0000											
D-oxygen	-0.7243	-0.5813	-0.6152	#1.0000										
S-pH	#0.7476	#0.7821	#0.7591	-0.2436	#1.0000									
W-pH	#0.7421	#0.7698	#0.7404	-0.2273	#0.9414	#1.0000								
Sand%	#0.8816	#0.9121	#0.9382	-0.5443	#0.7714	#0.7917	#1.0000							
Silt%	-0.9062	-0.9224	-0.9600	*0.5986	-0.7031	-0.7325	-0.9840	#1.0000						
Clay%	#0.8790	#0.9107	#0.9359	-0.5403	#0.7746	#0.7945	#1.0002	-0.9818	#1.0000					
O-matter%	-0.8933	-0.9192	-0.9493	*0.5651	-0.7504	-0.7741	-0.9983	#0.9931	-0.9973	#1.0000				
T-fauna	0.3211	0.5320	0.4237	0.1677	#0.6862	*0.6345	0.4926	-0.3848	0.4985	-0.4568	#1.0000			
Polychaeta	0.5112	#0.7007	*0.6054	-0.0972	*0.6825	*0.6597	*0.6602	-0.5810	*0.6642	-0.6349	#0.9343	#1.0000		
Crustacea	0.1069	0.3320	0.3031	0.1985	0.3462	0.2281	0.2439	-0.2120	0.2455	-0.2337	#0.7162	*0.6452	#1.0000	
Mollusca	-0.1100	0.0267	-0.0987	*0.5720	0.4631	0.4722	0.0254	0.1078	0.0334	0.0209	#0.7510	0.5080	0.3845	#1.0000

"*" - 5% Significance ($P<0.05$)
"#" - 1% Significance ($P<0.01$)
Degrees of freedom = 11

fauna and environmental parameters

Station 3 - High tide level

	Salinity	Sediment temp.	Water temp.	Dissolved oxygen	Sediment pH	Water pH	Sand%	Silt%	Clay%	Organic matter%	Total fauna	Polychaeta	Crustacea	Mollusca
Salinity	#1.0000													
S-Temp.	#0.9158	#1.0000												
W-temp.	#0.9485	#0.9447	#1.0000											
D-oxygen	-0.7243	-0.5295	-0.6152	#1.0000										
S-pH	#0.7693	#0.7966	#0.7200	-0.3612	#1.0000									
W-pH	#0.7421	#0.7898	#0.7404	-0.2273	#0.9567	#1.0000								
Sand%	#0.8897	#0.8713	#0.9359	-0.6427	*0.6126	*0.6044	#1.0000							
Silt%	-0.9055	-0.9238	-0.9595	*0.5954	-0.7189	-0.7374	-0.9622	#1.0000						
Clay%	#0.8071	#0.8761	#0.8651	-0.4480	#0.7756	#0.8300	#0.7796	-0.9207	#1.0000					
O-matter%	-0.6052	-0.5106	-0.6212	*0.5661	-0.2067	-0.1419	-0.8016	*0.6088	-0.2509	#1.0000				
T-fauna	*0.6719	#0.7473	#0.7261	-0.5581	0.4688	0.4327	*0.6106	-0.6184	0.5471	-0.4218	#1.0000			
Polychaeta	#0.7493	#0.8313	#0.7524	-0.5439	*0.5675	0.5516	*0.5817	-0.6520	*0.6656	-0.2641	#0.9052	#1.0000		
Crustacea	0.2849	0.3077	0.2162	-0.1607	0.5467	0.5124	0.0106	-0.1256	0.2738	0.2450	0.4946	0.4634	#1.0000	
Mollusca	-0.1725	-0.1415	-0.0487	-0.1799	-0.4869	-0.5400	0.0834	0.0800	-0.3037	-0.4190	0.3248	-0.0212	-0.2034	#1.0000

"*" - 5% Significance ($P<0.05$)
"#" - 1% Significance ($P<0.01$)
Degrees of freedom = 11

Table 5 41 Multiple regression analysis of biomass and the hydrographical parameters at station 1

Low tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	.0122	.0110	1.107	.3186	.1969
Sediment Temp.	-.0686	.0940	-.730	.4979	.0964
Water Temp.	.0407	.0553	.737	.4945	.0979
Dissolved Oxygen	-.1409	.0733	-1.922	.1126	.4249
Sediment *p*H	-.3953	.6659	-.594	.5786	.0658
Water *p*H	.2197	.6434	.341	.7466	.0228
Constant	2.8838				

Std. error of est. = .1089
Adjusted R squared = .6154
R squared = .8252
Multiple R = .9084

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	.2802	6	.0467	3.934	.0772
Residual	.0593	5	.0119		
Total	.3395	11			

Table 5.42 Multiple regression analysis of biomass and the hydrographical parameters at station 1

Mid tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	-.1013	.0260	-3.897	.0114	.7523
Sediment Temp.	.1587	.2729	.581	.5862	.0633
Water Temp.	.3674	.2124	1.730	.1442	.3744
Dissolved Oxygen	.1420	.1955	.726	.5002	.0954
Sediment *p*H	-1.2430	1.5950	-.779	.4711	.1083
Water *p*H	1.5084	1.2148	1.242	.2694	.2357
Constant	-15.6569				

Std. error of est. = .3386
Adjusted R squared = .5874
R squared = .8125
Multiple R = .9014

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	2.4836	6	.4139	3.610	.0902
Residual	.5733	5	.1147		
Total	3.0570	11			

Table 5.43 Multiple regression analysis of biomass and the hydrographical parameters at station 1

High tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	-.0634	.0106	-5.990	.0018	.8777
Sediment Temp.	.5461	.1063	5.139	.0036	.8408
Water Temp.	-.0858	.1146	-.749	.4876	.1009
Dissolved Oxygen	.1986	.0689	2.883	.0344	.6244
Sediment *p*H	4.5391	1.5532	2.922	.0329	.6307
Water *p*H	-1.0873	.4079	-2.666	.0445	.5870
Constant	-39.3606				

Std. error of est. = .1321
Adjusted R squared = .8928
R squared = .9513
Multiple R = .9753

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	1.7051	6	.2842	16.273*	3.843E-03
Residual	.0873	5	.0175		
Total	1.7924	11			

* - Significant at 5% level ($P<0.05$)

Table 5.44 Multiple regression analysis of biomass and the hydrographical parameters at station 2

Low tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	-.0017	.0287	-.060	.9544	7.1937E-04
Sediment Temp.	-.2623	.3823	-.686	.5231	.0861
Water Temp.	.1752	.2806	.625	.5596	.0724
Dissolved Oxygen	-.0318	.1999	-.159	.8796	.0051
Sediment *p*H	-.1910	1.3123	-.146	.8899	.0042
Water *p*H	1.6041	1.9219	.835	.4419	.1223
Constant	-7.7114				

Std. error of est. = .2976
Adjusted R squared =-.0916
R squared = .5038
Multiple R = .7098

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	.4496	6	.0749	.846	.5844
Residual	.4428	5	.0886		
Total	.8923	11			

Table 5.45 Multiple regression analysis of biomass and the hydrographical parameters at station 2

Mid tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	.0138	.0802	.172	.8700	.0059
Sediment Temp.	.0750	.1552	.483	.6492	.0446
Water Temp.	-.0328	.1684	-.195	.8533	.0075
Dissolved Oxygen	.0474	.1399	.339	.7487	.0224
Sediment *p*H	1.3053	1.7682	.738	.4935	.0983
Water *p*H	-.6694	1.8289	-.366	.7293	.0261
Constant	-6.0572				

Std. error of est. = .1732
Adjusted R squared = .5246
R squared = .7839
Multiple R = .8854

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	.5440	6	.0907	3.023	.1226
Residual	.1500	5	.0300		
Total	.6940	11			

Table 5.46 Multiple regression analysis of biomass and the hydrographical parameters at station 2

High tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	.0168	.0041	4.132	.0090	.7735
Sediment Temp.	.0046	.0466	.099	.9247	.0020
Water Temp.	-.0723	.0355	-2.037	.0972	.4535
Dissolved Oxygen	-.0169	.0240	-.706	.5119	.0906
Sediment *p*H	-1.2115	.3460	-3.501	.0172	.7103
Water *p*H	1.6161	.3518	4.593	.0058	.8084
Constant	-.6966				

Std. error of est. = .0464
Adjusted R squared = .9266
R squared = .9666
Multiple R = .9832

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	.3117	6	.0520	24.140*	1.526E-03
Residual	.0108	5	.0022		
Total	.3225	11			

* - Significant at 5% level ($P<0.05$)

Table 5.47 Multiple regression analysis of biomass and the hydrographical parameters at station 3

Low tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	-.0151	.0236	-.642	.5494	.0761
Sediment Temp.	.2015	.2108	.956	.3830	.1545
Water Temp.	-.1984	.2558	-.776	.4730	.1074
Dissolved Oxygen	-.1413	.1875	-.754	.4849	.1021
Sediment *p*H	-.3985	2.2011	-.181	.8634	.0065
Water *p*H	.3300	1.3272	.249	.8135	.0122
Constant	1.6133				

Std. error of est. = .2305
Adjusted R squared =-.2054
R squared = .4521
Multiple R = .6724

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	.2191	6	.0365	.688	.6720
Residual	.2655	5	.0531		
Total	.4847	11			

Table 5.48 Multiple regression analysis of biomass and the hydrographical parameters at station 3

Mid tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	-9.5864E-04	.0037	-.261	.8042	.0135
Sediment Temp.	.0296	.0255	1.161	.2981	.2123
Water Temp.	.0165	.0256	.643	.5486	.0763
Dissolved Oxygen	.1056	.0232	4.562	.0060	.0863
Sediment *p*H	-.2398	.0901	-.827	.4460	.1203
Water *p*H	-.0165	.1467	-.113	.9146	.0025
Constant	.3235				

Std. error of est. = .0395
Adjusted R squared = .6925
R squared = .8602
Multiple R = .9275

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	.0480	6	.0080	5.128*	.0467
Residual	.0078	5	.0016		
Total	.0558	11			

* - Significant at 5% level ($P<0.05$)

Table 5.49 Multiple regression analysis of biomass and the hydrographical parameters at station 3

High tide level

Variable	Regression Coefficient	Std. Error	T(df=5)	Prob.	Partial r^2
Salinity	-.0080	.0109	-.738	.4936	.0982
Sediment Temp.	.0335	.0641	.522	.6239	.0517
Water Temp.	.0033	.0717	.046	.9651	4.2247E-04
Dissolved Oxygen	-.0076	.0868	-.088	.9336	.0015
Sediment *p*H	1.3067	1.0699	1.221	.2764	.2298
Water *p*H	-.5974	.6814	-.877	.4207	.1333
Constant	-6.3867				

Std. error of est. = .1136
Adjusted R squared = .3403
R squared = .7001
Multiple R = .8367

