MACROBENTHOS OF MINICOY ISLAND, LAKSHADWEEP

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CERTIFICATE

This is to certify that this thesis entitled "**Macrobenthos of Minicoy Island, Lakshadweep**" is an authentic record of the research work carried out by Smt. Dalia Susan Vargis, Research Scholar (Reg. No. 2146), CUSAT under my supervision at Central Marine Fisheries Research Institute and that no part thereof has previously formed the basis for the award of any degree, diploma or associate ship in any University.

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Acronyms and Abbreviations

°C	Degree celsius
%	Percentage
nm	nanometre
mm	millimetre
cm	centimetre
m	metre
km	kilometre
g	Gram
kg	Kilogram
ml.	millilitre
l.	litre
wt.	weight
i.e.	That is
sp.	species
spp.	More than one species
st.	station
lat.	Latitude
long.	Longitude
N	North
E	East
ha	hectare
Fig.	Figure
e.g.	exempli gratia (Latin word meaning 'for the sake of example')
at.	atmospheric
hrs.	hours
ppt.	Parts per thousand
$\overline{X}$	Mean value (average)
no.	Number
DO	Dissolved oxygen
OC	Organic carbon
et al.	et alii (Latin word meaning 'and others')
etc.	et cetera (Latin word meaning 'and other similar things; and so on')
C. V.	Co-efficient of variation
µ g at/l	µ gram atom per litre
C	Carbon
S.	surface
In.	Interstitial
viz	videlicet (Latin word meaning 'namely')
y	year

CONTENTS

CHAPTER 3.   ENVIRONMENTAL PARAMETERS

CHAPTER 4.   BOTTOM FAUNA

Chapter. 1

INTRODUCTION

The Lakshadweep group of Islands is located off the southwest coast of India in the Arabian Sea. Exploratory surveys have been conducted in the past for assessment of productivity, hydrography as well as fishery potential of Lakshadweep sea during the cruises of R. V. *Varuna,* R. V. *Kalava,* ORV *Sagar Kanya and* FORV *Sagar Sampada* and the results have been well documented. However studies on benthos of Lakshadweep Islands are scanty and hence this attempt. Benthic production is of importance in assessing the biological productivity of an area.

'Benthos' refer to those organisms, which live on or in the bottom of any body of water (Bostwick, 1983). Benthic organisms are sometimes found on hard substrates such as rocks, wood or in soft sediments. Again, those found on the substrate are epifauna and those found within the substrate are termed as infauna. Benthic organisms are divided into three categories according to their size (1) Macrobenthos (> 500μ) (2) Meiobenthos (500μ to 63μ) and (3) Microbenthos (<63μ) (Mare, 1942). The division of benthos into different size groups varies according to the workers, substratum etc. Conventionally the benthos retained on a 0.5 mm sieve are treated as macrobenthos.

1. 1. Importance of benthos

As a result of the environmental complexity exhibited by the shallow waters, the benthos of the region show different feeding habits and constitute one of the major links in the marine food chain. Benthos play an important role in the regeneration and recycling of nutrients between pelagic and benthic realms, as they form an important source of food item for the demersal fishes and an indispensable link to higher trophic levels and provide food both directly and indirectly through the detritus food chain for various micro-consumers at the lower trophic level. Food and feeding habits of benthos differ mainly according to the substratum. There are filter feeders, suspension feeders, detritus feeders, carnivores, scavengers, and epiphytic grazers. Thus benthos with different functions of this kind occupy a certain domain according to their contributions and form a community in which certain species occur together in an area. The benthos are important as indicators of the health of the habitat and play a critical role as a major source of energy to economically and ecologically important demersal fishes.

The concept of indicator species is of great importance in biological monitoring and benthic invertebrates are recognised as useful tools. Benthic invertebrates like *Capitella capitella*, *Nereis caudata* and *Balanus amphitrite* have been identified as possible indicators to show the presence of certain chemical substances in the marine environment. Therefore many of them are treated as sentinel organisms and biomarkers in the assessment of health of the marine ecosystem. Thus they are the pollution indicators of marine environment because of their direct relationship with the type of bottom and the physical nature of the substratum. Thus benthos may be treated as sensitive indicators of the condition of accumulation of organic matter and its nature in the sediments (Bordovsky, 1964). Apart from the above, some of the macrobenthic organisms like gastropods, crabs, prawns, etc. contribute well to the economy of the region.

1. 2. Intertidal zone and benthos

The intertidal zone lies at the junction of the land and the sea subjected to the tidal ebb and flow. The vertical extent of this zone depends on the range of tides and the slope of the shore. The physical conditions occurring in the intertidal zone are quite dissimilar to those occurring elsewhere in the sea. Tides are of fundamental importance in shaping the intertidal environment. Another important physical factor, which influences the life and activities of organisms of the intertidal zone, is the waves. The profile and type of the shore, the size of particles remaining, fauna and flora are all controlled by the waves. In the intertidal zone, there is ample substratum and adequate illumination for the lush growth of rooted plants and therefore animals are associated with these plants for nutrition, substratum and shelter (Nair and Thampy, 1980). Phytoplankton productivity and organic matter accumulation are also high. The density of animals in sandy as well as muddy areas of the intertidal zone may be extremely high. In some areas, there is commonly a covering of algal mat, which has very high primary productivity to supply dense population of some species of gastropods (Sheppard *et al.*, 1992).

Because the organisms in the intertidal zone are subjected to greater stress of longer duration due to alternate exposure to water and air, wave action, fluctuations in light intensity, they have evolved certain means to adapt to these inconsistent environment. Most of these organisms are euryhaline and eurythermal and are able to tolerate the desiccation and prolonged anaerobic conditions. Most of the animals penetrate the substratum to tide over unfavourable conditions.

1. 3. Seagrass beds

Seagrass bed is one of the most conspicuous and widespread biotope types of the shallow marine environment throughout the world. About 48 species of sea grasses have been recorded, representing 12 genera and 2 monocotyledonous water plants throughout the world, of which 37 are tropical and rest are temperate species. Importance of seagrasses as the primary producers in coastal environments, for instance, in sustaining fisheries, was proposed as far back as the turn of the last century (Peterson, 1913, 1918). Seagrass beds are also common along coastal lagoons (Balasubramaniam and Khan, 2001) and sandy seas around the bases of shallow fringing and patch reefs. Throughout the western Indian Ocean seagrass beds are a common feature of intertidal mud and sand flats (Richmond, 1997). They represent a unique flora of angiosperms adapted to rigorous salinity, immersion, occasional desiccation, and hydrophilic pollination (Schwarz *et al.*, 2004).

Productivity of seagrasses is often enhanced by encrusting algal epiphytes (Sheppard *et al.,* 1992). A dense vegetation of seagrass produces a great quantity of organic material by itself and also offers a good substrate for epiphytic micro and macro algae and sessile fauna. The vegetation plays the role of sediment trap and minute suspended particles both organic and inorganic are deposited in this biotype (Mc Roy and Mc Millan, 1977; Walker, 1988). By trapping sediments, seagrasses play a vital role in stabilising mobile sand and protect shores from erosion. It also creates unique microhabitats for small animals (Kirkman, 1985, 1995; Gosliner *et al.,* 1996). Encrustations on seagrass blades include fauna such as sessile, often colonial invertebrates such as hydroids, bryozoans, sponges, barnacles and tunicates. These in turn attract other fauna (polychaetes, crustaceans like isopods, amphipods, mollusks and echinoderms), which form the basis of food chains within the seagrass ecosystems. Many amphipods, isopods, and tanaeids feed on the mixture of microflora and detritus. Numerous fish species feed on the leaves and use the seagrass beds as shelter from predators (Stoner, 1983). As there are few seagrass grazers, most of the plant materials are utilized by animals as semi decomposed organic substances on or in the substratum. Thus the seagrass ecosystem maintains both grazing as well as detritus food chain. Detritus feeding animals flourish in the decaying season of seagrass. On the other hand, herbivorous mobile fauna increases in the growing season of seagrass (Kikuchi and Peres, 1977). Faunal preferences are often noticed in different seagrasses.

It also serves as a nursery ground for juvenile fish and several crustaceans (Orth, 1986). Sand substrates are very essential for seagrass growth and seagrass beds generally occur from mid-eulittoral to depths of about 20 m. The development of seagrass beds is restricted by light availability and hence is limited by increasing water depth and suspended sediment.

1. 4. Mangrove ecosystem

Mangrove is the unique ecosystem with highly specialized, adapted vegetation types, distributed in the intertidal areas along tropical and subtropical coastlines (Untawale *et al.*, 1992). In India the total area covered by mangroves is estimated as 6,81,976 ha (Gopinathan and Rajagopalan, 1983) which includes the adjacent mudflats and brackish water systems. The high productivity resulting from mangrove litterfall supports a host of detritus feeding animals such as amphipods, mysids, harpacticoids, molluscs, crabs, and larvae of prawns and fishes (Mc Kee, 2003). Mangroves are also associated with the maintenance of biota, thereby assuming importance as a genetic reservoir. The major nursery function of mangrove roots highlights this and is a feature often exploited by artisanal fishermen and aquaculturists (Sheppard *et al.*, 1992). The mangroves have also significant roles in the maintenance of coastal water quality, reduction of the severity of coastal storms, waves and flood damage and as nursery and feeding grounds for fishery resources (Peterson, 1991; Guerreiro *et al.*, 1996; English *et al.*, 1997; Furukawa *et al.*, 1997;

Wolanski and Sarenski, 1997). Environmental factors such as tidal range, soil and freshwater input, do influence the diversity and productivity of mangrove ecosystems.

The mangrove environments provide living space for a dependent biota of more than two thousand species of flora and fauna of resident, semi resident or migratory mode of life. The uniqueness of the mangrove also lies with the low species diversity but richness of individual species. It is the concentration of individual species rather than their diversity, which characterizes the mangrove (Dugan, 1990). Low diversity is attributed to the generally severe climatic and environmental conditions with the limited range of suitable habitats and niches. The primary food source for aquatic organisms occurs in the form of particulate organic matter (detritus) derived chiefly from the decomposition of mangrove litterfall. Dissolved organic compounds of mangrove origin are an additional source of nutrition. The predators feed on the detritus feeders, which in turn form an important food source for both aquatic as well as terrestrial wildlife. Faunal assemblage of mangrove includes insects, crustaceans, molluscs, fishes, snakes, crocodiles, birds and mammals. Temperature, salinity, tides, rainfall, winds etc. are the major environmental factors, which influences the functions and stability of the mangrove ecosystem (Taylor *et al.*, 2003).

1. 5. Review of literature

1. 5. 1. Benthos

The pioneering work on quantitative study on benthos was done by Peterson in Danish waters in 1909 (Peterson, 1913). In India, the bottom fauna was first studied by Annandale and Kemp (1915) in Chilka Lake. Panikkar and Aiyar (1937) investigated the bottom fauna of brackish waters of Madras. Seshappa (1953) and Kurian (1953) worked on the benthos of Malabar and Trivandrum coasts respectively. Balasubramanian (1961) reported on the benthos of Vellar estuary and Rajan (1964) worked on the benthic fauna of Chilka Lake. Further, Kurian (1967) gave a detailed account of the benthos of southwest coast of India. Desai and Krishnan Kutty (1967) conducted investigations on the bottom fauna of the Cochin backwaters. They also made a comparative study of marine and estuarine benthic fauna of the nearshore regions of the Arabian Sea. Kurian (1972) reported the ecology of benthos of Cochin backwaters and Damodaran (1973) made observations on the benthos of mud banks of Kerala coast. Pillai (1978) investigated the macrobenthos of Vembanadu Lake.

Harkantra *et al.* (1980) worked on the benthos of shelf region along the west coast of India. Parulekar *et al.* (1980) made observations on the benthic macrofaunal annual cycle of distribution, production and trophic relation in the estuarine environments of Goa. Parulekar *et al.* (1982) gave an account of the benthic production and assessed it with reference to the demersal fishery resources of Indian seas. Raman and Ganapati (1983) studied the ecobiology of benthic polychaetes in Visakhapatnam harbour. Saraladevi (1986) conducted studies on the effects of industrial pollution on the benthic communities of Cochin backwaters. The distribution and abundance of benthos of the Ashtamudi estuary were reported by Nair and Aziz (1987). Benthic fauna in relation to physico-chemical parameters and sediment compostion of Vellar estuary was investigated by Chandran (1987). Benthos of prawn filtration farms were reported by Preetha (1994). The faunal composition of the mangrove environment of Maharashtra coast was observed by Jagtap *et al.* (1994). Manikandavelu and Ramdhas (1994) worked on the bioproduction dynamics of mangrove-bordered brackishwater along the Tuticorin coast. Prabhadevi *et al.* (1996) have given an account of the water quality and benthic fauna of the Kayamkulam backwaters and Arattupuzha coast. Chandra Mohan *et al.*

(1997) studied the role of Godavari mangroves in the production and survival of prawn larvae.