ANALYSIS OF VARIANCE TABLE

Source	Sum of Squares	D.F.	Mean Square	F ratio	Prob.
Regression	.1507	6	.0251	1.946	.2410
Residual	.0646	5	.0129		
Total	.2153	11			

Table 5.50 Matrix of correlation showing the coexistence of polychaete species

(a) Station 1 (b) Station 2 (c) Station 3

(a)

	B .singularis	E. tubifex	Eunice sp.	M. gravelyi	N. glandicncta	P. tenuis	T. annandalei
Branchiocapitella singularis	**1.0000						
Eunice tubifex	-0.0950	**1.0000					
Eunice sp.	-0.0288	**0.9059	**1.0000				
Marphysa gravelyi	0.0027	0.4728	*0.6674	**1.0000			
Nereis glandicincta	0.5432	*0.5769	*0.6661	0.1651	**1.0000		
Paraheteromastus tenuis	0.3527	**0.6883	**0.8205	**0.7040	*0.6683	**1.0000	
Talehsapia annandalei	-0.6269	-0.0308	-0.2212	-0.4657	-0.3973	-0.3118	**1.0000

(b)

	B. singularis	D. heteropoda	M. gravelyi	N. glandicincta	P. tenuis
Branchiocapitella singularis	**1.0000				
Dendronereides heteropoda	**0.6917	**1.0000			
Marphysa gravelyi	0.4315	*0.6459	**1.0000		
Nereis glandicincta	0.2058	0.3383	0.4411	**1.0000	
Paraheteromastus tenuis	**0.8239	0.4671	0.3495	0.3032	**1.0000

(c)

	D. estuarina	M. gravelyi	N. glandicincta	P. tenuis	T. annandalei
Dendronereis aestuarina	**1.0000				
Marphysa gravelyi	*0.6261	**1.0000			
Nereis glandicincta	**0.7999	*0.6079	**1.0000		
Paraheteromastus tenuis	0.4240	-0.1206	0.3223	**1.0000	
Talehsapia annandalei	0.3672	-0.0907	0.4250	**0.9085	**1.0000

* - 5% significance ($P<0.05$)
** - 1% significance ($P<0.01$)
Degrees of freedom = 11

5.16 DISCUSSION

Mangrove swamps are unique ecosystem in the coastal and insular areas of tropics and subtropics. The canopy of mangals provides a cool, stable and humid environment, quite favourable to many associated epifaunal and infaunal animals. The excellent supply of organic detrital matter derived from mangrove vegetation along with the fine loose soil as well as the abundant fungal and bacterial population, make the mangrove soil an ideal feeding ground for the associated animals.

5.16.1 DISTRIBUTION OF ORGANISMS

The present study is mainly concerned with the benthic organisms of Cochin mangroves. They naturally include a curious mixture of marine, estuarine, freshwater and terrestrial animals. The major benthic groups observed during the present investigation were polychaeta, crustacea and mollusca. Of these, polychaeta was the most dominant group in terms of population density as well as species diversity, and is followed by crustaceans and molluscs The occurrence of these three phyla in different mangrove ecosystems was reported by several workers: like Macnae and Kalk (1962) in Mozambique, Macnae (1963) in South Africa, Macnae (1967) in Australia, Macnae (1968) in Indo-West Pacific region, Berry (1963) and Sasekumar (1974) in Malaysia, Walsh (1967) in Hawaii, Odum and Heald (1972) and Evink (1975) in Florida, Rueda and Gosselck (1986) in southern Cuba, Frith *et al.*, (1976), Nateewathana and Tantichodok (1980) and Shokita *et al.*, (1983) in Thailand, Wells (1983) in northwestern Australia, Espinosa *et al.*, (1982) in Mexico, Victoria and Perez (1979) in Colombia, Zhou *et al.*, (1986) in Fujian, Shokita *et al.*, (1989) and Omori (1989) at Iriomote Island, Okinawa, Radhakrisha and Janakiram (1975), Untawale and Parulekar (1976), Bhunia and Choudhury (1981), Dwivedi and Padmakumar (1980), Nandi and Choudhury (1983), Padmakumar (1984), Choudhury *et al.*, (1984a, 1984b), Kasinathan and Shanmugam (1985), Misra and Choudhury (1985), Patra *et al.*, (1988, 1990) and Chakraborty and Choudhury (1992) in India.

Among the polychaetes, nereids, eunicids and capetellids were dominated (Table 5.2) in the present study. Misra and Choudhury (1985) reported the dominance of errant polychaetes than the sedentaria group in Sunderbans mangroves and a similar situations is observed around Cochin. According to them the species *Dendronereis aestuarina*, *Dendronereides heteropoda*, *Nereis indica*, *Lumbriconereis heteropoda*, *L. Polydesma*, *Marphysa mossambica* and capitellid group were most commonly encountered. *Paraheteromastus tenuis* and *Scoloplos armiger* were the most abundant polychaete species in Phuket mangroves (Frith *et al.*, 1976). However, in Cochin mangroves the common polychaetes observed were *Paraheteromastus tenuis*, *Marphysa gravelyi*, *Nereis glandicincta*, *Dendronereis heteropoda*, *Dendronereis aestuarina* and capitellid group (unidentified). Among these *P. tenuis* is an element found in Phuket but missing in Sunderbans.

The species diversity of the Nereidae and Eunicidae groups was higher than in other groups in the study area. Misra and Choudhury (1985) also reported similar findings in Sundarbans mangroves. They noted the occurrence of nereid worms, *Dendronereides heteropoda*, *Dendronereis aestuarina*, *D. arborifera*, *Namalycastis indica*, *Lycastonereis indica*, *Neanthes chingrighattensis*, *N. cricognatha* and *Perinereis nigropunctata*. The Eunicidae group consists of *Marphysa mossambica*, *M. macintoshi*, *Diopatra cuprea*, *Lumbriconereis heteropoda*, *L. notocirrata* and *L. polydesma* in the mangroves of Sunderbans. In the present study the nereid species *Dendronereides heteropoda*, *Dendronereis aestuarina*, *D. arborifera*, *Perinereis cavifrons*, *Perinereis* sp., *Nereis kauderni*, *Nereis chilkaensis*, *Nereis glandicincta*, *Ceratonereis costae* and *Nereis* sp. were found in the mangrove biotope. The Eunicidae group included the species *Diopatra neapolitana*, *Eunice tubifex*, *Eunice* sp., *Marphysa gravelyi, M. stragulum, Lumbriconereis latreilli, L. pseudobifilaris, L. simplex* and *Lumbriconereis* sp.. Frith *et al.* (1976) also reported high species diversity of Nereidae and Eunicidae group in the Phuket mangrove shore. They noted the presence of nereid worms, *Ceratonereis erythraeenis, Dendronereis arborifera, Nereis chingrighattensis, Perinereis aibuhitensis, P. nuntia, P. vancaurica* and *Nereis falsa* within the mangroves. The Eunicidae group consists of *Arabella iricolor, Diopatra monroi, D. neapolitana, Drilonereis filum, L. impatiens, Marphysa mossambica* and *Onuphis* sp.. Low diversity of Nereidae and Eunicidae species was noted in Malayan mangrove swamp by Sasekumar (1974). He observed the presence of *Lepidonotus kumari, Nereis capensis, Dendronereis* sp., *Lumbriconereis malaysiae, Diopatra neapolitana, Glycera tesselata, Praheteromastus tenuis, Leiochrides australis* and *Clymene annandalei* in the Malayan mangroves. Omori (1989) reported *Capitella* sp., *Prionospio* sp., *Ceratonereis* sp. and *Heteromastus* sp. from the mangrove swamps of Iriomote Island, Okinawa. According to Nandi and Choudhury (1983) the polychaete fauna of Sagar Island in Sunderbans consist of *Lumbriconereis polydesma, L. notocirrata, Lumbriconereis* sp., *Diopatra neapolitana* and *Talehsapia annandalei.* Padmakumar (1984) reported the occurrence of *Ancistrosyllis constricta, Lumbriconereis simplex, L. plydesma, Dendronereis arborifera, Ammotrypane aulogaster, Lycastis indica, Glycera convoluta, Scolelepsis squamata, Goniadopsis incerta , Nereis* sp. and *Polydora* sp. in the mangrove swamps of Bombay.

The species recorded from both Cochin and Sunderbans mangrove areas include *Dendronereis aestuarina, D. arborifera, Dendronereides heteropoda, Talehsapia annandalei, Glycera alba, Glycera* sp., *Diopatra neapolitana, Prionospio cirrifera, Phyllodoce* sp., *Perinereis* sp., *Marphysa* sp., *Lumbriconereis* sp. and *Polydora* sp.. *Dendronereis arborifera, Lumbriconereis* sp., *Nereis* sp., and *Polydora* sp. are the elements, found both in the mangrove swamps of Cochin and Bombay. The occurrence of the species *Diopatra neapolitana*, *Dendronereis arborifera*, *Ceratonereis* sp., *Nereis* sp., *Perinereis* sp., *Lumbriconereis* sp., *Marphysa* sp. and *Paraheteromastus tenuis* in the Phuket mangrove shore (Frith *et al.*, 1976) are also recorded from the Cochin mangroves. The species such as *Diopatra neapolitana*, *Nereis* sp., *Dendronereis* sp., *Lumbriconereis* sp., *Glycera* sp., and *Paraheteromastus tenuis* recorded in the Malayan mangrove shores (Sasekumar, 1974) are also found in the present study area.

From the above it is to be noted that, *Marphysa* spp., *Paraheteromastus tenuis* and *Dendronereis* spp. are typical mangrove members, though *P. tenuis* is not recorded from Sunderbans and *Marphysa* spp. from Malaya. Members of the genera *Dendronereis* and *Marphysa* found in highly deoxygenated soils of South African mangrove (Macnae, 1968) are also recorded from the present study area.

It has been reported that Cochin mangroves (Rajagopalan *et al.*, 1986a) are formative. However, an earlier account has been given by Troup (1921) about Kerala mangroves (who included Buordillon's (1908) reference). Gamble's (1915-36) work also recorded mangroves along Kerala coastline. Further information is available in literature (Thomas, 1962; Rao and Sastri, 1974; Blasco, 1975; Kurian, 1984 and Ramachandran and Mohanan, 1987) about the occurrence of mangroves along Kerala coast. Blasco (*loc. cit*) opined that Kerala had 70, 000 ha of mangroves, which have become reduced to a large extent and mainly confined to some estuaries and creeks (Ramachandran and Mohanan, *loc.cit*). So, it can evidently be said that they are not formative but remnants of an earlier well established mangrove ecosystem similar to Sunderbans and Andaman-Nicobar Islands in India. It has already been stated in this work that, evidently the demographic pressure and agricultural practices have destroyed mangroves along Kerala coast to a large extent.

The similarity in the distribution of above mentioned polychaetes in Cochin as well as other mangrove areas suggest that these elements are largely similar, though incomplete records also exists throughout Indian sub continent.

It is interesting to note that the polychaetes such as *Marphysa gravelyi, Nereis glandicincta, Eunice tubifex, Eunice* spp., *Branchiocapitella singularis* and *Pista indica* are not hitherto reported from east Indian and Sunderbans, though widely occur at Cochin. But, another species of *Marphysa* (*Marphysa mossambica*) has been recorded from Sunderbans (Misra and Choudhury, 1985), Phuket (Frith *et al.*, 1976) and South African mangrove shores (Macnae, 1968).

According to Misra and Choudhury (1985) the firm substrate provided by roots and the dense canopy of the mangrove forest, providing protection against desiccation, may offer a suitable habitat for polychaetes. According to Frint *et al.* (1976) the moisture, cooler and muddier conditions are apparently more favourable to the polychaete worms and majority of them are omnivorous. The associated common species in Cochin mangroves are *euryhaline* to suit the changing salintiy conditions and may enable them to survive year around.

Among the brachyuran crabs, fiddler crabs are common in the present study area at station 1. Several factors influence the distribution and abundance of fiddler crabs (Teal, 1958). From the present study it is seen that the sediment with high percentage of sand at station 1, may be favourable for fiddler crabs, as is pointed out by Macnae (1968) and Chakraborty and Choudhury (1985) in the mangrove areas of Indo-West Pacific region and Sunderbans respectively. Substrate characteristic is the most important factor influencing the distribution and abundance of brachyuran crabs in Sunderbans (Chakraborty and Choudhury, 1992). *Metapograpssus messor* and *Sesarma* sp. were found rarely. *Gammarus* sp., *Sphaeroma* sp., *Apseudes chilkensis* and *Corophium triaenonyx* were common, utilising the detritus food. The former is a plant grazer (McLusky, 1971). Mangrove ecosystem provides an important habitat for the life history stages of many shell and fin fishes (Untawale and Parulekar, 1976 and Silas, 1987). Juveniles of *Palaemon* sp. are commonly observed throughout Cochin mangroves. The detritus of the area provide nutritious food for these organisms (Kurian, 1984 and Rajagopalan *et al.*, 1986b)).

During the present study, most of the molluscan species were found infaunal in nature. The species such as *Hydrobia* sp., *Bittium* sp., *Cuspidaria* sp., *Musculista* sp., *Villorita cyprinodes, Tellina* sp., and *Tapes* sp. were found buried in the soil. *Hydrobia* sp. was found to be common at all the stations. Hydrobiids typically feed on micro-organisms and detritus (Newell, 1962, 1965). The epifaunal mollusc *Nerita* sp. was poorly represented in the study area. *Crassostrea* sp. was found on the hard substratum and *Littorina* sp. were found attached to the mangorve trees. *Terebralia* sp. was found rarely at station 1. Rajagopal *et al.* (1986a) reported the occurrence of wood boring bivalves, *Littorina* sp., *Nerita* sp., *Terebralia* sp., *Cerethedium* sp. and *Crassostrea* sp. from the mangrove ecosystem of Cochin backwaters. The occurrence of epifaunal molluscan species from the mangrove swamps was also reported by Macnae (1963, 1968), Berry (1963), Radhakrishna and Janakiram (1975), Sasekumar (1974), Frith *et al.* (1976), Pillai and Appukuttan (1980), Kasinathan and Shanmugam (1985) and Shokita *et al.* (1989).

The significant factors that may influence the distribution of benthic fauna are temperature, salinity, dissolved oxygen, *p*H and the nature of the substratum. According to Kinne (1966) the physico-chemical properties of estuarine waters vary considerably, depending upon the volume of freshwater entry into the estuary, structural components of its bed, tides and macro climate of the geographic area.

5.16.2 BENTHIC FAUNA IN RELATION TO HYDROLOGY

The hydrological conditions of the mangroves in this area is subjected to drastic changes with the onset of the southwest monsoon. The entire mangrove area get flooded. Temperature, salinity and *p*H decrease and dissolved oxygen increases during this season. Of the various hydrological parameters studied, salinity was found to be an 'ecological master factor' (Kinne, 1971) governing, to a large extent, the distribution of a variety of organisms. Salinity showed significant positive correlation with the benthic fauna (Tables 5.32-5.40). During monsoon season, only those species which can withstand the low saline condition can survive in the area. It has been observed that salinity of the mangrove area was below 1‰ during the months of June and July in all the stations. A steady increase in salinity was found during the postmonsoon period and the maximum salinity was observed during the premonsoon period. A close observation on the benthic fauna during different seasons revealed that salinity has profound influence on the distribution of the fauna. Therefore, an attempt has been made to classify the benthic fauna on the basis of salinity distribution.

Grouping of organisms based on salinity in which they can survive has been carried out by some workers (Panikkar and Aiyar, 1937; Kinne, 1971 and Antony and Kuttyamma, 1983). The diverse type of environments in Cochin mangroves exhibit an interesting pattern of distribution of benthic fauna, especially polychaetes, depending on their salinity preference. Based on salinity preference the polychaete fauna in the Cochin mangrove area can be classified into three groups.

1. *Species able to tolerate small variations in salinity*

This group confined themselves to high saline areas of the mangroves where the salinity was found to be above 24‰. The tolerance limit of these species seems to be very narrow and their occurrence is restricted to the station near bar mouth during the premonsoon period. The species included in this group are *Glycera alba, G. longipinnis, Diopatra neapolitana, Goniada* sp., *Nereis kauderni, Polydora* sp., *Phyllodoce* sp. and *Lumbriconereis simplex*. Since the occurrence of these species is restricted to the high saline areas, it is obvious that they are stenohaline forms which have little tolerance capacity in the estuarine mangrove environment.

2. *Moderately tolerant forms*

Species included in this group withstood a salinity as low as 20‰. The following species are included in this category - *Ceratonereis costae, Lumbriconereis pseudobifilaris, Nereis chilkaensis, Prionospio cirrifera, Pista indica, Dendronereis aestuarina, D. arborifera* and *Dendronereides heteropoda*.

3. *Highly tolerant euryhaline forms*

This group include the species which inhabit in salinities ranging from 0.2 to 29.76‰. The species included in this group are *Marphysa gravelyi, Branchiocapitella singularis, Lumbriconereis latrelli, Paraheteromastus tenuis, Nereis glandicincta, Pulliella armata, Eunice tubifex, Eunice* sp., *Perinereis* sp. and *Talehsapia annandalei*. Of this *M. gravelyi, P. tenuis* and *N. glandicincta* are the most common species that were seen throughout the year.

The polychaete species *Amphicteis gunneri, Perinereis cavifrons, Prionospio pinnata* and *Mercierella enigmatica* are found very rarely.

Most of the literature available on the benthos of mangrove swamps deals mainly with the composition and distribution of the fauna. The information on the seasonal variation of benthic fauna in relation to the hydrological parameters is scarce. This aspect with reference to Cochin estuarine system is briefly discussed below.

With the advent of south west monsoon and freshwater influx during June-July, except the truly euryhaline fauna, the entire organisms in the area perish, due to the sudden fall in salinity. The true estuarine species may be surviving by their physiological adaptations or by some protective secretion around their body (Kinne, 1964). A fairly rich fauna was present during premonsoon and postmonsoon periods, which decreased during the peak monsoon period. Desai and Krishnankutty (1967), Ansari (1974), Kurian (1967, 1972), Pillai (1977), Batcha (1984) and Devi and Venugopal (1989) reported a decline of benthic fauna in Cochin backwaters during southwest monsoon. Untawale and Parulekar (1976) also reported a decline of benthic fauna during the monsoon period due to the decrease in salinity in the estuarine mangroves of Goa. A similar trend was observed in Sunderbans also with higher population density in premonsoon and postmonsoon periods (Bhunia and Choudhury, 1981 and Nandi and Choudhury, 1983).

The temperature was more or less uniform, at all the three stations. The maximum temperature (air 34.2°C, water 34.7°C and sediment 33.5°C) was recorded in the premonsoon period and minimum (air 26.5°C, water 26.5°C and sediment 26°C) in the monsoon period. The results showed that the temperature is generally higher in March-April month. Kurian *et al.* (1975) and Pillai (1978) suggested that temperature is not an important factor that affect the distribution of fauna in Cochin waters. From the statistical analysis it is seen that temperature also showed significant and positive correlation with the benthic fauna (Tables 5.32-5.40) in the premonsoon and postmonsoon. Kinne (1977) opined, both salinity and temperature are responsible for decreased population in the monsoon period and the latter is very important in regulating the reproductive activity of organisms.

Dissolved oxygen content in water ranged from 2.23 to 5.26 ml/litre. Oxygen values are higher in monsoon months than the premonsoon and postmonsoon seasons. In shallow estuarine system where the flow of water is continuous, dissolved oxygen may not be a limiting factor for benthic fauna (Parulekar and Dwivedi, 1975; Parulekar *et al.*, 1975 and Ansari, 1974). In the present study also dissolved oxygen is not seem to be a limiting factor as regards the occurrence of benthic fauna and the statistical analysis showed a negative correlation (Tables 5.32-5.40).

From the ecological stand point, *p*H is an important factor that influences the distribution of benthic fauna. Both the sediment and water *p*H showed seasonal variation with the highest value during the end of postmonsoon period. The sediment *p*H ranged between 7.25 to 8.25 and the water *p*H between 7.1 to 8.1 during the period of observation. The results showed that *p*H was generally lower in monsoon period. Though results of the statistical analysis showed correlation between *p*H and benthic fauna (Tables 5.32-5.40), the effect of *p*H is largely controlled by salinity conditions.

Of the various hydrological parameters studied, as already pointed out salinity plays a major role in controlling the distribution and abundance of benthic fauna in the mangrove swamps of Cochin area, so also temperature. The other factors - dissolved oxygen and *p*H do not seem to act as major limiting factors.

5.16.3 SEASONAL VARIATION OF BENTHIC FAUNA

Regarding the seasonal occurrence of benthic fauna the maximum number is found in the postmonsoon and premonsoon seasons and the minimum in the monsoon season (June-July) (Figs. 5.7-5.9). The pattern of population density was as follows: station 1 showed seasonal range of $4840/m^2$-premonsoon (PR), $2620/m^2$-monsoon (MO) and $4980/m^2$-postmonsoom (PO) in the low tide level; $5410/m^2$-PR, $3530/m^2$-MO and $8970/m^2$-PO in the mid tide level and $3790/m^2$-PR, $3030/m^2$-MO and $6430/m^2$-PO in the high tide level. It was $6920/m^2$-PR, $2860/m^2$-MO and $4980/m^2$-PO in the low tide level; $7640/m^2$-PR, $3670/m^2$-MO and $6390/m^2$-PO in the mid tide level and $3250/m^2$-PR, $1110/m^2$-MO and $1830/m^2$-PO in the high tide level at station 2. At station 3, the seasonal range was $4130/m^2$-PR, $3860/m^2$-MO and $6050/m^2$-PO and $2370/m^2$-PR, $2010/m^2$-MO and $4730/m^2$-PO in the low and mid tide levels respectively. It was $2750/m^2$-PR, $1480/m^2$-MO and $2220/m^2$-PO in the high tide level. In June, with the onset of south west monsoon, a sudden change in the ecological condition occurs and as a result, population density showed a decreasing trend. From September onwards the salinity conditions along with temperature become more favourable and the faunal density gradually increases (Fig. 5.30). As already stated in this work (Kinne, 1977) that salinity and temperature affect the distribution of organisms during monsoon. Postmonsoon season shows fresh recruitment, increasing biomass.