A study on the distribution of benthic infauna in the Cochin backwaters in relation to environmental parameters was conducted by Sheeba (2000). Sunil Kumar (2001, 2002) studied the macrofaunal assemblages of mangrove ecosystem of tropical estuary as well as Indo-pacific region. Studies on macro and meiobenthos from the shelf areas of South west coast of India were conducted by Joydas (2002) and Sajan Sebastian (2003) respectively. Jagtap *et al.* (2003) studied the status of a seagrass ecosystem, being a sensitive wetland habitat.

1. 5. 2. Earlier Investigations in Lakshadweep

Alcock set sail on 17th October 1891 by R.M.S. *Investigator* and cruised the Lakshadweep Sea for two months and documented the flora and fauna of Lakshadweep Island ecosystem. Gardiner (1900) described the atoll of Minicoy. The Cambridge University Expedition under the leadership of Prof. J. Stanley Gardiner was a significant event in the marine biological and oceanographic research in these waters and the results were reported in 2 volumes of 'Fauna and Geography of the Maldive and Laccadive Archipelagos' (Gardiner (Ed.) 1903, 1906 a & b). These volumes covered descriptions of marine invertebrates from Minicoy atoll which included foraminifera, corals, coelenterates, nemertines, echiuroides, sipunculoids, stomatopods, lobsters, alphids, molluscs and echinoderms by earlier investigators like Borradaile (1903), Shipley (1903 a & b), Lanchester (1903), Coutiere (1906), Eliot (1906) etc. Later, Hornell (1910) and Ayyengar (1922) explored the same area. Ellis (1924) provided a short account on the Laccadive Islands and Minicoy. The importance of the water in this region and its special ecological conditions were reported by Jones (1959) and Jayaraman *et al.* (1966). Patil and Ramamirtham (1963) observed the current circulatory patterns in Lakshadweep sea during winter and summer months and Rao and Jayaraman (1966) recorded upwelling in the Minicoy region and attributed it to diverging current systems. Fishery environmental studies were conducted during the cruises of R.V.*Kalava* and R.V.*Varuna* (1959 and 1969 respectively) during the IIOE cruises. The results of the exploratory surveys of R. V. *Varuna* in the sea around the Islands have been well documented by Silas (1969). Qasim and Bhattathiri (1971) determined the primary production of the seagrass beds of Kavaratti atoll. Results of the detailed ecological survey of the marine fauna of the Minicoy atoll have been given by Nagabhushanam and Rao (1972). Grain size variations in the Kavaratti lagoon sediments was studied by Mallik (1976) and zonation of molluscan assemblages at Kavaratti atoll (Laccadive) was studied by Namboodiri and Sivadas (1979).

Thomas (1979) studied the demospongiae of Minicoy Island and Jagtap and Untawale (1984) studied the chemical composition of marine macrophytes and their surrounding water including the sediments from Minicoy, Lakshadweep. Benthic macro and meiofauna of seagrass (*Thalassia hemprichii*) bed at Minicoy was studied by Ansari (1984). Ansari *et al.* (1984) studied macro and meio faunal abundance of six sandy beaches of Lakshadweep Islands during the 3 cruises of R.V.*Gaveshani* (1985-1987). General features of Lakshdweep were recorded by Jones (1986). Narayanan and Sivadas (1986) conducted studies on the intertidal macrofauna of the sandy beach at Kavaratti atoll (Lakshadweep). Pillai and Mohan (1986) studied the ecological stress in Minicoy lagoon and its impact on tuna bait fishes. An account on the environmental features of the seas around Lakshadweep was given by Nair *et al.* (1986). A historical resume of the marine fisheries research in Lakshadweep was given by James *et al.* (1986). Suseelan (1989) edited a publication on marine living resources in and around Lakshadweep. Ansari *et al.* (1990) conducted studies on seagrass habitat complexity and macro invertebrate abundance in Lakshadweep coral reef lagoons. Vijayanand made observations on coral fishes in 1994. Aspects of geology, geography, environmental features etc. of five atolls of Lakshadweep were studied by Vadivelu *et al.* (1993). A comprehensive list of marine fauna from Indian reefs is given by Bakus (1994), and Lakshadweep reefs by Rodrigues (1996). Geological survey of India (1995) made a scientific data base on Lakshadweep. Rivonker and Sangodkar (1997) studied the macrofaunal density along the intertidal region of three atolls of Lakshadweep. Coral reef structure of Lakshadweep Islands was studied by Wafar (1997), Rodrigues (1997) and Pillai (1986, 1997). Structure of seagrass beds at three Lakshadweep atolls was done by Jagtap (1998). Dhargalkar and Shaikh (2000) studied the primary productivity of marine macrophytes in the coral reef lagoon of the Kadmat Island, Lakshadweep. Haneefa (2000) studied the ecology, chemical constitutents and culture of marine macroalgae of Minicoy Island, Lakshadweep.

Benthic studies in Minicoy were limited to benthic macro and meiofauna of seagrass bed by Ansari (1984) during the 104 cruise of R. V. *Gaveshini* to Minicoy. It was only a one-time collection study up to the level of major benthic groups. The study of Ansari *et al.* (1984) was restricted to sandy beaches and the fauna was recorded only up to the higher taxa. Thus there is no information on benthic faunal associations of this region at a community level of organisation *vis-à-vis* abiotic factors that regulate species composition, abundance or their diversity. Thus the present study on macrobenthos of Minicoy atoll is a continuous study for two years from intertidal zones of two sensitive ecosystems, mangroves and seagrasses. Species wise identification of benthos was done along with numerical abundance and biomass. Sand texture and environmental parameters were also studied simultaneously.

1. 6. Scope and purpose of study

A perusal of the literature available indicated that the information on the benthos, especially the diversity, richness and abundance is rather scanty. Moreover, the systematic studies inventorying the benthic fauna/ flora in the region dates back to the beginning of the last century. In the present study, an attempt has been made to study the distribution and community structure of benthos at different ecosystems of the Minicoy Island. The present study will be useful as a baseline report for further investigations from the same area.

The objectives of the present study were to:

- Study the distribution of benthos, their biomass and numerical abundance in seagrass and mangrove ecosystems.
- Identify the benthos, group wise and species wise.
- Make spatial, temporal and seasonal comparison of the benthos.
- Study the inter-relationship and effect of environmental parameters on benthos.
- Analyse the trophic relationship of benthos and finfishes of the Island ecosystem.

Chapter. 2

MATERIALS AND METHODS

2. 1. Study Area

Lakshadweep, otherwise known as the 'coral paradise' of India consists of 36 Islands and lies between 08° 00' -12° 30' N and 70° 00' - 74° 00' E in the Arabian Sea. Minicoy Island located at 08° 17' N and 73° 04' E is the southern most Island in the Lakshadweep group with a land area of 4.4 km^2 and length of 9.5 km. Tidal amplitude is approximately 1.75 m. The lagoon occupies about 30.5 km^2 area with an average depth of 4 m. The Atoll of Minicoy is situated on the southwestern side of Peninsular India and is about 400 km from the mainland. It is approximately oval shaped and elongated in the northeast southwest direction. The shore side of the lagoon is sandy with a wide distribution of seagrasses and the seaward side is rocky with reef flat. The Island has a height of 1.8 m from the mean sea level.

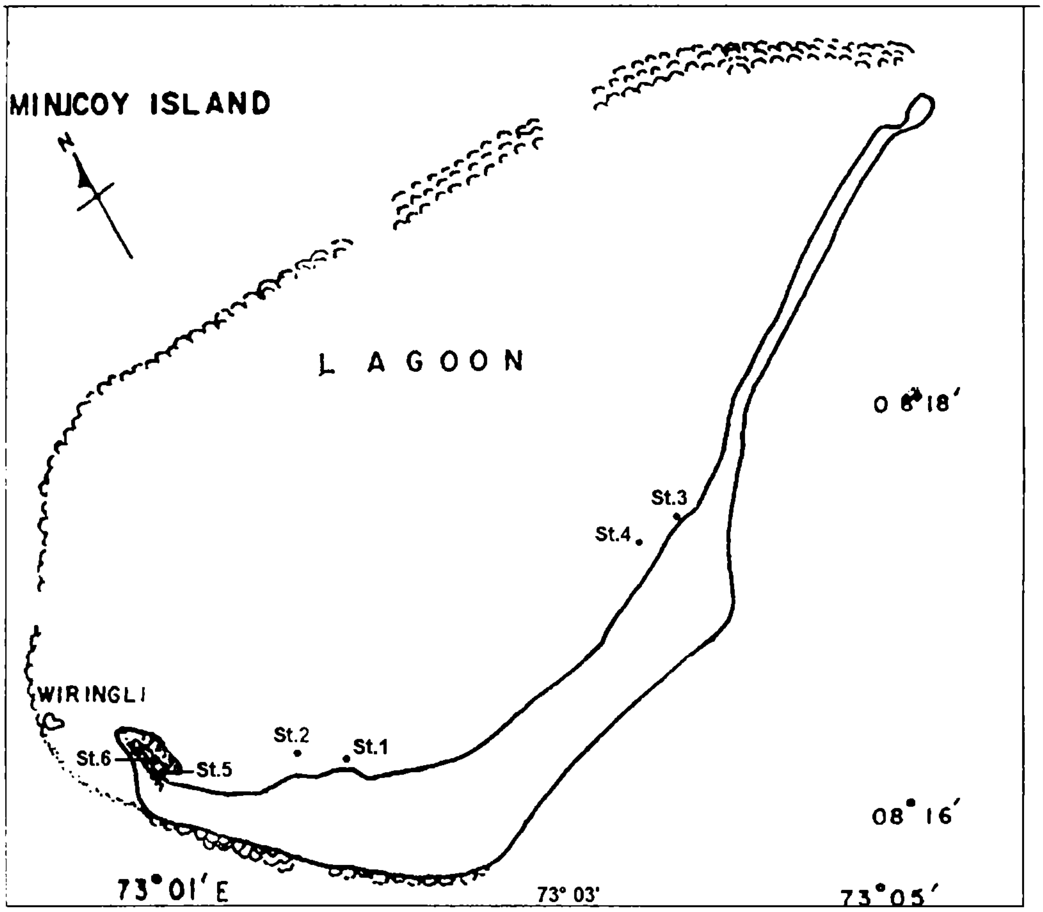
The area exposed between tides, referred to, as the Intertidal zone is the one with rocky boulders on one side and sand and seagrasses on the other. A thick bed of seagrass is visible on the windward shore area. However, the dominant species of seaweeds and seagrasses often differ with respect to region. The southern region is dominated by seagrass species of *Thalassia* and *Halophila* while the northern side is dominated by species of *Cymodaceae* and *Syringodium.* Seagrasses were found along with seaweed species such as *Gracilaria, Halimida, Pedina, Caulerpa, Acanthophora* etc. Mangrove region of Minicoy is limited to two patches of about 1 ha each. In many coral Islands and atolls, there are only few mangrove species, which are generally stunted and confined to small inland mangrove depression. The Mangroves noticed in Minicoy Island of Lakshadweep are in the formative stage and free from serious human pressure. The area is flushed daily by the tide and the depth of water is about 0.5 m. Mangrove associated flora involves *Avicinnia marina, Cereops tagal, Pemphis acidula* and *Bruguiera* spp. Mangrove fauna of this region includes the Mangrove whelk *Terebralia Palustris,* Fiddler crabs *Uca* spp., etc.

2. 2. Period of study

The study was conducted from September 1999 to August 2001. The Islands of Lakshadweep group have a tropical climate and based on the weather, the year may be divided in to three seasons, pre-monsoon (February–May), monsoon (June–September) and post-monsoon (October–January).

2. 3. Sampling sites and frequency of sampling

A reconnaissance fortnightly survey was made in August 1999, to identify the sampling sites and to determine sampling frequency based on accessibility for collection, bio-diversity exhibited, type of substratum, topography of land, variations in the number and biomass of fauna etc. Six stations were selected for sampling based on this pilot survey. Of the selected six stations, four were located in the intertidal zone (occupied by seagrasses) and two in the mangrove swamp (Fig. 2.1). Monthly triplicate



St. 1 - station 1 Southern *Thalassia* bed
St. 2 - station2 Southern *Thalassia-Halophila* bed
St. 3 - station 3 Northern *Cymodaceae* bed
St. 4 - station 4 Northern *Syringodium* bed
St. 5 - station 5 Mangrove station bordered by *Cereops tagal*
St. 6 – station 6 Mangrove station bordered by *Avicinnia marina*

Fig. 2. 1. Location Map of Minicoy showing the sampling stations

collections were made from the above stations (Holme and Mc Intyre, 1984).