5.16.4 BENTHIC FAUNA IN RELATION TO SEDIMENT

The nature of the substratum observed during the course of the present investigation showed that the composition of the sediment varied markedly among the three stations and also in the three tidal levels. Based on the data obtained in the present investigation, the mangrove region under study can be differentiated into two major sedimentological division. (1) area with dominance of fine sand fraction (station 1 and low tide level of station 3) (11) area with clayey sand and silty sand (station 2 and high tide level of station 3).

Analysis of the data on the distribution of the benthic fauna of the Cochin mangrove reveals that the faunal assemblage exhibits a relationship between fauna and type of sediment. Diversity and abundance of species were the maximum in the substratum having more sand particles. Station 1 showed a total of 49 species as against 25 and 24 species at stations 2 and 3 respectively. This shows that species diversity was notably higher at station 1, where the substratum is sandy. Species diversity and richness at stations 2 and 3 were low. This may be due to the presence of the clayey sand and silty sand substratum at these stations.

When the total number of organisms are taken into account, station 1 and 2 recorded the maximum population ($43600/m^2$ and $38640/m^2$ respectively) and station 3 recorded the minimum number ($29600/m^2$). The highest population was found in the mid tide level at station 1 ($17910/m^2$) where the substratum was sandy type. At station 2 the highest population density ($17700/m^2$) was recorded in the mid tide level, where the substratum was clayey sand during premonsoon and postmonsoon seasons and silty sand during monsoon season. At station 3 the highest population density was found in the low tide level ($14760/m^2$) where the substratum was sandy. In the high tide level of this station, with clayey sand and silty sand substratum, supported a lower population density ($6450/m^2$). This shows that high population density was associated with sandy type sediment. It is seen that in all the stations the percentage of sand content was dominated. The highest population density of polychaete was found where the substratum is with comparatively less clay and silt. The highest crustacean population was also found in the substratum where the sand fraction is comparatively more. So, in the present investigation area, the nature of the substratum is found to be an influencing factor in the occurrence and abundance of benthic organism.

The relationship of the benthic fauna with the type of the substratum has been established some earlier workers (Thorson, 1957b; Johnson, 1971; Bloom *et al.*, 1972; Parulekar and Dwivedi, 1974; Parulekar *et al.*, 1980; Chandran *et al.* 1982; Ansari *et al.*, 1986; Harkantra and Parulekar, 1987; Prabhu and Reddy, 1987; Varshney *et al.*, 1988; Bhat and Neelkantan, 1988; Raman and Adiseshasai, 1989; Devi and Venugopal, 1989; Vijayakumar *et al.*, 1991; Murugan and Ayyakkannu, 1991; Jagadeesan and Ayyakkannu, 1992 and Prabhu *et al.*, 1993). Sanders (1958) and Mc Nulty *et al.* (1962) found a close relationship between the feeding habits of the infauna, gross organic matter content and the texture of the sediment. Odum and Heald (1975) suggested that the mangrove ecosystem is self sufficient in production and utilization of food material, as it is mainly a detritus based system. The presence or absence of a particular benthic organism to a particular type of substratum shows its specific substratum preference (Thorson, 1957b and Christei, 1975). According to them the quality of the substrate has a direct influence on some species, but no apparent effect on others.

Regarding the substrate preference, some species displayed substrate specificity. The polychaete *Dendronereides heteropoda* and *Dendronereis aestuarina* and the bivalve *Villorita cyprinoides* showed substrate preference. *D. heteropoda* was found in the clayey sand and silty sand at station 2 whereas the *D. aestuarina* was found only in the sandy sediment at station 3. *V. cyprinoides* was also found in the sandy substratum at station 3. For many species (please refer to the classified list of polychaetes on the basis of salinity: page no. 84), salinity influences them more than the nature of substratum.

As far as the station wise standing stock value is concerned, station 1 with sandy substratum (organic matter range: 0.6-1.53%) showed the highest biomass value (209.416 g/m^2), followed by clayey sand and silty sand substratum (organic matter range: 2.57-4.79%) at station 2 (127.308 g/m^2). The lowest biomass value was recorded at station 3. At this station, comparatively high biomass value (43.457 g/m^2), was found in the sandy substratum (organic matter range: 0.84-1.4%) of the low tide level and it was decreased in the clayey sand and silty sand substratum (organic matter range: 2.64-5.17%) of the high tide level (22.453 g/m^2). The higher biomass values associated with sandy substratum, followed by silty substratum was reported in the estuarine complex of Goa by Parulekar and Dwivedi (1975). Though it has been stated by various workers that soil with high concentration of clay holds more organic matter and relatively high benthic biomass, the present study indicates that biomass content is relatively higher in places where the substratum is with higher content of sand with lower concentration of organic matter. This shows that the texture of the soil seems to have more direct relation with the benthic fauna than the organic matter content in the sediment. It is already been stated in this work that, when a correlation is sought between organic matter content and sediment particles, comparatively less organic matter is found in the substratum having higher concentration of sand (please refer chapter 4.2.2.2). The mangroves play an important role in the formation of detritus (Untawale and Parulekar, 1976 and Untawale *et al.*, 1977). Rajagopalan *et al.* (1986b) estimated that the average quantity of detritus resulting from mangrove litter fall was 1500 kg/ha/annum in Cochin. In the present study it is observed that comparatively high percentage of sand content mixed with abundant detritus-mangrove origin-provide a special habitat for the flourishment of benthic productivity.

5.16.5 VERTICAL DISTRIBUTION OF FAUNA IN THE SUBSTRATUM

A comparative study of the fauna in three depth strata reveals that the upper strata supports the maximum population and there is a gradual decrease in the fauna with the increase in depth. Of the total population 65.58%, 20.75% and 13.68% (average value) of the fauna were collected from upper 5 cm strata, middle (5-10 cm depth) and lower (10-15 cm depth) strata respectively. Though polychaetes, crustaceans and molluscs were observed at all the depths, they considerably decreased towards the deeper strata (Fig. 5.23-5.25). It is noted that at station 1 the most dominant species, *Paraheteromastus tenuis*, was abundant in the 0-5 cm strata and its population density significantly decresed towards the deeper strata. On the other hand, *Marphysa gravelyi* had its maximum occurrence in the deeper strata and the minimum in the surface layer. *Dendronereides heteropoda* was distributed more or less equally at the three depth strata. Eventhough, *Dendronereis aestuarina* and *Nereis glandicincta* were found all the depth strata, their population density was comparatively higher in the upper strata. Only a few species of polychaetes such as *Marphysa gravelyi, Dendronereides heteropoda,* and *Dendronereis aestuarina* and the mollusc, *Hydrobia* sp. were found as deeper penetrants below 15 cm. As a typical deposit feeder, its feeding habits on different substrata (Newell, 1962, 1965) and also its relationship between environmental variables (Wells, 1978), which may enable *Hydrobia* sp. to survive in the deeper layer of the mangrove substratum. As already stated in this work, the species of the genera *Marphysa* and *Dendronereis* are typical mangrove polychaetes and their adaptability to this specialised habitat may help them to exist below 15 cm depth. It is observed that the above mentioned polychaetes have well developed characteristic gills which may be a behavioural adaptation, for lower oxygen content.

The mangrove soil, is oxygenated only to a depth of a few centimetres from the surface. The deeper layers of the soil are not only anoxic but are also with hydrogen sulphide and those polychaetes which live in such soil are relatively insensitive to unfavourable conditions prevailing there or should have developed behavioural patterns which enable them to survive (Macnae, 1968).

Another aspect noticed in the present study is that the sediment textural characteristics and organic matter do not vary considerably from surface to 15 cm depth. So, these factors are not significantly influencing the depth wise distribution of benthic fauna.

According to Odum and Heald (1975) and Newell (1973) the fallen mangrove leaves are turned to detrital particles by microbial activity. Hence, abundant supply of food materials are available from the surface to a few cm below the surface. The above mentioned factors may be the reason for the high population density of benthic fauna in the upper strata of the mangrove soil. However, it has been observed that a large quantity of putrified vegetation from the surface zone, tidal area, is removed by a way of tidal wash out.

5.16.6 BENTHIC FAUNA IN RELATION TO THE TIDAL LEVEL

Although the population density of benthic fauna varies in different tidal zones; the species composition is not changed considerably, though, the infaunal organisms showed specific preference to the mid and low tidal level. Regarding the distribution of macrobenthos, the maximum density was found in the mid tide region. It is noted that least percentage composition of the fauna was found in the high tide level (Fig. 5.26). When the entire study area is taken into consideration, the mid tide level contributed 39.99% and the low tide level contributed 36.87% of the total fauna. The lowest composition of 23.14% was found in the high tide level.

Generally the sediment type in the three tidal levels were not changed expect at station 3. The firmness of the substratum increases and the moisture content decreases due to evaporation towards the high tide mark and this region is submerged only during high tide. In general, benthic population above the level of mid tide mark was poor. Shokita *et al.* (1989) has reported that near the high tide level organisms are exposed to the air or by dry conditions for a considerable time. So, only few species are adapted to such conditions. According to Misra and Choudhury (1985) the region above the mid water mark was poorly populated and the polychaetes prefer the unconsolidated substratum where the burrowing is easy. The present findings agree with the observations made by the the above workers. The substratum with intricate root system nearer to the base of mangals especialy, *Rhizophora mucronata*, also seems to confine the nature of substratum as well as abundance of infauna in the high tide regions, in the present study.

5.16.7 CHARACTERISTICS OF MANGROVE FAUNA

The mangrove swamp community at Cochin includes a complex faunal assemblage of resident, semi-resident and migrant species. The epifauna and infauna of this habitat is dominated by polychaetes, crustaceans and molluscs - three groups that are physically and physiologically adapted to withstand the changing environmental conditions in the area.

Macnae (1968), in his studies on the Indo-West Pacific mangrove macrofauna, considered that there is no specialised mangrove macrofauna as such, and that animals living within a mangrove environment occur there because of the suitable conditions prevailing there. Warner (1969), however, on the basis of his studies on crabs in a Jamaican mangrove, considered that there is definite mangrove fauna, in view of the similarities between mangrove crab fauna in different parts of the world and their adaptations to the environment. The comparison of the mangrove molluscan fauna of South India with that of Malaya (Berry, 1963 and Brown, 1971) have shown that the South Indian and Malaysian mangroves have greater affinity in the molluscan fauna than that of South Africa and South India (Kasinathan and Shanmugam, 1985). Day (1974), Sasekumar (1974) and Frith *et al.* (1976), from their studies on mangrove fauna in South Africa, West Malaysia and Phuket mangrove shores respectively, also considered to have a characteristic mangrove fauna. Pillai and Appukuttan (1980) compared the mangrove associated molluscs of southeast coast in India with those of the East Indies and Western Indian Ocean and reported that the Indian mangroves have faunal elements from both eastern and western Indian Ocean. In the present study a affinity has been noticed among the polychaetes of Cochin, Malaya, Phuket, South Africa, Bombay and Sunderbans and it has already been discussed.