Station 1. Southern *Thalassia* bed

This site was located on the southern side of the Island and mainly constituted by luxuriant growth of sea grass *Thalassia* spp. Along with seagrass, thick growth of seaweed species like *Chaetomorpha*, *Halimeda*, *Laurencia*, *Cladophora*, *Gracilaria* etc. were also seen. Sediments in this region consisted of fragments of corals, gastropod shells, calcareous algal remnants *(Halimeda* spp.), coarse to fine sand and clay (a very low percentage). Poor wave action, currents and thick growth of seagrass prevented removal of finer sediment particles and causes trapping of them in seagrass rhizomes and roots (Plate 2. 1. a).

Station 2. Southern *Thalassia-Halophila* bed

This station was located on the southern side about 100 m away from the high tide mark to the lagoon side. Here the abundance of macrophytes was slightly less than what was observed at station 1. The floor of the sea at this site contains calcareous algal remnants. The sand component was slightly higher when compared to that of the previous one. Along with *Thalassia* spp., *Halophila ovalis* also flourished in this site (Plate 2. 1. b).

Station 3. Northern *Cymodaceae* bed

This site was located on the northwest side of the Island and had only sparse growth of seagrass (*Cymodaceae spp.*). This was in the nearshore area partly protected from heavy wave action and currents by the 80-100 m wide zone of large coral conglomerates. Lagoon bottom consisted mainly of coarse to fine sand. Seaweeds such as species of

Gracilaria, Caulerpa, Acanthophora, etc. were extensively seen in this region (Plate 2. 2. a).

Station 4. Northern *Syringodium* bed

This site was located on the northwest side of the Island almost 200 m away from the high tide mark into the lagoon and the vegetation wass mainly constituted by *Syringodium* spp. of seagrass. This area was also partly protected by large coral conglomerates. Substratum was sandy with coral fragments and gastropod shell remnants. Coarse sand was observed in this region due to the weaker trapping ability of *Syringodium* roots (Plate 2. 2. b)

Station 5. Mangrove site bordered by *Cereops tagal*

This site was located on the southwestern side of the Island near the helipad. The area was flushed daily by the tide and the depth of water in the embayment varies from 0.25 to 1.75m. This site was near to the bund to facilitate exchange of water and the banks were bordered by *Cereops tagal* (Plate 2. 3. a).

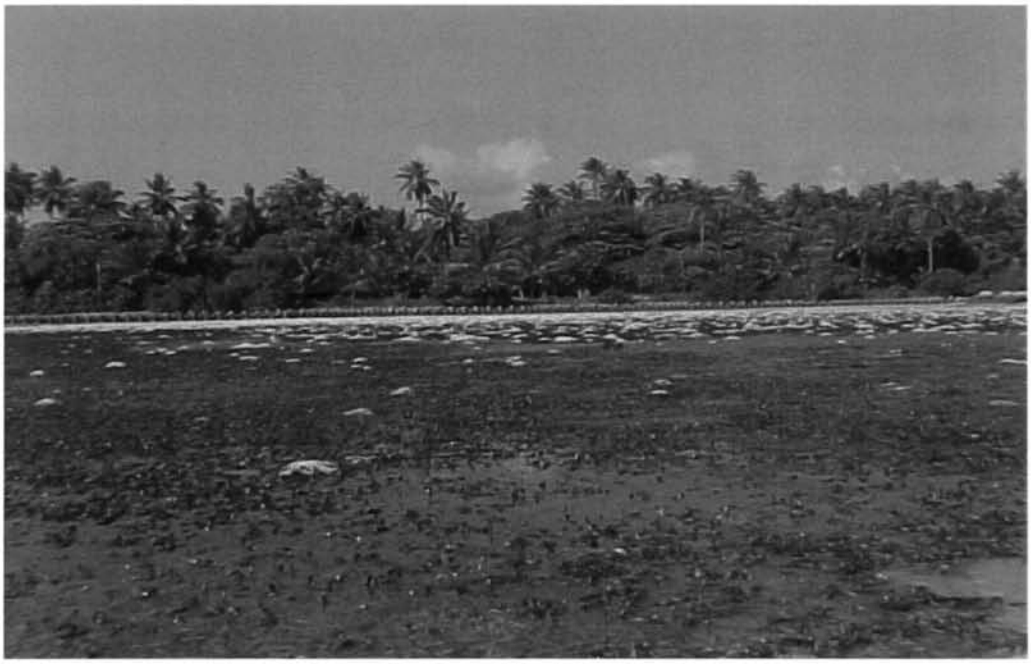
Station 6. Mangrove site bordered by *Avicinnia marina*

This site was located on the southwestern side of the Island, slightly away from the bund (water channel from the lagoon) and the banks were bordered by *Avicinnia marina*, a typical mangrove tree (Plate 2. 3. b).

Different species of seagrass from the study area are given in Plate 2.4

2. 4. Sampling methods

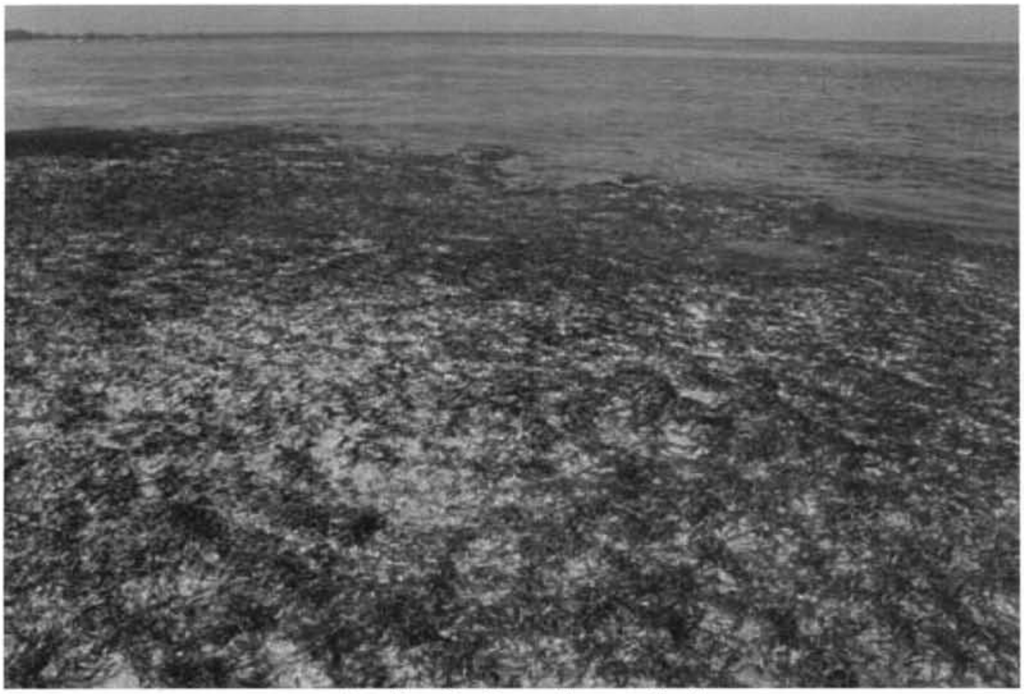
2. 4. 1. Water: Water samples were collected from the surface using a plastic bucket every month during low tide from all the stations for the



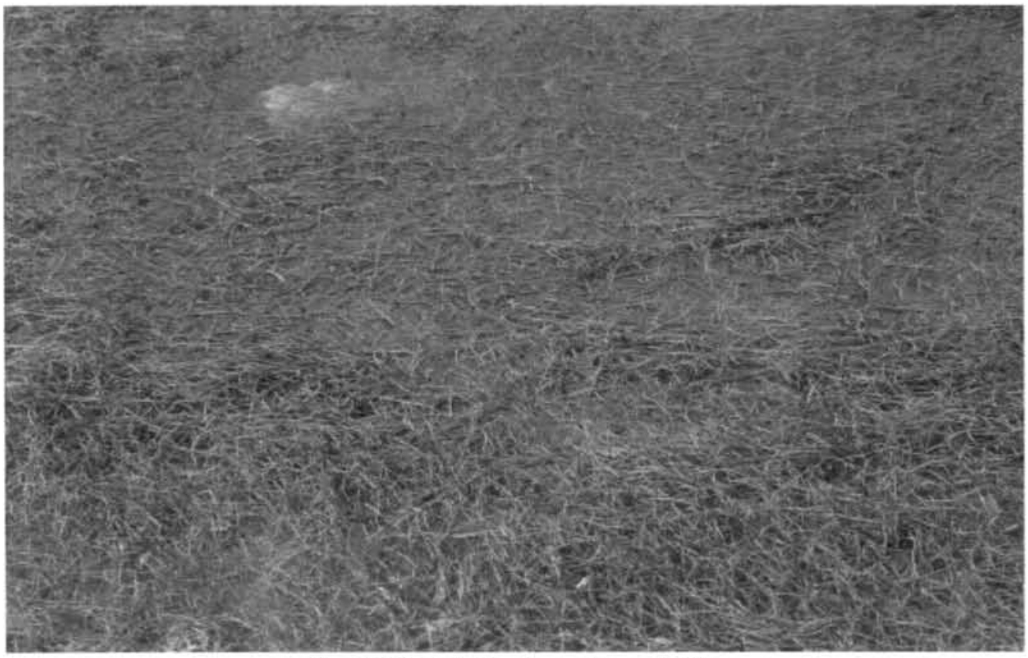
a. Station 1-*Thalassia* bed

b. Station 2-*Thalassia* - *halophila* bed

Plate 2. 1. Southern Seagrass stations



a. Station 3-*Cymodaceae* bed



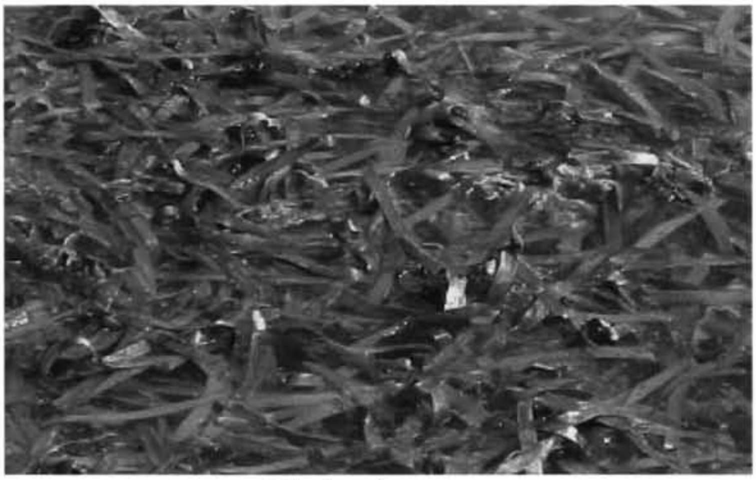
b. Station 4-*Syringodium* bed

Plate 2. 2. Northern Seagrass stations

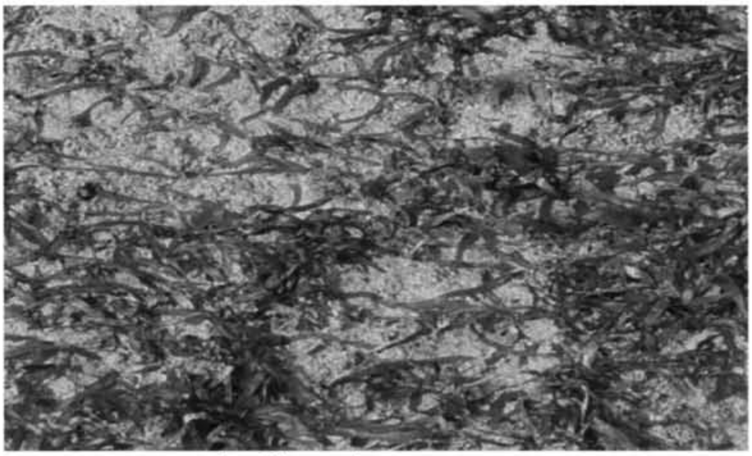
a. Station 5-Mangrove station bordered by *Cerops tagal*

b. Station 6-Mangrove station bordered by *Avicinnia marina*

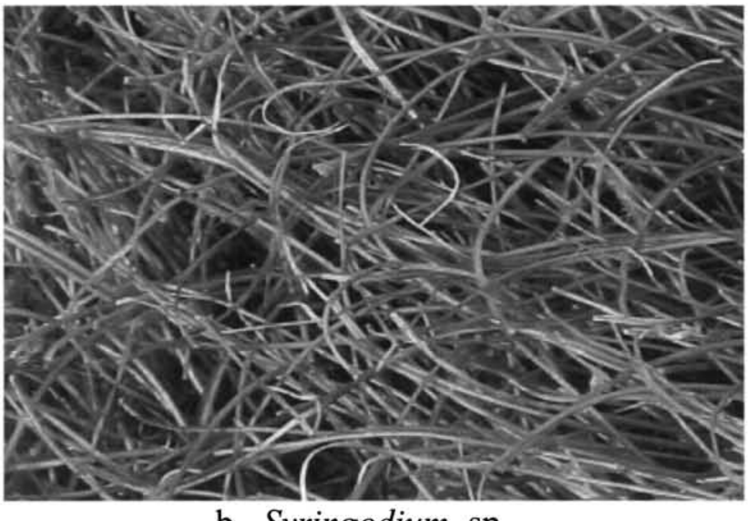
Plate 2. 3. Mangrove Stations



a. *Thalassia* sp.



b. *Cymodaceae* sp.



b. *Syringodium* sp.

Plate 2. 4. Major seagrass species from the study area

measurement of temperature, salinity, pH, dissolved oxygen and nutrients. Temperature of water was measured in the field itself. For estimation of dissolved oxygen, water was taken in 125 ml stoppered glass bottles taking care that no air bubbles were trapped in the sample and fixed with Winkler solutions. For salinity, pH and nutrients estimation, water samples were collected in plastic bottles and taken to the laboratory and stored in an insulated box till they were analysed. Interstitial water was taken with the help of an air stone, connected to a plastic siphoning tube and a pipette connected to the other end of the tube, by hand vacuum suction method (Sarda and Burton, 1995). The stone was inserted in the sediment to the desired depth and then only suction applied.

2. 4. 2. Sediment: Sediments for grain size analysis and organic carbon estimation were taken at low tide from each station. Samples were taken with a plexiglass corer of 5 cm diameter up to a depth of 10 cm (Holme and Mc Intyre, 1984). Samples were tied in polythene bags and taken to the laboratory for analysis.

2. 4. 3. Benthos: Triplicate samples were collected every month using a metal quadrat of 25cm X 25cm size up to a depth of 15 cm (Ansari *et al.*, 1984; Eleftheriou and Holme,1984). Quadrat data was gathered at 10 m intervals along 10 m distant transect lines (drawn perpendicular to the main parallel shore line), which were selected by random sampling every month. This method followed recommendations by Hiscock (1987), Hiscock and Mitchell (1989) and Bakus (1990). All samples were collected during low tide when maximum intertidal exposure prevailed and were sieved by a 0.5 mm metal sieve (Birkett and Mc Intyre, 1971; Holme and Mc Intyre, 1984) in the nearby running water and the residue retained on the sieve was collected in polythene bag and carried to the laboratory for further analysis.

2. 5. Analytical methods

2. 5. 1. Water

Temperature: Atmospheric temperature and seawater temperature were measured using a 0 to 50°C high precision thermometer.

Salinity: The water samples were stored in an insulated box till they were analysed. Salinity was determined by the Mohr's titrimetric method (Strickland and Parsons, 1968). 10 ml of the sample was titrated against silver nitrate solution using potassium chromate as indicator. Silver nitrate solution was standardised using standard seawater. Titration was repeated for concurrent values.

pH: pH was measured using a pH meter (Mettler Toledo MP- 120) having a glass electrode and a calomel electrode as reference. Before taking the pH of the sample, the meter was calibrated with standard buffer solutions, having pH 5, 7 and 9 at room temperature.

Dissolved Oxygen: Dissolved oxygen was estimated employing modified Winkler method of Strickland and Parsons (1972). 100 ml of sample was pipetted out and titrated against standard sodium thiosulphate. This method depends on the oxidation of manganous dioxide by the oxygen dissolved in the samples resulting in the formation of a tetravalent compound, which on acidification liberates iodine equivalent to the dissolved oxygen present in the sample. The iodine liberated can be determined by titration with sodium thiosulphate.

Nutrients: A standard graph was prepared for each nutrient factor using known concentrations of standards. The absorbance of the sample was measured using Erma AE, 11 photoelectric colorimeter and the nutrient values were expressed in international units of microgram atom per litre (μg at /l).

a. Silicate-Silicon: Silicon present in seawater in the dissolved form was estimated by the method described by Strickland and Parsons (1968). The determination of the dissolved silicon compound was based on the formation of a yellow silicomolybdic acid, when a more or less acidic sample was treated with a molybdate reagent. Since this acid was weak, the same was reduced by ascorbic acid to intensely coloured blue complexes. The absorption of the sample was measured against distilled water at a wavelength of 660 nm. 20 ml of the sample was pipetted out in to 50 ml graduated flask containing 3 ml of the acid molybdate reagent and mixed thoroughly. After 10 minutes, 15 ml of reducing agent was made up to 50 ml with distilled water. The solution was allowed to stand for 3 hours and measured colorimetrically at 660 nm.

b. Inorganic Phosphate: Phosphorus present in seawater in the form of dissolved orthophosphate was determined quantitatively by the ascorbic acid method given by Murphy and Riley (1962). Determination of inorganic phosphate involves the measurement of the concentration of orthophosphate ions by the formation of a reduced phosphomolybdenum blue complex in an acid solution containing molybdic acid, ascorbic acid and trivalent antimony. 8 ml. of mixed reagent was added to 50 ml of the sample. After 5 minutes and preferably within the first 30 minutes, the optical density was measured colorimetrically at 660 nm.

c. Nitrite-Nitrogen: Nitrite-Nitrogen present in seawater was estimated by the method described by Strickland and Parsons (1968). 50 ml seawater samples were measured out in conical flask. One ml of sulphanilamide solution was added to the sample. After 2 minutes but not later than 8 minutes 1 ml of N.N.E.D. (N- (1-naphthyl) ethylene diamene dihydrochloride) solution was added and mixed thoroughly. The optical density was measured at 530 nm.

*d. **Nitrate-Nitrogen***: Nitrate Nitrogen in seawater was estimated by the method of Mullin and Riley (1955). The nitrite in the water sample was reduced to nitrate and then measured in the same way as described for nitrite. To each water sample a buffer reagent and reducing agent ($CuSO_4$ and hydrazine sulphate) were added and kept in dark for 20 hrs. This reduced solution was treated with sulphanilamide and intensity of colour developed was measured. 50 ml of the sample was taken in a volumetric flask and 2 ml buffer reagent (Phenol and Sodium hydroxide) was added followed by 1 ml reducing agent (Copper sulphate and Hydrazine sulphate) on gentle mixing. The sample was then kept in the dark for 20 hours. 2 ml acetone solution was added and after 2 minutes, 1 ml of sulphanilamide solution. After not less than 2 minutes and not longer than 8 minutes 1 ml of N.N.E.D. (N- (1-naphthyl) ethylene diamene dihydrochloride) solution was added to the sample. The absorbance of the sample was determined after 10 minutes at 530 nm.

2. 5. 2. Sediment

Each sediment sample brought to the laboratory was transferred to a glass dish and dried in an oven at 60°C and stored in a desiccator for further analysis.

Grain size analysis: Mechanical analysis by international pipette method was followed for grain size analysis (Krumbein and Petti John, 1938). Separation of sediment particles was done based on various sizes of individual particle. The principle employed here is dispersion and fractionation of particles. The percentage of each grade (sand, silt and clay) was calculated. 20g soil was weighed in a beaker and moistened with water. 30 ml of 6% H_2O_2 was added and heated for 1 hour for the complete evolution of CO_2. The solution was cooled and diluted with 100 ml water and 25 ml of 2 N HCl was added and stirred vigorously. Filtering was done through No.1 Whatman filter paper and washed thoroughly with hot distilled water. The soil was transferred into a beaker and 10 ml 1 N NaOH was added and stirred again for 10 minutes. The solution was transferred in to a sedimentation cylinder and shaken vigorously for 10 minutes and after sufficient settling time (according to time-temperature chart) 10 ml of suspension was drawn using a pipette at 10 cm depth and dried at 105° C. Suspension was again shaken and a 10 ml sample was dried. The whole quantity has been transferred in to a large beaker and the entire clay and silt fraction was removed by thorough washing. The beaker containing fine and coarse sand was evaporated and weighed properly.

Organic Carbon: Organic carbon was determined by the wet oxidation method of El-Wakeel and Riley, 1957.

2. 5. 3. Rain fall data collection and tidal level estimation

Rainfall data of Minicoy was collected from the data sheets of Indian Meteorological Department. Tide level was estimated using the tide tables of the year 1999, 2000 and 2001 for Minicoy region of Lakshadweep.

2. 5. 4. Benthos

Numerical abundance: The benthos in the sediment sample recovered after sieving through 0.5 mm mesh sieve was brought to the laboratory in polythene bags, transferred to a large white bottomed tray and the animals which were moving or easily recognizable were hand sorted. After this preliminary examination, the whole sediment was treated with 5% buffered formalin and kept for further analysis. After the preliminary examination, detailed examination of each sample was carried out. A portion of sediment in the white tray was transferred to a large glass petridish and examined with the help of a stereomicroscope by providing black and white backgrounds for the petridish. The individuals were counted specieswise. The numerical abundance was extrapolated into 0.25 m^2 for easier data comparison.

Biomass: For biomass analysis, the formalin-preserved samples were taken only after eight weeks since, Lovegrove (1966) has shown that preservation in formalin may change the biomass, the weight loss being rapid immediately after preservation, attaining equilibrium thereafter. So only after 8 weeks of preservation the sample was taken and washed in freshwater. Extra water was wiped out using a blotting paper. Before taking the wet weight biomass, bivalve and gastropod shells were removed (small gastropods were weighed shell on). The biomass was extrapolated into $1m^2$ for comparison purpose. Individual organisms having comparatively very high wet weight were not extrapolated to $1m^2$, instead taken as such in order to avoid a biased picture.

Along with numerical abundance and biomass, the size of the organism (selected individuals) was also measured to analyse the recruitment and recolonisation patterns.

Identification of benthos up to species/generic level: Identification was carried out upto species level. In some cases specimens could not be identified upto the species level due to damage. The lowest reliable taxonomic level was given to the individual in such cases. The unidentified specimens were kept in formalined bottles for later identication by giving special code numbers. Specimens were later identified with the help of standard books for identification of each taxonomic group as well as using early references from the study area. Different departments of Central Marine Fisheries Research Institute, National Institute of Oceanography and Marine science division of CUSAT played significant roles in the confirmation of species. The species with only one individual under the particular genus was denoted by "sp." and if many species present in the same genera were denoted by "spp.". The identified samples are kept at Central Marine Fisheries Research Institute for any further reference.

2.6. Benthic productivity estimation

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

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

Dry weight-	using conversion figures for each group (Parulekar *et al.*, 1980). (0.062 for molluscs, 0.119 for worms, 0.141 for crustaceans and 0.09 for miscellaneous).
Carbon content-	34.5% of dry weight (Parulekar *et al.*, 1980).
Annual benthic production-	carbon content X 2 g C/Yr (Sanders, 1956)
Annual biomass production-	2 X standing stock (Harkantra and Parulekar, 1994).
The potential yield-	10% of the benthic standing stock (Parulekar *et al.*, 1982).

2. 7. Statistical methods

3-way ANOVA: Three-way analysis of variance was applied to the transformed data for testing the significance of differences and comparison between species, stations and months (Snedecor and Cochran, 1967; Jayalakshmi, 1998).

Community structure: Benthic community structure was studied by using PRIMER 5 for windows (version 5) and diversity/evenness indices such as Margalef's species richness index (Margalef, 1968), Shannon Weaver's diversity index (Shannon and Weaver, 1963), Simpson's species concentration factor (Simpson, 1949), Pielou's species dominance index (Pielou, 1966 a & b) and Heip's evenenss index (Heip, 1974; Jayalakshmi, 1998).

Similarity index: Similarity between species/months was calculated using PRIMER 5 for windows. For this Bray-Curtis similarity index method was used. Dendrogram was plotted for grouping species/months at different stations.

Multivariate Q-mode and R-mode factor analysis: This was conducted for grouping of species and stations based on the factor scores obtained, which provide the maximum information about the study area (Morrison, 1978).

Predictive step up multiple regression model: Relation between species and parameters was studied. The regression model for total density based on water quality parameters was carried out (Jayalakshmi, 1998), applying suitable transformation of data using Tucky's test of additivity (Tuckey, 1949) wherever possible.

Chapter. 3

ENVIRONMENTAL PARAMETERS

3. 1. Hydrography

The parameters studied were temperature (atmospheric and sea surface), salinity (sea surface and interstitial), pH, dissolved oxygen, nutrients (sea surface and interstitial) such as PO_4, SiO_3, NO_2 and NO_3. For the study of hydrological parameters, the sampling stations were categorised in three areas. Stations 1 and 2, which were closer to each other, registered identical values and therefore together treated as study **area 1.** Similarly stations 3 and 4 were treated as study **area 2** and stations 5 and 6 as study **area 3.**

3. 1. 1. Temperature (°C)

Atmospheric temperature

At southern seagrass area, the temperature varied from 26.2°C (December 1999) to 31.6°C (October 1999). In the northern seagrass area, the value ranged from 26.5°C (December 1999) to 32.6°C (May 2001). Minimum atmospheric temperature recorded in the mangrove area was 26°C (December 1999) and the maximum 31°C (May 2001) (Fig. 3. 1).