It is stated that the mangrove associated species have evolved many special adaptation for feeding (Frith *et al.*, 1976). The various species have also developed coexisting traits that make life without much competition. The coexistence of polychaetes in this specialised habitat is made possible owing to the harmony, adaptability and euryhalinity of species, while competition and predation among the annelids may not be a profound. The varying rates in decomposition of detritus derived from mangrove vegetation, ensures a steady supply of energy to the consumers at all seasons. The coexistence among the species indicates this long term inter-relationship and adaptation to the mangrove habitat. The high population density and standing stock of these organisms clearly indicate their protracted breeding periodicity and high growth rate. In addition to this, a steady supply of food and the suitable substratum are also favourable to the occurrence and abundance of polychaete fauna in the mangrove area. Odum and Heald (1972, 1975) suggested that the degree of relationship between the mangrove and associated benthic fauna varies in accordance with the feeding requirements of the fauna concerned.

5.16.8 DETRITUS BASED FOOD CHAIN IN THE MANGROVE ECOSYSTEM

In the mangrove swamps, the bulk of the detritus originates directly from plant biomass. Though animal biomass is also included, the production of plant biomass always exceeds that of animals. Animal faeces, which are largely by herbivoury, are a secondary source. Mangroves itself act as a primary producer. Much of this primary production eventually enters the aquatic system as plant debris. This is worked out by micro-organisms and is subsequently consumed by a variety of detritivores. Heald (1971) estimated the production of organic detritus in a mangrove swamp as 9 tonnes/ha/year. Odum and Heald (1975) stated that the decaying mangrove leaves become permeated by fungi, protozoans, micro-algae and bacteria. The process of detritus formation is accelerated by this biological processes. The convertion of detritus into bacterial and fungal biomass makes it much more readily available to other organisms. In such conditions, organic detritus is the chief link between primary and secondary production (Odum and de La Cruze, 1967), and the major energy flow between autotrophic and heterotrophic levels is by means of 'detritus food chain' rather than the 'grazing food chain' (Teal, 1962).

A diverse group of detritivorous benthic organisms, principally invertebrates, play an important role in the detritus food web which contributes stability to the benthic community and also its diversity and richness providing a continuing yield of energy to the system. Leaves that remain on the forest floor are fragmented by crabs, some of which feed almost exclusively on leaf material (Malley, 1978). Amphipods are prominent among the animals that graze mangrove leaf litter (Odum and Heald, 1975 and Boonruang, 1980). The mangrove soil meiofauna, particularly nematodes, are strongly implicated as regulators of the rate of microbial decomposition. There is evidence that, by selectively grazing litter micro-organisms and meiofauna stimulate microbial action (Lee, 1980). Jeyaseelan (1981) reported that the nematodes are the major meiofaunal constituents found to play an important role in the food web relationship in mangroves. Nematodes, along with detritus, are consumed by polychaetes, amphipods and mugilid fish.

The extent to which aquatic organisms utilise mangrove food sources has emerged through analysis of the gut contents from inshore fish and invertebrates (Odum and Heald, 1972, 1975). Sasekumar *et al.* (1984) reported that in addition to mangrove plant detritus, these sources include the benthic and epiphytic assemblages of mangrove algae, faecal matter, the intertidal fauna and larvae released by mangrove invertebrates. Macintosh (1979) reported that the mudskipper, *Boleophthalmus*, ingests surface fungi, diatoms and blue-green algae from the mangrove substratum. A study has been carried out on the food web pattern of the fish communities from Pichavaram mangrove system by Jeyaseelan (1981). He reported that strict detritus feeders are absent, although 88% of omnivores take detritus as food. According to Chong *et al.* (1990) tropical coastal mangroves function more importantly as feeding grounds than as nursery grounds for juveniles of commercially important fish species. Mangrove and mud flats are utilized during flood tides by many periodic foragers from the inshore waters. However, they reported that coastal mangroves and mud flats are important nursery areas for commercially important prawn species. Robertson and Duke (1990) reported that the secondary production by fish is extremely high in the tropical mangrove systems. According to them a verity of species especially juvenile fish inhabit the mangrove areas at high tide. Most of these fish shelter in small shallow tributaries of the estuary at low tide. Sasekumar *et al.* (1984) have shown that a variety of fish feed in Malaysian mangrove forests during high tide periods.

Specimens of some inshore penaeid species collected from Selangor waters were found to have consumed 64 to 86% of animal material and 12 to 36% of plant material; of which 11 to 59% was identified to be mangrove origin (Leh and Sasekumar, 1984). Planktonic *Acetes* shrimp collected from the same waters had gut contents of mangrove detritus (Tan, 1977). Virtually all the commercially important species of mangrove associated prawns are omnivorous. Many studies have shown that prawns consume a varied diet that can include zooplankton, diatoms, benthic algae, meiofauna, detritus, animal remains and inorganic particles. Post-larvae of prawns are strongly planktophagous, whereas benthic food sources are increasingly exploited by the juveniles and later stages. The larger *Penaeus* sp. tend to be more carnivorous, taking whatever animals they can capture (Hall, 1962). The stomach content analysis of the juveniles of *Palaemon* sp. collected from the present study area revealed its detritus feeding habit. Their gut contents include mangrove detritus, animal remains and sediment particles, the major component being the mangrove detritus. Robertson (1988) indicated that the intertidal mangrove forest habitat is an important feeding and shelter site for juvenile prawns.

From the above it is seen that mangrove detritus play an important role in the food chain of mangrove fauna. Most of the benthic invertebrate species are eaten by mangrove associated fishes and prawns. The biomass of the mangrove fauna, contributed predominantly by polychaetes, crustaceans and molluscs, form the major component of the food item of fishes and prawns in the area. The food chain is complex with elaborate interactions between organisms at different trophic levels and thereby forming intricate food webs. It is seen that large amount of detritus occurs in the mangrove swamps of Cochin, derived from the mangrove vegetation and majority of

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the benthic animals feed on detritus and play an important role in the food chain. The detritus forms the substratum for bacterial and fungal growth, and these in turn provide food for detritus feeders. The bacteria and fungi together with detritus, form the food of meiofauna such as nematods, protozoan and harpacticoid copepods. The detritus, along with microfauna and meiofauna are consumed by macrofauna, especially polychaetes, molluscs and crustaceans. These consumers, together with detritus are in turn consumed by mangrove-associated fishes and prawns. Thus the invertebrate benthos form a major link in the food web of higher organisms in the mangroves of Cochin backwaters as is else where.

Chapter VI

THE POLYCHAETOUS ANNELIDS OF COCHIN MANGROVE AND THE ESTUARY _ A COMPARATIVE ANALYSIS

It is observed that the polychaetes constitute 51.61% of the toatal benthic species of Cochin mangroves. Out of total 54 species collected, polychaetes formed 33 species. An attempt is made here to compare the structure and compositon of polychaete fauna inhabiting the mangrove swamps and the non-mangrove adjacent estuarine habitats.

6.1 RESULTS AND DISCUSSION

The species composition and population density of polychaetes in the two biotopes are given in Table 6.1 and Fig. 6.1 respectively.

Station 1

While 29 species of polychaetes are found in the mangrove area, only 9 species could be collected from the adjacent area in the estuary. The species found in the estuary were *Marphysa gravelyi, Nephthys polybranchia, Nephthys* sp., *Paraheteromastus tenuis, Dendronereis aestuarina, Prionospio polybranchiata, P. cirrifera, Talehsapia annandalei, Ancistrasyllus constricta and Nereis chilkaensis.* The species found common in both the areas were *M. gravelyi, P.tenuis, N. chilkensis, D. aestuarina* and *T. annandalei. N. polybranchia, Nephthys sp., A. constricta* and *P. polybranchiata* were found only in the estuarine collections.

Station 2

At this station, 6 species - *Praheteromastus tenuis, Talehsapia annandalei, Dendronereis arborifera, Prionospio cirrifera, P. polybranchiata* and *Glycera longipinnis* were found in the estuary. But 12 species were found in the mangrove area. The species *P. tenuis* and *T. annandalei* were found in both the areas.

Station 3

While 9 species were recorded from the estuary, 14 species were found in the mangrove area. The species found in the estuary were *Nereis chilkaensis, Dendronereis aestuarina, D. arborifera, Nephthys polybranchia, Nephthys* sp., *Paraheteromastus tenuis, Perineries* sp., *Glycera longipinnis* and *Prionospio polybranchiata. N. chilkaensis, D.arborifera, D. aestuarina, P. tenuis* and *Perinereis* sp. were the species that were found in both the areas. At the same time the species *N. polybranchiata* and *Nephthys* sp. were collected only from the estuary.

6.1.1 Population density

The population density of polychaetes was found to be higher in the mangrove areas than that of the adjacent areas in the estuary in all the stations (Fig. 6.1). When a total population density of $7880/m^2$, $8650/m^2$ and $5550/m^2$ were recorded in the low tide, mid tide and high tide level respectively in the mangrove area at station 1, only $900/m^2$ was recorded in the estuarine collection. Similarly, a total population density of $6740/m^2$, $11310/m^2$ and $2980/m^2$ were recorded in the low tide, mid tide and high tide level respectively at station 2, only $180/m^2$ was recorded from the estuary. At station 3 a total population density of $6810/m^2$, $4780/m^2$ and $3020/m^2$ were recorded in the low tide, mid tide and