The minimum average seasonal value observed was 28.4°C (post-monsoon of 1st year) and the maximum was 30.8°C (post-monsoon of 2nd year) at the southern seagrass area. The minimum and maximum seasonal averages at the northern seagrass area were 26.7°C (1st year monsoon) and 29.4°C (2nd year pre-monsoon) respectively. The mangrove area recorded a minimum average value of 27.5°C during 1st year post-monsoon and a maximum of 29.8°C during 1st year monsoon (Table 3. 1. 1).

Suface water temperature

The range in surface water temperature noticed at area 1, area 2 and area 3 were 26.55°C (August 2001) to 31.5°C (May 2001), 26.5°C (October 1999) to 31.05°C (May 2001) and 26.5°C (December 1999) to 30.5°C (April 2000) respectively (Fig. 3. 2).

The seasonal average value was lowest in 2nd year monsoon (27.7°C) and highest in 2nd year pre-monsoon (29.8°C) at area 1. At area 2, the lowest value was noticed in 2nd year post-monsoon (27.5°C) and the highest in 2nd year pre-monsoon (29.1°C). Area 3 showed the lowest value in 2nd year monsoon (28.2°C) and highest in 1st year pre-monsoon (29.4°C) (Table 3. 1. 2).

3. 1. 2. Salinity (ppt)

Surface salinity

At southern seagrass area, the surface salinity varied from 27ppt (August 2000) to 35ppt (November 2000). At the northern seagrass area, the values ranged from 28.11ppt (August 2000) to 34.95ppt (November 2000). Minimum surface salinity recorded at the mangrove

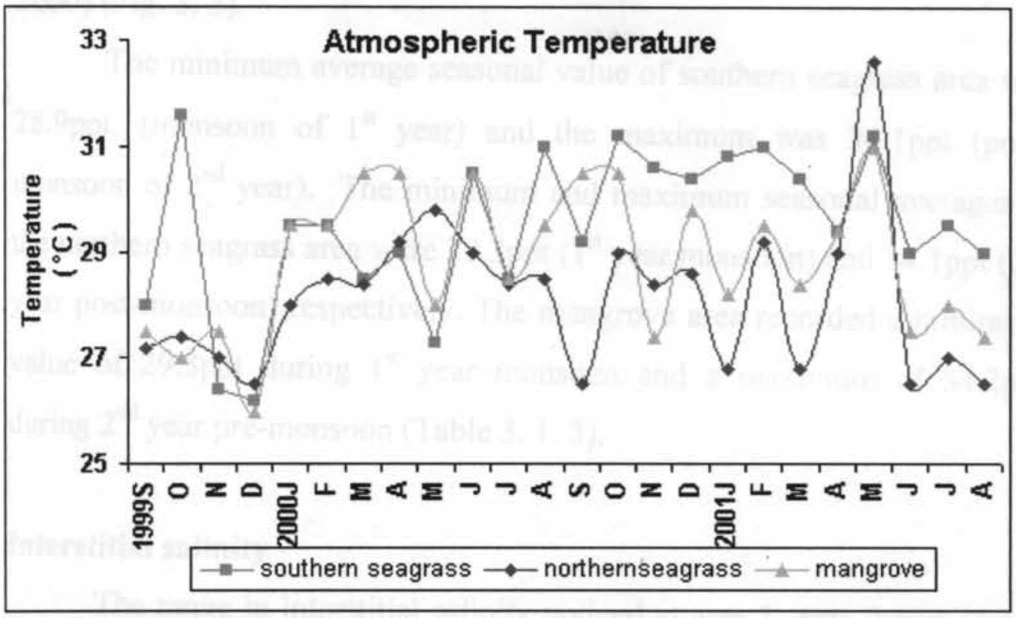


Fig. 3. 1. Monthly variations in At. temperature at the three study regions

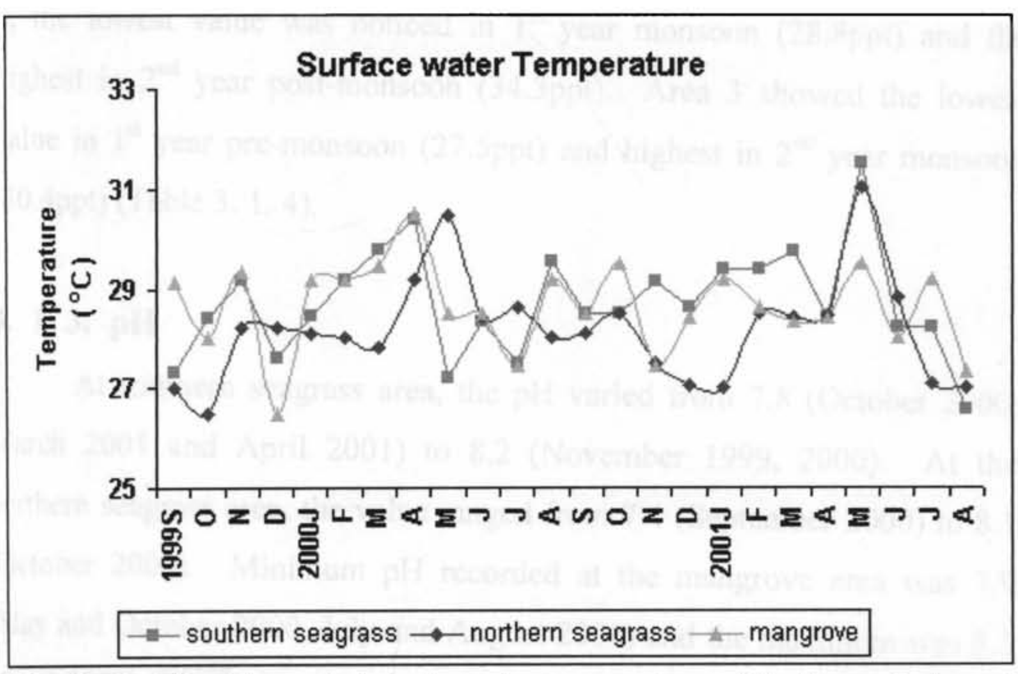


Fig. 3. 2. Monthly variations in water temperature at the three study regions

area was 28.4ppt (September 2000) and the maximum was 35.6ppt (May 2000) (Fig. 3. 3).

The minimum average seasonal value of southern seagrass area was 28.9ppt. (monsoon of 1st year) and the maximum was 34.1ppt (post-monsoon of 2nd year). The minimum and maximum seasonal averages at the northern seagrass area were 29.3ppt (1st year monsoon) and 34.1ppt (2nd year post-monsoon) respectively. The mangrove area recorded a minimum value of 29.3ppt during 1st year monsoon and a maximum of 34.2ppt during 2nd year pre-monsoon (Table 3. 1. 3).

Interstitial salinity

The range in interstitial salinity noticed at area 1, area 2 and area 3 were 27.26ppt (September 2000) to 35.69ppt (February 2001), 25.6ppt (May 2001) to 35.7ppt (October 2000) and 26.17ppt (April 2000) to 32.58ppt (May 2001) respectively (Fig.3. 4).

The seasonal average value was lowest in 1st year monsoon (28.2ppt) and highest in 2nd year pre-monsoon (34.3ppt) at area 1. At area 2, the lowest value was noticed in 1st year monsoon (28.8ppt) and the highest in 2nd year post-monsoon (34.3ppt). Area 3 showed the lowest value in 1st year pre-monsoon (27.5ppt) and highest in 2nd year monsoon (30.4ppt) (Table 3. 1. 4).

3. 1. 3. pH

At southern seagrass area, the pH varied from 7.8 (October 2000, March 2001 and April 2001) to 8.2 (November 1999, 2000). At the northern seagrass area, the value ranged from 7.4 (September 2000) to 8.1 (October 2000). Minimum pH recorded at the mangrove area was 7.9 (May and October 2000, July and August 2001) and the maximum was 8.5 (April 2000) (Fig. 3. 5).

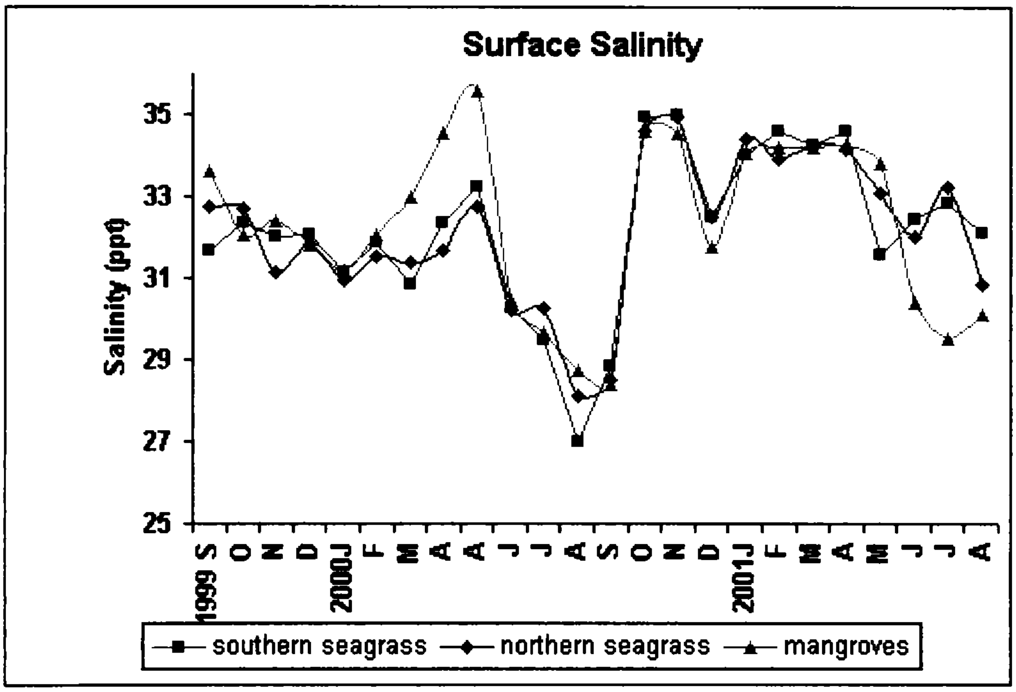


Fig. 3. 3. Monthly variations in S. salinity at the three study regions

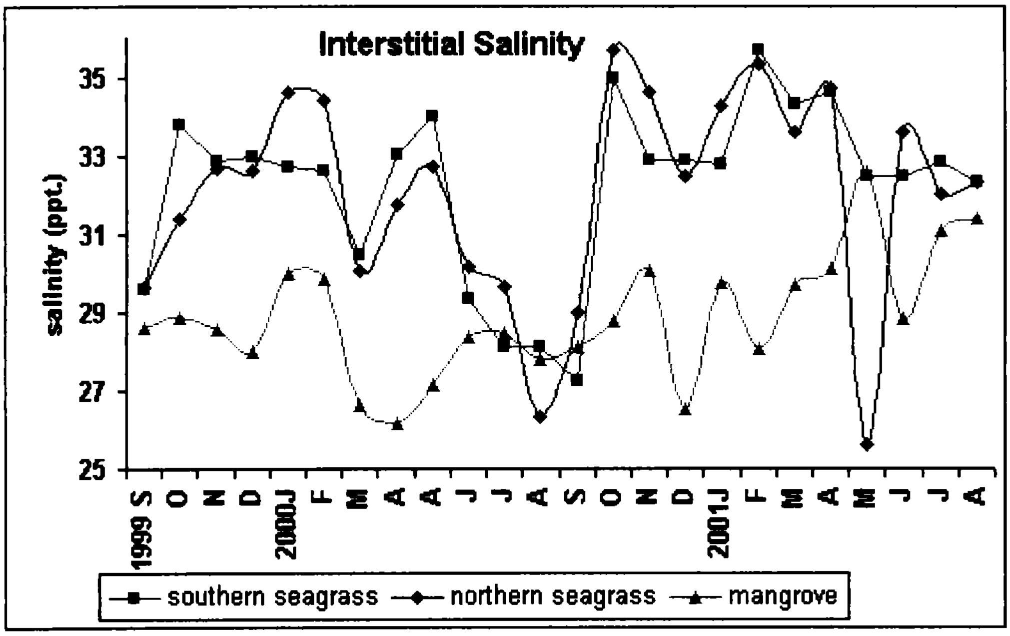


Fig. 3. 4. Monthly variations in In. salinity at the three study regions

The seasonal variations were very low at all the three areas (Table 3. 1. 5).

3. 1. 4. Dissolved oxygen (ml/l)

The lowest value of dissolved oxygen was noticed at area 1, area 2 and area 3 during November 1999 (2.33ml/l), January 2000 (3.13ml/l) and November 1999 (1.25ml/l) respectively. The highest value was noticed in October 2000 for all areas, and the magnitude of values were 6.45ml/l for area 1, 5.5ml/l for area 2 and 4.35ml/l for area 3 (Fig. 3. 6).