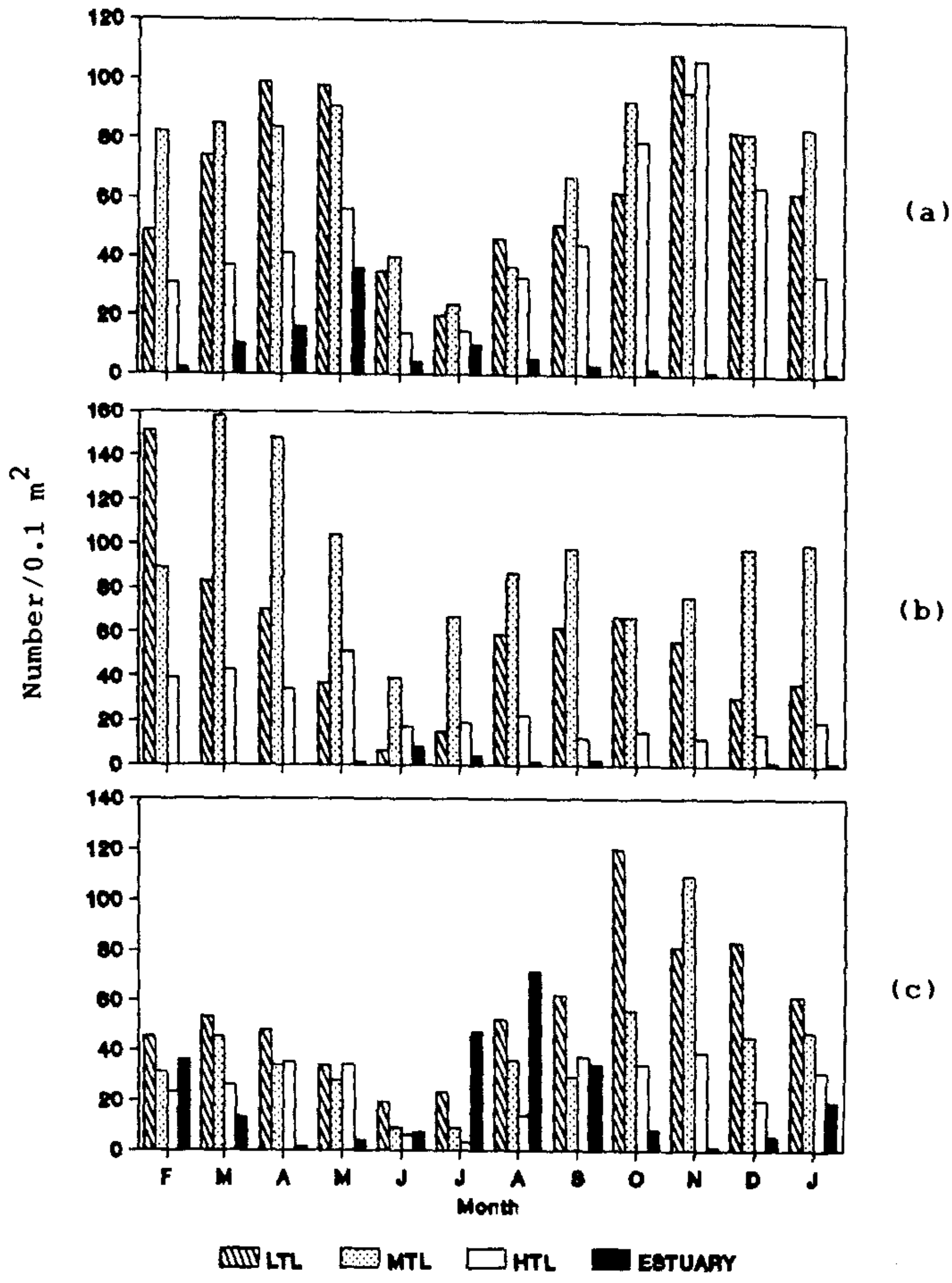

Figure 6.1 Monthly variations of polychaete fauna in the mangrove swamps and in the estuary
(a) Station 1 (b) Station 2 (c) Station 3

high tide level respectively in the mangrove area. The population density in the estuary was only 2460/m^2 (Fig. 6.2a). In all the mangrove stations studied the polychaetes were more abundant than in the non-mangrove habitat.

6.1.2 Substratum

The sediment characteristics of the adjacent area in the estuary are shown in Table 6.2. Organic matter and sand-silt-clay contents (average value) in the mangorve area (three tidal levels) and in the estuary are given in Fig. 6.2b and 6.3.

Station 1

In general, sediment type in the estuary was silty clay. Clay dominated as the major component. The sand content of the sediment ranged from 10.24 to 27.49%. The silt and clay content ranged from 27.6 to 44.63% and 42.7 to 45.13% respectively. The organic matter in the sediment was 4.67% (average value). This shows that while the sediment type in the estuary was silty clay (Table 6.2), it was sandy (Table 4.1) in the mangrove area.

Station 2

In the estuary, the sediment was silty clay. The percentage of sand ranged from 1.29 to 1.67. The silt fraction was found to vary from 36.67 to 45.08% and the clay component varied from 53.63 to 56.75%. The organic matter of the sediment was 4.83% (average value). In the mangrove swamp the sediment type was clayey sand and silty sand (Table 4.2). But it was silty clay, dominated by clay fraction in the estuary.

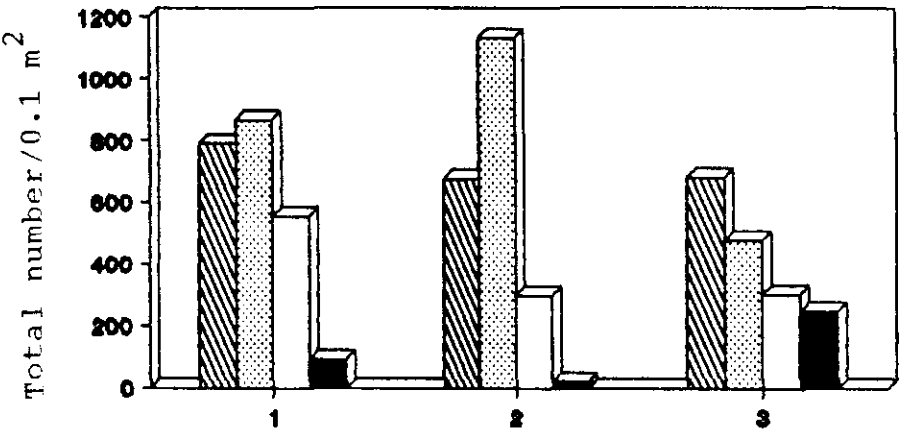

Figure 6.2a Comparison of population density in the mangrove swamps and in the estuary

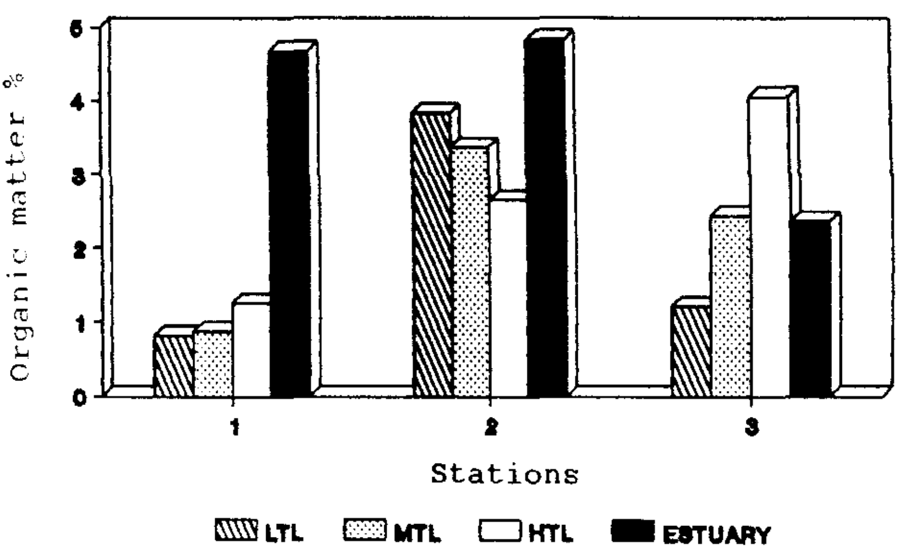

Figure 6.2b Comparison of organic matter content in the two bic:opes

Station 3

The sediment type was silty clay and clayey sand in the estuary. The sand, silt and clay fraction constituted 2.72 to 72.69%, 1.9 to 46.1% and 24 to 51.18% respectively. The organic matter content in the sediment was 2.36% (average value). In the mangrove area the sediment type was sandy in the low tide level, clayey sand and silty sand in the mid tide and high tide level (Table 4.3). But it was silty clay and clayey sand in the estuary.

From a comparative study of the benthic polychaetes in the two biotopes - mangrove area and the estuarine area, the species composition as well as population density showed dominance in the mangrove area. Majority of the species that occured in the mangrove areas was not found in the estuarine collections. But all the species of polychaetes except *Nephthys polybranchiata, Nephthys* sp., *Ancistrasyllus constricta* and, *Prionospio polybranchiata* found in the estuary were also seen in the mangrove swamps. Their population density always showed higher values in the mangrove area. Since no significant variation in salinity was observed in these two biotopes, the textural difference of the substratum seems to have influence on the distribution of polychaetes.

The sediment type in the estuary varied from that of the mangrove area. Clay particle dominated in the estuarine substratum. But in the mangrove areas, sand fraction was dominant. Tidal and wave effect remove the clay from surface and subsurface soil. The clay content was found to be 44.23, 57.46 and 34.21% (average value) at station 1, 2 and 3 respectively in the estuarine sediment (Table 6.2). It was 7.95, 15.82 and 10.63% (average value of the three tidal levels) in the mangrove sediment at station 1, 2 and 3 respectively (Table 4.1-4.3). The silt content was 36.46% at station 1, 41.11% at station 2 and 17.08% at station 3 in the

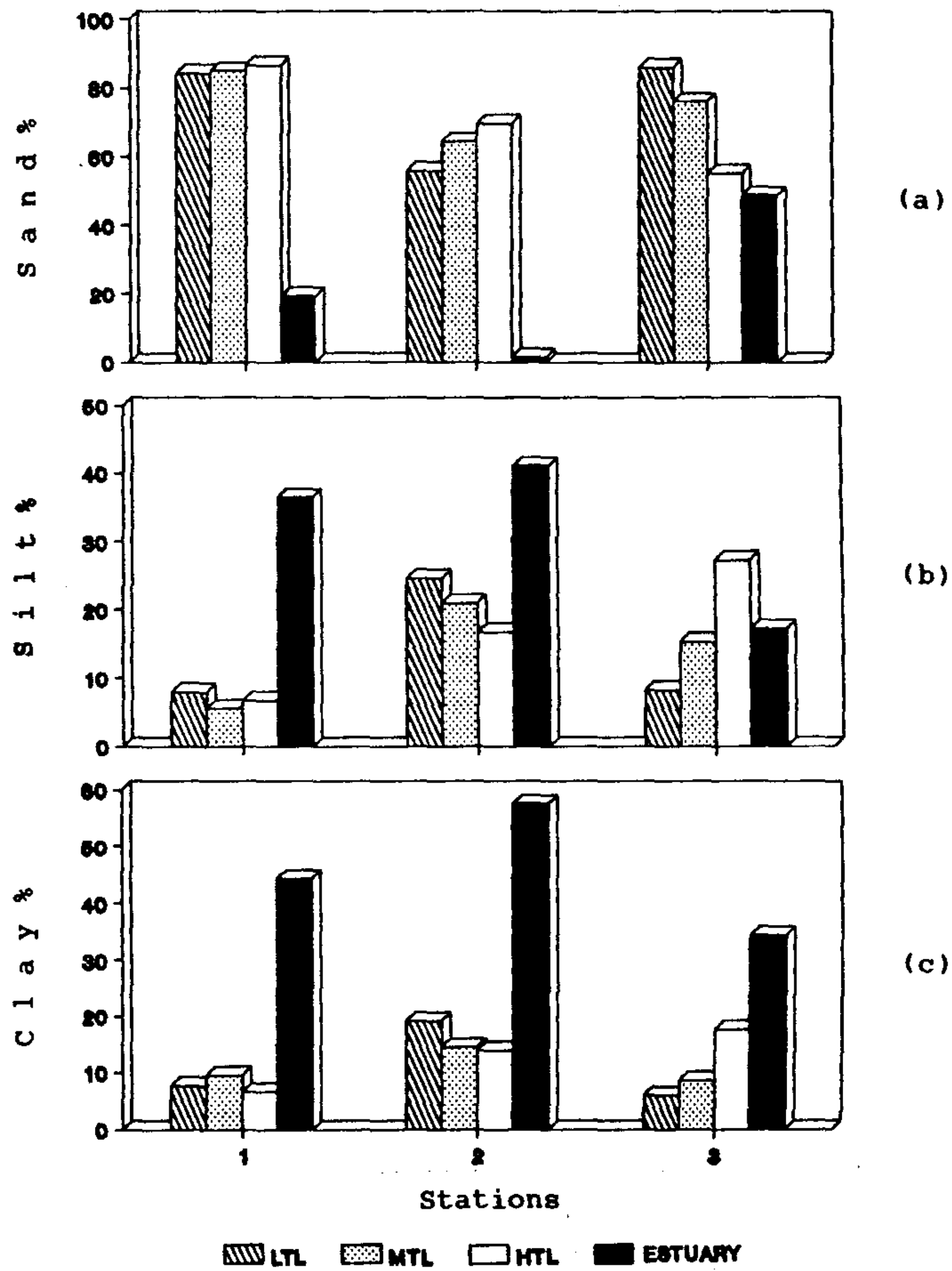

Figure 6.3 Comparison of sand-silt-clay contents in the two biotopes
(a) Sand (b) Silt (c) Clay

estuary. In the mangrove area, it was 6.7% at station 1, 20.7% at station 2 and 27.23% at station 3. As far as the percentage of the sand content is concerned, it was 19.31, 1.43 and 48.71% at station 1, 2 and 3 respectively in the estuarine sediment. In the mangrove sediment , it was 85.35% at station 1, 63.49% at station 2 and 72.53% at station 3. The sediment texture in the estuary is different from that of the mangrove area, so also the organic matter content. It was 4.67, 4.83 and 2.36% (average value) at station 1, 2 and 3 respectively in the estuary (Table 6.2) while it was 0.98, 3.29 and 2.56% (average value of the three tidal levels) at station 1, 2 and 3 respectively in the mangrove area (Table 4.1-4.3). This clearly indicates that a substratum having more concentration of clay particles support higher percentage of organic matter. The relationship between organic matter content and sand-silt-clay particles in the sediment has already been stated (please refer chaper 4.2). The present study showed that the estuarine sediment has relatively high organic matter content than the mangrove sediment, probably of mangrove origin as well as from run off from uplands and nearby arable land.

According to Devi and Venugopal (1989) and Devi *et al.* (1991) the sediment in the northern limb of Cochin estuary is silty clay, rich in organic matter. Shanmukhappa (1987) opined that the nature of sediment is found to influence the organic matter in the three biotopes - mangroves, estuary and the sea. He has reported that the Pichavaram mangrove has high clay, low sand content and high organic matter. But, in the present study area, generally high sand fraction with low organic matter was found. Only at station 2, comparatively high organic matter content was observed. Rao and Sarma (1983) pointed out that the low organic matter in the sediment is due to the sandy nature of the substratum. The high silt, clay content and the compact nature of the sediment may be the reason for the high organic matter content. Ganapati and Raman (1973) indicate that high values of organic matter lead to anaerobic conditions, thereby affecting the benthic community. This may be one of the reasons for the lower population density of polychaete fauna in the estuarine biotope, when compared to the mangrove area. According to Harkantra (1982) very low and high values of organic matter content show poor fauna and medium values show rich fauna.

The sandy biotope seems to possess a more diversified benthic community than muddy biotope (Sanders, 1958, 1968; Young and Rhoads, 1971 and Chandran *et al.*, 1982). In the present study, it is seen that sand was dominated in the mangrove substratum where higher population density and species diversity as well as richness of polychaetes occured. Stickney and Stringer (1957), Horikoshi (1970) and Sanders (1968) have reported that there are fewer species in mud than in sand. According to them, this may be because, sand possess more micro-habitats, permanent burrowers can exist there; and due to good permeability, oxygen and food particles can move through it. In mud, however, permeability is poor and there is often an anoxic layer just below the surface, resulting in most animals living close to or on the surface. In the present study it is observed that comparatively high sand particles mixed with abundant detritus of mangrove origin make the substratum, an ideal habitat for polychaetes in the mangroves while in the estuarine biotope the amount of detritus was very poor, though high organic matter was found. According to Harkantra *et al.* (1982) faunal distribution in relation to the type of sediment showed low population density in clay deposits. The present study clearly shows a comparatively low population density of polychaetes in the estuarine substratum where clay content prevails.

The suitable texture of the soil, high detrital food available and special physiological adaptations of the worms are some of the factors that enable the polychaetes to thrive in mangrove ecosystem. The results of the present study indicate that there is a characteristic and distinct polychaete fauna in the mangrove areas. As a whole, the polychaetes form an integral part of the mangrove ecosystem. The occurrence and abundance of polychaetes of the mangrove habitat and the adjacent non-mangrove habitat varied mainly based on the nature of the substratum.

Table 6.1 List of polychaetes collected from mangrove swamps and in the estuary

No.	Name of species	Mangrove	Estuary
1.	*Amphicteis gunneri*	+	-
2.	*Ancistrosyllis constricta*	-	+
3.	*Branchiocapitella singularis*	+	-
4.	*Ceratonereis costae*	+	-
5.	*Diopatra neapolitana*	+	+
6.	*Dendronereides heteropoda*	+	-
7.	*Dendronereis asetuarina*	+	+
8.	*Dendronereis arborifera*	+	+
9.	*Eunice tubifex*	+	-
10.	*Eunice* sp.	+	-
11.	*Glycera alba*	+	-
12.	*Glycera longipinnis*	+	+
13.	*Goniada* sp.	+	-
14.	*Lumbriconereis latreilli*	+	-
15.	*Lumbriconereis pseudobifilaris*	+	-
16.	*Lumbriconereis simplex*	+	-
17.	*Lumbriconereis* sp.	+	-
18.	*Marphysa gravelyi*	+	+
19.	*Marphysa stragulum*	+	-
20.	*Mercierella enigmatica*	+	-
21.	*Nereis kauderni*	+	-
22.	*Nereis chilkaensis*	+	+
23.	*Nereis glandicincta*	+	-
24.	*Nereis* spp.	+	-
25.	*Nephthys polybranchia*	-	+
26.	*Nephthys* sp.	-	+
27.	*Paraheteromastus tenuis*	+	+
28.	*Pulliella armata*	+	-
29.	*Pista indica*	+	-
30.	*Phyllodoce* sp.	+	-
31.	*Polydora* sp.	+	-
32.	*Perinereis cavifrons*	+	+
33.	*Perinereis* sp.	+	+
34.	*Prionospio pinnata*	+	-
35.	*Prionospio cirrifera*	+	+
36.	*Prionospio polybranchiata*	-	+
37.	*Talehsapia annandalei*	+	+
38.	Capitellidae group (unidentified)	+	-

Table 6.2 Sand-silt-clay content, organic carbon and organic matter content (%) of the substratum in the estuary (a) Station 1 (b) Station 2 (c) Station 3

Month	Sand%	Silt%	Clay%	Organic carbon%	Organic matter%	Sediment type	
JUN 90	27.49	27.66	44.85	2.93	5.05	Silty clay	
SEP	10.24	44.63	45.13	2.58	4.45	Silty clay	(a)
JAN 91	20.20	37.10	42.70	2.61	4.50	Silty clay	
Average:	19.31	36.46	44.23	2.71	4.67		
JUN 90	1.29	45.08	53.63	2.94	5.07	Silty clay	
SEP	1.33	36.67	62.00	2.79	4.81	Silty clay	(b)
JAN 91	1.67	41.58	56.75	2.67	4.60	Silty clay	
Average:	1.43	41.11	57.46	2.80	4.83		
JUN 90	2.72	46.10	51.18	2.76	4.76	Silty clay	
SEP	72.69	3.23	24.08	0.54	0.93	Clayey sand	(c)
JAN 91	70.72	1.90	27.38	0.80	1.38	Clayey sand	
Average:	48.71	17.08	34.21	1.37	2.36		

SUMMARY

The thesis entitled "Studies on the benthic fauna of the mangrove swamps of Cochin area" embodies the results of investigation on the mangroves of Cochin over a period of two years, with special reference to their associated free living benthic organisms, its distribution and abundance, in relation to the hydrological parameters and the substrate characteristics of the habitat.

The zonation and composition of mangals and their associates were also investigated. Ten typical mangrove plants were identified from Cochin mangrove areas. The dominant species are *Rizophora mucronata, Avicennia officinalis* and *Acanthus ilicifolius*. The ecological and economical importance of mangrove ecosystem and the need for its conservation have been emphasised.

The hydrological conditions of the mangrove area showed seasonal variations. The premonsoon period is with high temperature, less rainfall and the maximum salinity conditions. The salinity of water showed annual variations within the range of 0.19 to 29.76‰. The south west monsoon is characterised by heavy rainfall and low salinity. During the peak of south west monsoon (July), the lowest salinity of 0.19‰ was observed. Generally salinity showed a decreasing trend from station 1 to 3. The sediment and water temperature varied from 26°C to 33.5°C and 26.5°C to 34.5°C respectively. Seasonal variations were also reflected in dissolved oxygen and pH, but were not so prominent when compared to salinity and temperature. Dissolved oxygen values of water ranged from 2.23 to 5.26 ml/l. pH of sediment and water ranged from 7.25 to 8.25 and 7.1 to 8.1 respectively. Of these four hydrological parameters, salinity plays a major role in the distribution and abundance of benthic fauna; temperature is the next important parameter.

The nature of the substratum showed that the composition of the sediment varied markedly at the three stations investigated. Sand is the dominant factor in all the stations with an admixture of silt and clay. Based on the data obtained, the substratum of mangrove area can be differentiated into four sediment types - sandy, clayey sand, silty sand and sandy silt. Textural analysis showed sandy sediment at station 1 throughout the year. At station 2, type of sediment was clayey sand during premonsoon and postmonsoon and silty sand during monsoon season. Station 3 showed sandy sediment in the low tide level throughout the year. At the same time clayey sand was observed during premonsoon and postmonsoon and silty sand during monsoon period in the high tide level. The content of organic matter in the sediment varied from 0.6 to 1.53% at station 1, 2.55 to 4.79% at station 2 and 0.84% to 5.17% at station 3; the maximum being in the area where high percentage of silt and clay occur. The clayey sand and silty sand have higher organic matter content than the sandy type sediment. The study reveals that there is correlation between particle size and organic matter in the sediment. Depth wise distribution of sediment characteristics do not show considerable variations. The sediment type was not changing at the three depth strata (0-5, 5-10 and 10-15 cm), during the study period.