The average seasonal value was lowest in 2nd year pre-monsoon (3.1ml/l) and highest in 1st year pre-monsoon (3.9ml/l) at area 1. At area 2, the lowest value was noticed in 1st year post-monsoon (4ml/l) and the highest in 2nd year post-monsoon (4.6ml/l). Area 3 showed the lowest value in 2nd year pre-monsoon (1.9ml/l) and highest in 1st year monsoon (3.5ml/l) (Table 3. 1. 6).

3. 1. 5. Nutrients (µg at /l)

3. 1. 5. 1. Silicates

Surface: At southern seagrass area, the surface silicates varied from 1 µg at /l (June 2000) to 9.5 µg at /l (May 2001). At the northern seagrass area, the value ranged from 1 µg at /l (October 2000) to 5.67 µg at /l (March 2000). Minimum surface silicates recorded at the mangrove area was 1.11 µg at /l (June 2000) and the maximum was 6 µg at /l (March 2001) (Fig. 3. 7).

The minimum average seasonal value of 1.8 µg at /l was noticed in monsoon of 2nd year and the maximum, 7 µg at /l in pre-monsoon of 2nd year at the southern seagrass area. The minimum and maximum seasonal averages at the northern seagrass area were 1.6 µg at /l (1st year post-monsoon) and 3.6 µg at /l (1st year pre-monsoon) respectively. The mangrove area recorded a minimum value of 1.7 µg at /l during 2nd year

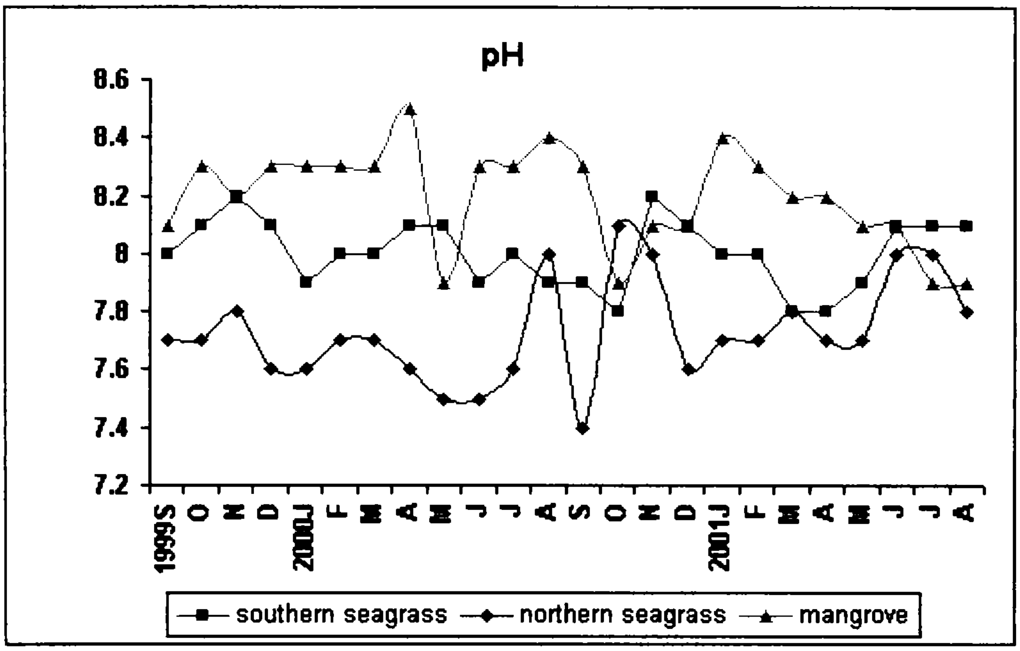


Fig. 3. 5. Monthly variations in pH at the three study regions

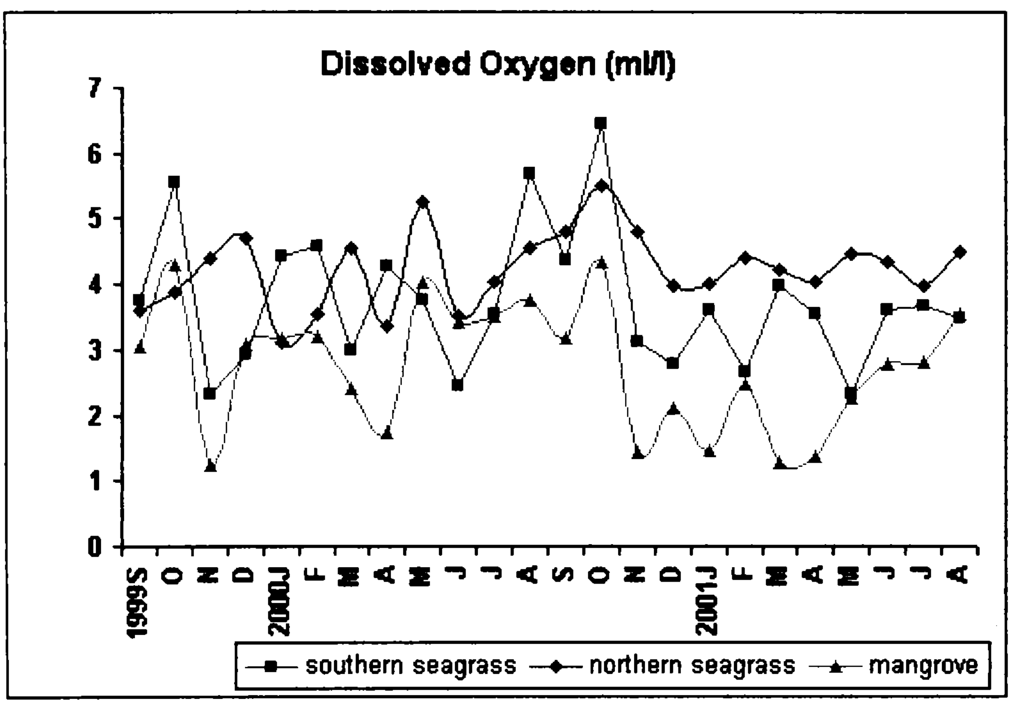


Fig. 3. 6. Monthly variations in D. O. at the three study regions

monsoon and a maximum of 4.6 μg at /l during 2nd year pre-monsoon (Table 3. 1. 7).

Interstitial: The range in interstitial silicates noticed at area 1, area 2 and area 3 were 1.56 μg at /l (June 2001) to 6.4 μg at /l (May 2001), 1.45 μg at /l (December 2000) to 6.7 μg at /l (April 2001) and 2.67 μg at /l (December 2000) to 7.88 μg at /l (May 2001) respectively (Fig. 3. 8).

The average seasonal value was lowest in 2nd year monsoon (2.4 μg at /l) and highest in 2nd year pre-monsoon (4.4 μg at /l) at area 1. At area 2, the lowest value was noticed in 2nd year monsoon (2.3 μg at /l) and the highest in 2nd year pre-monsoon (5 μg at /l). Area 3 showed the lowest value in 1st year post-monsoon (4.3 μg at /l) and highest in 2nd year pre-monsoon (7.3 μg at /l) (Table 3. 1. 8).

3. 1. 5. 2. Phosphates

Surface: At southern seagrass area, the surface phosphates varied from 0.75 μg at /l (April 2000) to 4.4 μg at /l (April 2001). At the northern seagrass area, the value ranged from 0.86 μg at /l (February 2001) to 4.5 μg at /l (October 1999). Minimum surface phosphates, recorded at the mangrove area was 0.75 μg at /l (April 2000) and the maximum was 2.7 μg at /l (May 2001) (Fig. 3. 9).

Seasonal variations of phosphate were very low at all three areas, when compared to that of other parameters (Table 3. 1. 9).

Interstitial: The range in interstitial phosphates noticed at area 1, area 2 and area 3 were 3μg at /l (March 2001) to 24.8 μg at /l (April 2000), 3.15 μg at /l (July 2000) to 19 μg at /l (February 2001) and 2.57μg at /l (January 2001) to 35 μg at /l (February 2000) respectively (Fig. 3. 10).