The important benthic faunal group observed during the study, are polychaeta, crustacea and mollusca. A total of 54 species were identified. Among the various groups, polychaeta was the dominant group. Altogether 33 species of polychaetes belonging to 20 genera were recorded, of which, 24 species belong to errantia and the remaining 9 species to sedentaria group. A maximum of 30 species were recorded from station 1 and a minimum of 12 species at station 2. 14 species were recorded from station 3. The common species that were found in all the three stations were *Marphysa gravelyi* and *Nereis glandicincta*. *Paraheteromastus tenuis*, *Dendronereides* *heteropoda* and *Dendronereis aestuarina* were abundantly found throughout the year at stations 1, 2 and 3 respectively. The species diversity of nereidae and eunicidae groups of polychaeta was higher. Crustacea was mainly represented by amphipod, isopod, tanaid and decapod groups. Totally 11 species of crustacea were observed. Among these *Gammarus* sp. was the most common. A total of 9 species of mollusca were collected. Of these, *Hydrobia* sp. was found to be very common.

When the percentage contribution of benthic population is taken as a whole, polychaeta, crustacea, mollusca and other groups contributed 51.7, 15.12, 26.23 and 6.95% respectively. The biomass in the study area also showed a high contribution by polychaetes (51.44%) while the crustacea, mollusca and other group together contributed only 48.46%. The biomass was always high at station 1. The maximum biomass was observed during the postmonsoon period followed by premonsoon and monsoon period. The standing crop 57.86 g/m^2 and 30.03 g/m^2 were estimated during postmonsoon period in the mid tide level at stations 1 and 2 respectively while 16.57 g/m^2 was estimated in the low tide level at station 3 during postmonsoon.

Species diversity and richness of benthic fauna were lower at stations 2 and 3 than at station 1. Species richness (Margalef's index) varied from 1.31 in the low tide level to 4.5 in the mid tide level at station 1. It varied from 0.62 in the high tide level to 3.26 in the low tide level at station 2 and 0.38 in the high tide level to 2.74 in the low tide level at station 3. Species diversity (Shannon's index) value ranged from 1.65 in the low tide level to 3.03 in the mid tide level, 1.07 in the high tide level to 2.69 in the low tide level and 0.52 in the high tide level to 2.34 in the mid tide level at stations 1, 2 and 3 respectively. Although there was some difference in the evenness indices, it did not vary considerably among three stations. Regarding the species diversity and richness of polychaetes, the highest value was found at station 1, and it was decreased towards station 3. This clearly reveals that the maximum abundance and diversity of polychaete is seen at station 1.

Salinity was found to be the most important factor that controls the occurrence and abundance of benthic organisms in the Cochin mangroves, though some direct correlation between temperature was also observed. Distribution of benthic organisms in different seasons showed maximum population density during postmonsoon and premonsoon and the minimum during the monsoon period (June-August). With respect to seasons, the species richness of benthos varied from 1.90 during monsoon to 4.33 during premonsoon at station 1, at the same time its diversity varied from 2.01 in the monsoon to 2.89 in premonsoon. At station 2 richness and diversity varied from 0.98 during monsoon to 2.82 during premonsoon and 1.32 during monsoon to 2.27 during premonsoon respectively. Richness and diversity ranged from 0.78 during monsoon to 2.49 during postmonsoon and 1.05 during monsoon to 2.20 during postmonsoon respectively at station 3. Correlation was observed between polychaetes and salinity. On the basis of salinity preference, polychaetes are classified into three groups such as, (1) *species able to tolerate small variations in salinity,* (2) *moderately tolerant* and (3) *highly tolerant euryhaline forms.*

The nature of the substratum has much influence on the distribution and abundance of fauna. The standing crop as well as species diversity and richness is more in areas where the substratum is predominantly sandy, mixed with low percentage of silt and clay. On the other hand, diversity and biomass of fauna was low, where the substratum is with more clay and silt. The pattern of quantitative distribution was as follows: station 1 recorded the maximum population ($43600/m^2$) followed by station 2 ($38640/m^2$) and station 3 recorded the minimum number ($29600/m^2$). Station 1 showed a total of 49 species, as against 25 and 24 species at stations 2 and 3 respectively reflecting a salinity gradient of ocean dream followed by the influence of substratum. The pattern of station wise standing stock was as follows: station 1 with sandy substratum (organic matter range: 0.6-1.53%) showed the highest biomass value (209.416 g/m^2), followed by clayey sand and silty sand substratum (organic matter range: 2.57-4.79%) at station 2 (127.308 g/m^2). The lowest biomass value (88.011 g/m^2) was estimated at station 3 (organic matter range: 0.84-5.17%). At this station, comparatively high biomass (43.457 g/m^2) was found in the sandy substratum (organic matter: 0.84-1.4%). This shows that the texture of the soil seem to have more direct correlation with the benthic fauna, rather than the concentration of organic matter in the sediment that mainly depend upon the sand-silt-clay range. However, it is revealed that the excellent supply of detrital material, evidently mangrove origin, make the substratum more suitable for benthic productivity, in the present study area.

Studies on the vertical distribution of benthic fauna showed that 50-75% of the total population occurred in the upper 5 cm strata of the sediment. 16-30% and 10-23% of the fauna were seen in the middle and lower strata respectively. This shows that though the organisms were found at all the three depth levels, a decreasing trend in the species composition as well as the numerical abundance of organisms was formed from the surface to the lower strata. It was observed that among polychaetes, *Marphysa gravelyi*, *Dendronereides heteropoda* and *Dendronereis aestuarina* and the mollusc, *Hydrobia* sp. were found to penetrate below 15 cm depth level. The behavioural adaptations of the species, which may enable them to exist in the deeper layer of the mangrove substratum. The sediment textural characteristics and organic matter content do not vary considerably from surface to 15 cm depth. Hence these factors seem not to be significantly influencing the depth wise distribution of the fauna.

The occurrence and abundance of benthic fauna at three tidal levels have been studied. The density of benthic population showed variations at the tidal area. Of the three tidal levels, the mid water level supports the maximum population. Of the total population in the three tidal zones, 39.99% was found in the mid tide level. 36.87 and 23.14% of the total fauna were found in the low and high tide level respectively. The species diversity as well as richness were also higher in the mid tide level than in the low and high tide level. The highest species diversity (3.03), richness (4.46) and Hill's diversity (20.70) were found in the mid tide level at station 1. Diversity indices of species were found to be lower at the high tide level in all the three stations. In general, benthic population above the level of mid tide mark was poor. When compared to high water mark, loose sediment in the mid and low tide levels may favour the high benthic productivity, while the exposed zone, is more consolidated by distinctive features of tidal rhythms that provide little interstices for infauna resulting to a structural complexity.

The study shows that the polychaete fauna of mangrove habitat is rich and varied, and form the most prominent element among the euryhaline component. The coexistence among the species indicates a long term inter-relationship and adaptation of the polychaetes to the mangrove habitat. The high population density and standing stock of these organisms clearly indicate, their adaptation to changing environmental parameters, especially salinity.

A comparative study on the polychaetes of the mangrove habitat and the adjacent non-mangrove habitat in the estuary was conducted. While 33 species of polychaetes were recorded from the mangroves; only 14 species were found in the adjoining estuarine area. The pattern of population density in the two biotopes was as follows: $7880/m^2$, $8650/m^2$ and $5550/m^2$ were recorded in the low, mid and high tide levels respectively in the mangrove area at station 1, only $900/m^2$ was recorded in the estuarine bitope. Similarly, $6740/m^2$, $11310/m^2$ and $2980/m^2$ were found in the low, mid and high tide levels respectively at station 2 while only $180/m^2$ was found in the estuary. At station 3 it was $6810/m^2$ in the low tide level, $4780/m^2$ in the mid tide level, $3020/m^2$ in the high tide level and $2460/m^2$ in the estuary. Sediment characteristics of the two biotopes also showed considerable variations. In general, while sand particle dominated in the mangrove area, clay particle dominated in the estuarine collection. It is revealed that the constant tidal action prevents the settlement of finer particles in the fringing mangrove substratum especially at station 1. The sediment type in the mangrove area was sandy, clayey sand, silty sand and sandy silt, while it was predominantly silty clay followed by clayey sand in the estuarine non-mangrove substratum. Along with the texture of the sediment, the organic matter content in the two biotopes were also varied. The average value of organic matter was 4.67, 4.83 and 2.36% at stations 1, 2 and 3 respectively in the estuary while it was 0.98, 3.29 and 2.56% at stations 1, 2 and 3 respectively in the mangrove substratum. Since there was no significant variation in salinity in these two biotopes, the quality of the substratum seem to have direct influence on the distribution of polychaetes. In addition to this the availability of food is more favourable for the occurrence and abundance of polychaetes in the mangrove area. The putrified vegetation along with abundant fungal and bacterial population may furnish a rich source of food for polychaete species in the mangrove habitat.

Significant similarity and strong association were noticed among the macrobenthos in the present study. The abundance of *Marphysa gravelyi*, *Paraheteromastus tenuis*, *Musculista* sp., *Gammarus* sp. and *Hydrobia* sp. at station 1, *Dendronereides heteropoda*, *Nereis glandicincta*, capitellidae group (unidentified) and *Hydrobia* sp. at station 2 and *Dendronereis* *aestuarina, Nereis glandicincta, Hydrobia* sp. and *Gammarus* sp. at station 3 in all the seasons accounted for high similarity values among the macrobenthos. The assemblages of these euryhaline species indicate their strong interaction and adaptation towards the mangrove habitat, rather than competition for space and food, as they can flourish in the tropical mangrove areas in Cochin backwater.

The present study revealed a similarity in the polychaetous annelids of Malaya, Phuket, Sunderbans and Cochin. The members of the genera *Dendronereis* and *Marphysa* are found to be typical mangrove polychaetes. *Marphysa gravelyi, Nereis glandicincta, Eunice tubifex, Eunice* spp., *Branchiocapitella singularis* and *Pista indica* are found at Cochin, though so far not reported from Malayan, Phuket and Sunderbans mangrove habitats.

The Cochin mangroves have been over exploited for various purposes and destruction is still going on and what is left now would be very less. Recently a National Committee on Mangroves, Wet lands and Coral reefs has been constituted in the Ministry of Environment and Forest, Government of India, to protect and strengthen our mangrove resources throughout the country and some actions are already on the way by the state authorities as suggested by the above mentioned national committee. The mangrove swamps, which stabilize our shoreline, should be conserved to augment our shell and fin fish fisheries, since the benthic fauna along with the detritus chain in the biotope provide a feeding link in the mangrove ecosystem. Since the ecosystem is valuable in many ways there is an imperative need to protect them and a few suggestions by way of an action plan in this regard are given.

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