The average seasonal value was lowest in 2nd year post-monsoon

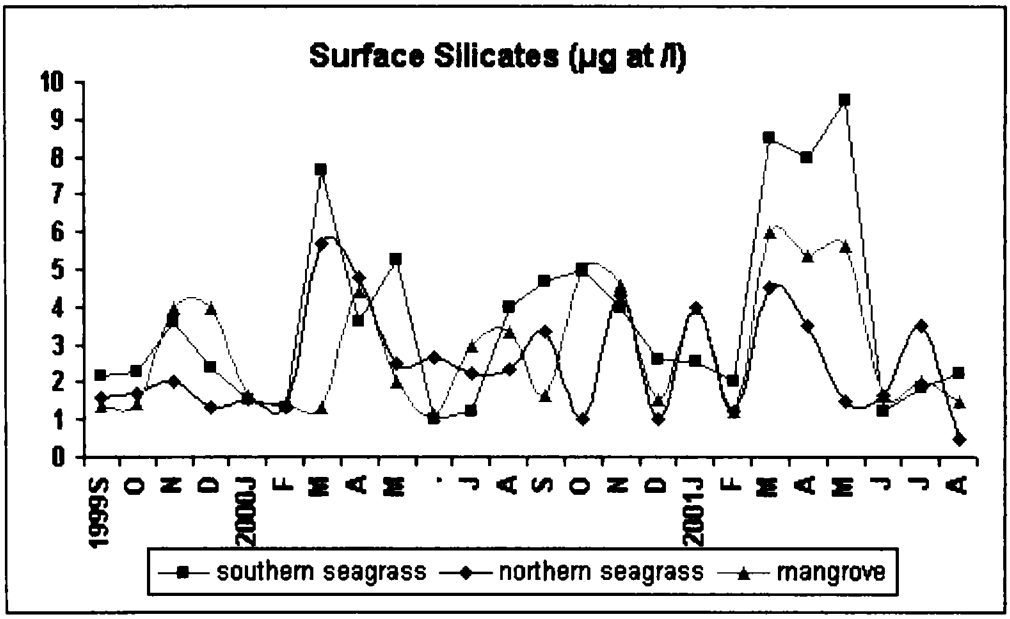


Fig. 3. 7. Monthly variations in S. silicates at the three study regions

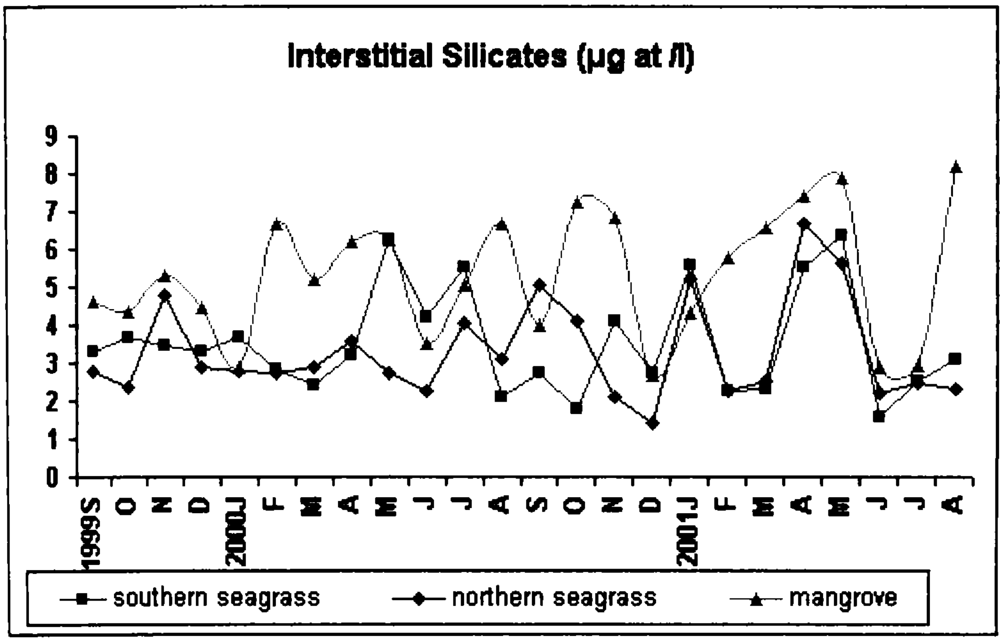


Fig. 3. 8. Monthly variations in In. silicates at the three study regions

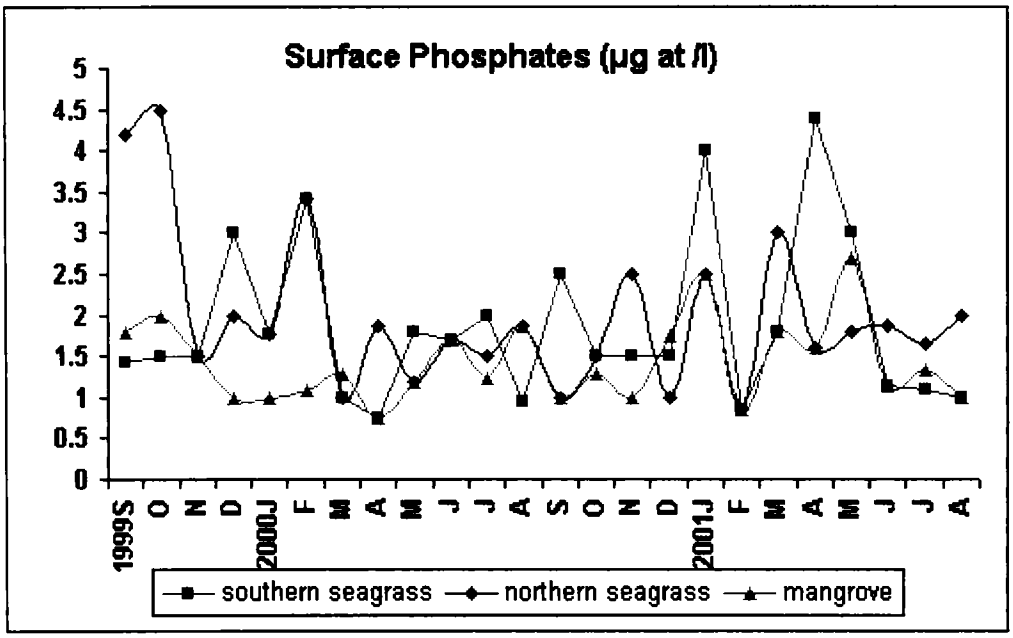


Fig. 3. 9. Monthly variations in S. phosphates at the three study regions

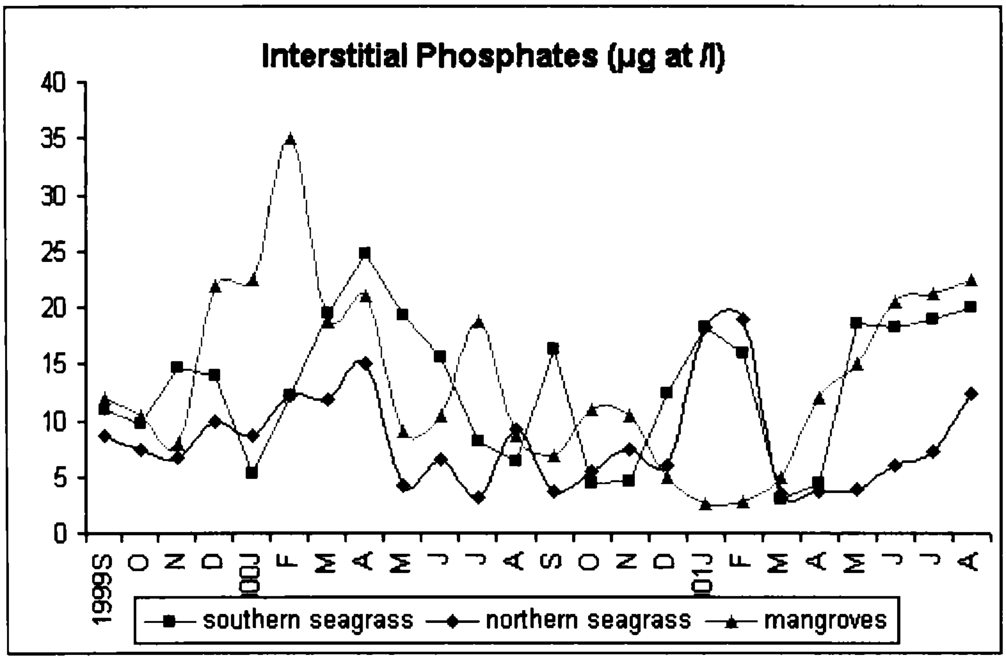


Fig. 3. 10. Monthly variations in In. phosphates at the three study regions

(10 μg at /l) and highest in 2nd year monsoon (19.1 μg at /l) at area 1. At area 2, the lowest value was noticed in 1st year monsoon (5.6 μg at /l) and the highest in 1st year pre-monsoon (10.9 μg at /l). Area 3 showed the lowest value in 2nd year post-monsoon (7.3 μg at /l) and highest in 2nd year monsoon (21.4 μg at /l) (Table 3. 1. 10).

3. 1. 5. 3. Nitrite-Nitrogen

Surface: At southern seagrass area, the surface nitrites varied from 0.17 μg at /l (February 2000) to 2.5 μg at /l (March 2001). At the northern seagrass area, the value ranged from 0.05 μg at /l (November 2000) to 2.5 μg at /l (February 2001). Minimum surface nitrites recorded at the mangrove area, was 0.12 μg at /l (March 2000) and the maximum was 3.75 μg at /l (February 2001) (Fig. 3. 11).

The lowest average seasonal value was observed in the 1st year pre-monsoon for all three areas (0.3 μg at /l, 0.4 μg at /l and 0.3 μg at /l for area 1, 2 and 3 respectively) and the highest in 2nd year pre-monsoon (2.1 μg at/l, 1.5 μg at /l and 1.9 μg at /l for area 1, 2 and 3 respectively) (Table 3. 1. 11).

Interstitial: The range in interstitial nitrites observed at area 1, area 2 and area 3 were 0.29μg at /l (August 2000) to 6.67 μg at /l (May 2001), 0.92 μg at /l (November 1999) to 8.65 μg at /l (February 2001) and 0.56 μg at /l (December 2000) to 7.5 μg at /l (April 2001) respectively (Fig. 3. 12).

The lowest average seasonal value was 0.9 μg at /l at area 1 (in both 1st year pre-monsoon and monsoon). The lowest value was noticed in 2nd year monsoon (2.1 μg.at./) at area 2 and 1st year monsoon (1.1 μg at /l) at area 3. The highest seasonal averages were seen in 2nd year pre-monsoon (5.1 μg at /l, 5.1 μg at /l and 3.6 μg at /l respectively for area 1, 2 and 3) (Table 3. 1. 12).

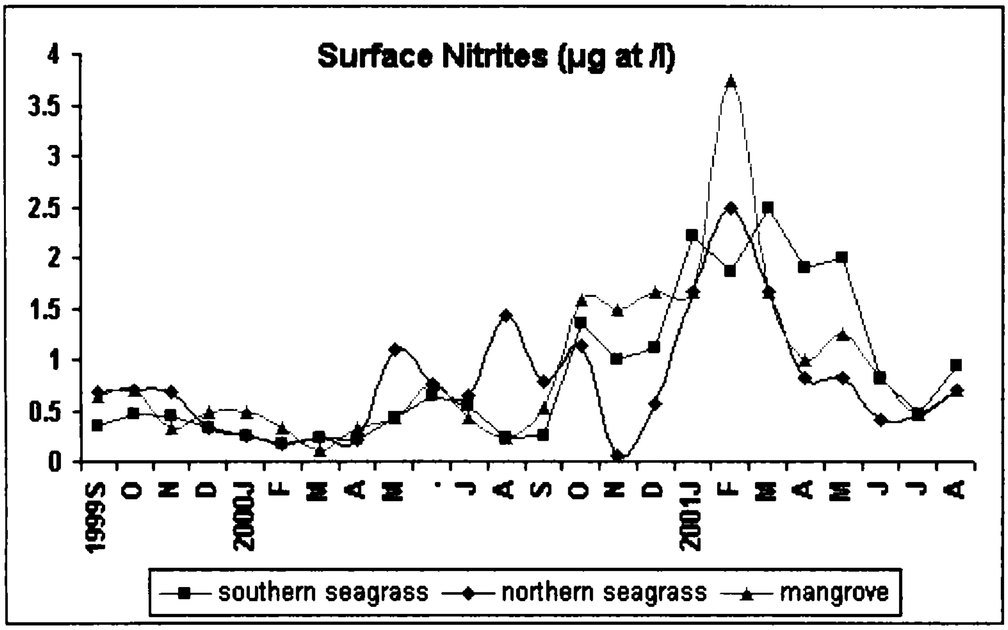


Fig. 3. 11. Monthly variations in S. nitrites at the three study regions

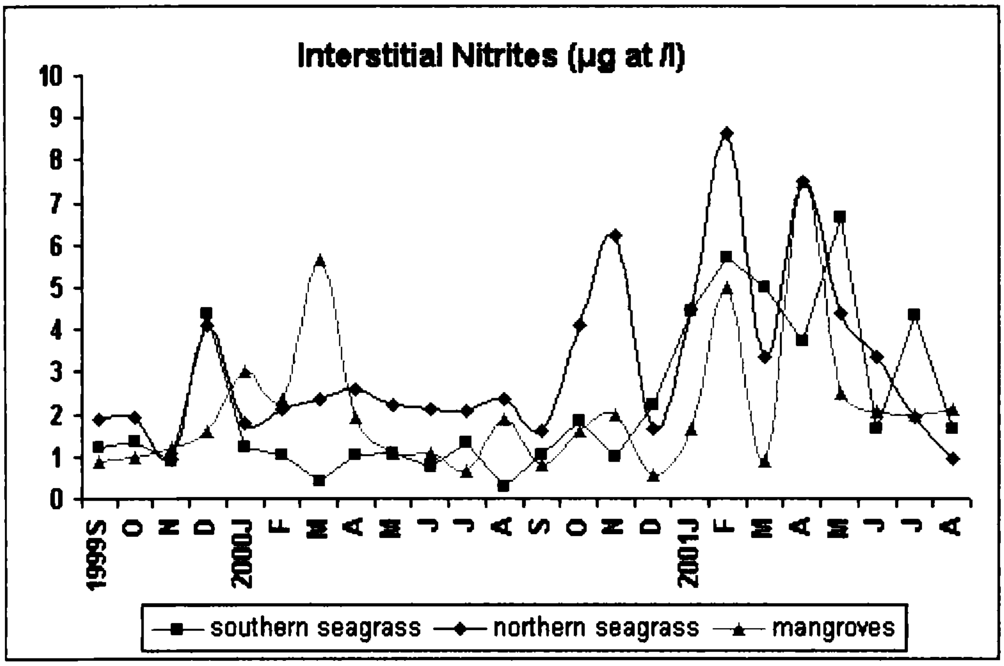


Fig. 3. 12. Monthly variations in In. nitrites at the three study regions

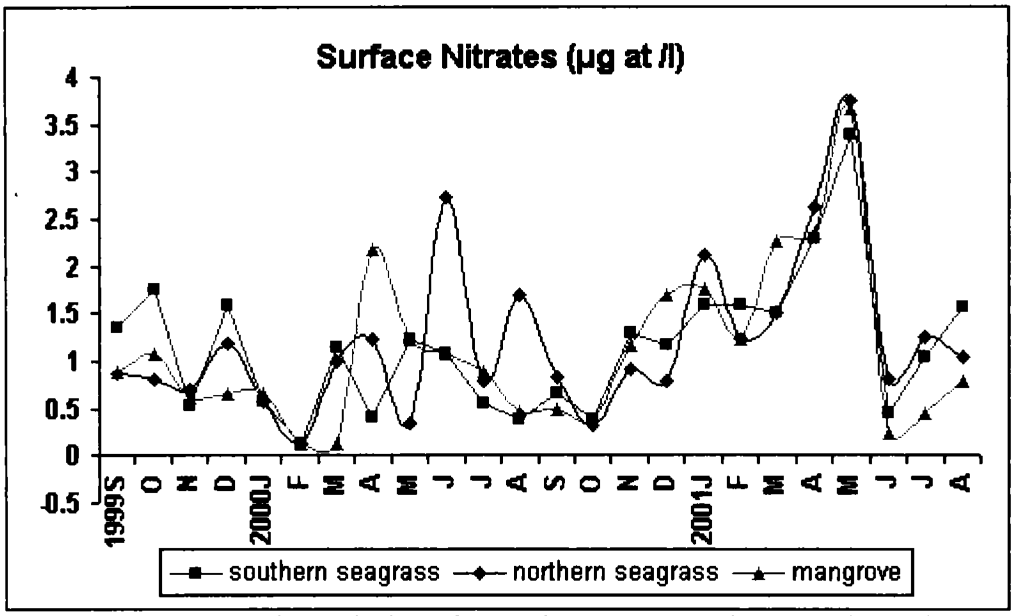


Fig. 3. 13. Monthly variations in S. nitrates at the three study regions

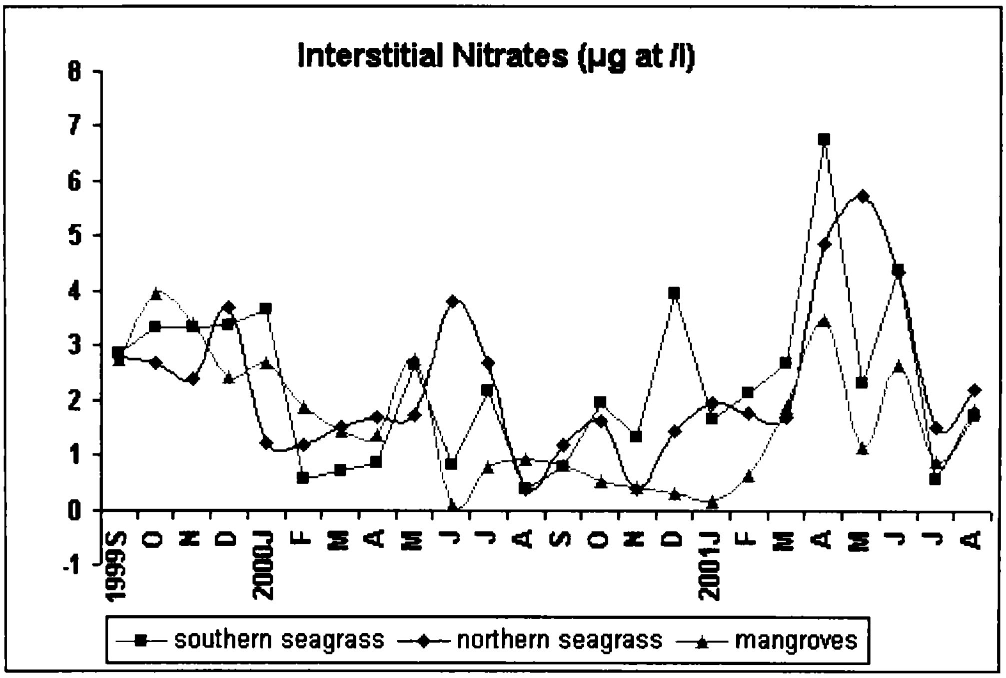


Fig. 3. 14. Monthly variations in In. nitrates at the three study regions

Table 3. 1. Seasonal average of hydrographic parameters

Year	Season	area 1	area 2	area 3
1. Atmospheric temperature (°C)				
year 1	post-monsoon	28.4	27.2	27.5
	pre-monsoon	28.6	29.0	29.6
	monsoon	29.8	28.1	29.8
year 2	post-monsoon	30.8	28.2	29.0
	pre-monsoon	30.5	29.4	29.6
	monsoon	29.2	26.7	27.6
2. Surface water temperature (°C)				
year 1	post-monsoon	28.4	27.8	28.3
	pre-monsoon	29.2	28.9	29.4
	monsoon	28.5	28.3	28.4
year 2	post-monsoon	28.9	27.5	28.6
	pre-monsoon	29.8	29.1	28.7
	monsoon	27.7	27.6	28.2
3. Surface salinity (ppt.)				
year 1	post-monsoon	31.9	31.7	31.9
	pre-monsoon	32.1	31.9	33.8
	monsoon	28.9	29.3	29.3
year 2	post-monsoon	34.1	34.1	33.8
	pre-monsoon	33.8	33.9	34.2
	monsoon	32.5	32.1	30.0
4. Interstitial salinity (ppt.)				
year 1	post-monsoon	33.1	32.8	28.9
	pre-monsoon	32.5	32.2	27.5
	monsoon	28.2	28.8	28.2
year 2	post-monsoon	33.4	34.3	28.8
	pre-monsoon	34.3	32.3	30.1
	monsoon	32.5	32.6	30.4

Table 3. 1. contd…

Year	Season	area 1	area 2	area 3
5. pH				
year 1	post-monsoon	8.1	7.7	8.3
	pre-monsoon	8.1	7.6	8.3
	monsoon	7.9	7.6	8.3
year 2	post-monsoon	8.0	7.9	8.1
	pre-monsoon	7.9	7.7	8.2
	monsoon	8.1	7.9	8.0
6. Dissolved oxygen (ml/l)				
year 1	post-monsoon	3.8	4.0	3.0
	pre-monsoon	3.9	4.2	2.9
	monsoon	4.0	4.2	3.5
year 2	post-monsoon	4.0	4.6	2.3
	pre-monsoon	3.1	4.3	1.9
	monsoon	3.6	4.3	3.0
7. Surface silicates (µg at /l)				
year 1	post-monsoon	2.5	1.6	2.8
	pre-monsoon	4.5	3.6	2.3
	monsoon	2.7	2.6	2.3
year 2	post-monsoon	3.5	2.6	3.8
	pre-monsoon	7.0	2.7	4.6
	monsoon	1.8	1.9	1.7
8. Interstitial silicates (µg at /l)				
year 1	post-monsoon	3.5	3.2	4.3
	pre-monsoon	3.8	3.1	5.9
	monsoon	3.5	4.1	5.2
year 2	post-monsoon	3.8	2.9	4.6
	pre-monsoon	4.4	5.0	7.3
	monsoon	2.4	2.3	4.7
9. Surface phosphates (µg at /l)				
year 1	post-monsoon	1.9	2.4	1.4
	pre-monsoon	1.7	1.9	1.1
	monsoon	1.8	1.5	1.5
year 2	post-monsoon	2.1	1.9	1.6
	pre-monsoon	2.5	1.8	1.7
	monsoon	1.1	1.8	1.2

Table 3. 1. contd...

Year	Season	area 1	area 2	area 3
10. Interstitial phosphates (μg at /l)				
year 1	post-monsoon	10.9	8.2	15.8
	pre-monsoon	18.9	10.9	20.9
	monsoon	11.6	5.6	11.2
year 2	post-monsoon	10.0	9.3	7.3
	pre-monsoon	10.5	7.5	8.7
	monsoon	19.1	8.6	21.4
11. Surface nitrite (μg at /l)				
year 1	post-monsoon	0.4	0.5	0.5
	pre-monsoon	0.3	0.4	0.3
	monsoon	0.4	0.9	0.5
year 2	post-monsoon	1.4	0.9	1.6
	pre-monsoon	2.1	1.5	1.9
	monsoon	0.8	0.5	0.7
12. Interstitial nitrite (μg at /l)				
year 1	post-monsoon	2.0	2.2	1.7
	pre-monsoon	0.9	2.4	2.9
	monsoon	0.9	2.0	1.1
year 2	post-monsoon	2.6	4.1	1.4
	pre-monsoon	5.1	5.1	3.6
	monsoon	2.6	2.1	2.1
13. Surface nitrate (μg at /l)				
year 1	post-monsoon	1.1	0.8	0.8
	pre-monsoon	0.7	0.7	0.9
	monsoon	0.7	1.5	0.7
year 2	post-monsoon	1.1	1.0	1.3
	pre-monsoon	2.2	2.3	2.4
	monsoon	1.0	1.0	0.5
14. Interstitial nitrate (μg at /l)				
year 1	post-monsoon	3.4	2.5	3.1
	pre-monsoon	1.2	1.5	1.9
	monsoon	1.0	2.0	0.7
year 2	post-monsoon	2.2	1.3	0.4
	pre-monsoon	3.5	3.5	1.8
	monsoon	2.2	2.7	1.8

3. 1. 5. 4. Nitrate-Nitrogen

Surface: At southern seagrass area, the surface nitrates varied from 0.13 µg at /l (February 2000) to 3.4 µg at /l (May 2001). At the northern seagrass area, the value ranged from 0.13 µg at /l (February 2000) to 3.75 µg at /l (May 2001). Minimum surface nitrates recorded at the mangrove area was 0.13 µg at /l (February 2000) and the maximum 3.67 µg at /l (May 2001) (Fig. 3. 13).

The variations were not significant spatially. The highest value was observed in the 2^{nd} year pre-monsoon (2.2 µg at /l, 2.3 µg at /l and 2.4 µg at /l for area 1, 2, 3 respectively) (Table 3. 1. 13).

Interstitial: The range in interstitial nitrates observed at area 1, area 2 and area 3 were 0.4µg at /l (August 2000) to 6.75 µg at /l (April 2001), 0.38 µg at /l (August 2000) to 5.8 µg at /l (May 2001) and 0.1 µg at /l (June 2000) to 3.97 µg at /l (October 1999) respectively (Fig. 3. 14).

The seasonal averages ranged from 1 µg at /l to 3.5 µg at /l, 1.3 µg at/l to 3.5 µg at /l and 0.4 µg at /l to 3.1 µg at /l at area 1, 2 and 3 (Table 3. 1. 14).

3. 2. Comparison of stations based on hydrographic parameters

3. 2. 1. Atmospheric temperature

Average atmospheric temperature was maximum (29.49°C) at station 1 and 2 and least (28.12°C) at stations 3 and 4. Atmospheric temperature was consistently distributed over the period of study with coefficient of variation very low 4.72% (st.5, 6) - 4.93% (St.1-4). Average temperature at stations 1 and 2 were significantly different from that at stations 3 and 4 ($t_{(46,1\%)} = 3.273$, $P<0.01$) (Fig. 3. 15. a).

3. 2. 2. Water temperature

Water temperature was highest at station 1 and 2 (28.73°C) and lowest at station 3 (28.15°C) with low temporal variation (C.V.% -3.01 (station 5) - 3.72 (station 1). Water temperature did not show large-scale variations between stations (P>0.05) (Fig. 3. 15. b).

3. 2. 3. Surface salinity

Average surface salinity ranged between 32.35 ppt. (station 5) and 32.16 ppt. (station 4). Temporal variations in the surface salinity ranged between C. V % 5.53 (station 4) and 6.39 (station 5). Stationwise difference in the surface salinity distribution was not highly significant (P> 0.05) (Fig. 3. 15. c).

3. 2. 4. Interstitial salinity

Among 6 stations, interstitial salinity on an average ranged between 32.24 ppt. (station 1) and 28.9 ppt. (station 5). Temporal variations were higher than that of surface salinity variations, which ranged between C. V. % 5.27 (station 5) and 8.17 (station 4). Values at stations 1, 2, 3 and 4 were significantly different from that at stations 5 and 6 ($t_{(22,\ 1\ \%)} > 4.507$, P<0.01) (Fig. 3. 15. d).

3. 2. 5. pH

Temporal distribution of pH showed that average pH was least at stations 3 and 4 (7.73) and maximum at stations 5 and 6 (8.2). Variations of pH were low over the study period with maximum variations of 2.28% at st.3 and 4. pH at stations 1 and 2 were significantly different from the other stations (P<. 01) and pH at stations 3 and 4 were highly different from stations 5 and 6 (P<0.01). In both cases $t_{(46,\ 1\ \%)} > 2.578$, P<0.01 (Fig. 3. 15. e).

3.2.6. Dissolved oxygen (DO)

Dissolved oxygen values were least at stations 5 and 6 (2.74 ml/l) and highest at stations 3 and 4 (4.25 ml/l). DO was more heterogeneously distributed over the study period with least variation C. V. at stations 3 and 4 (C.V.=13.42%) and maximum variation at stations 5 and 6 (C.V.=34%). Average dissolved oxygen values at stations 1 and 2 were significantly different from that at station 3, 5 and 6. Dissolved oxygen values at st.3 & 4 were significantly different from that at stations 5 and 6 ($t_{(46, 5\%)} > 1.96$, ($P<0.05$) (Fig. 3. 15. f).

3.2.7. Surface silicates

Coefficient of variation for surface silicates was maximum at stations 1 and 2 (66.26%) and least at stations 3 and 4 (54.82%). Average surface silicate was maximum at stations 1 and 2 (3.68 µg at /l) and minimum at station 3 and 4 (2.49 µg at /l). It was observed that stations 3 and 4 were highly significantly different from station 1 and 2 ($t_{(46, 5\%)} > 1.96$, $P< 0.05$) (Fig. 3. 15. g).

3.2.8. Interstitial silicate

Average silicate was distributed more or less similarly at stations 1-4 with a range of 3.28 µg at /l (station 3) to 3.57 µg at /l (station 2) where as the values at stations 5 and 6 were high [5.29 µg at /l (station 6) - 5.38 µg at /l (station 5)]. A reverse pattern of spatial distribution was observed with respect to temporal variation [C.V.% ranges between 29.84% (st.6) and 40.42% (st.3)]. Average interstitial silicate at stations 5 and 6 were significantly different from that at stations 1 to 4 ($t_{(46, 1\%)} > 3.92$, $P< 0.01$) (Fig. 3. 15. h).

3. 2. 9. Surface phosphates

This parameter on the average showed least values (1.44 μg at /l) at stations 5 and 6 and maximum value (1.99 μg at /l) at stations 3 and 4 with seasonal variation ranging between 34.29% (station.5, 6) and 52.07% (station 1 and 2). Phosphate concentration at stations 3 and 4 were significantly higher than that at stations 5 and 6 ($t_{(46, 5\%)} > 2.54$, P<. 05) (Fig. 3. 15. i).

3. 2. 10. Interstitial phosphate

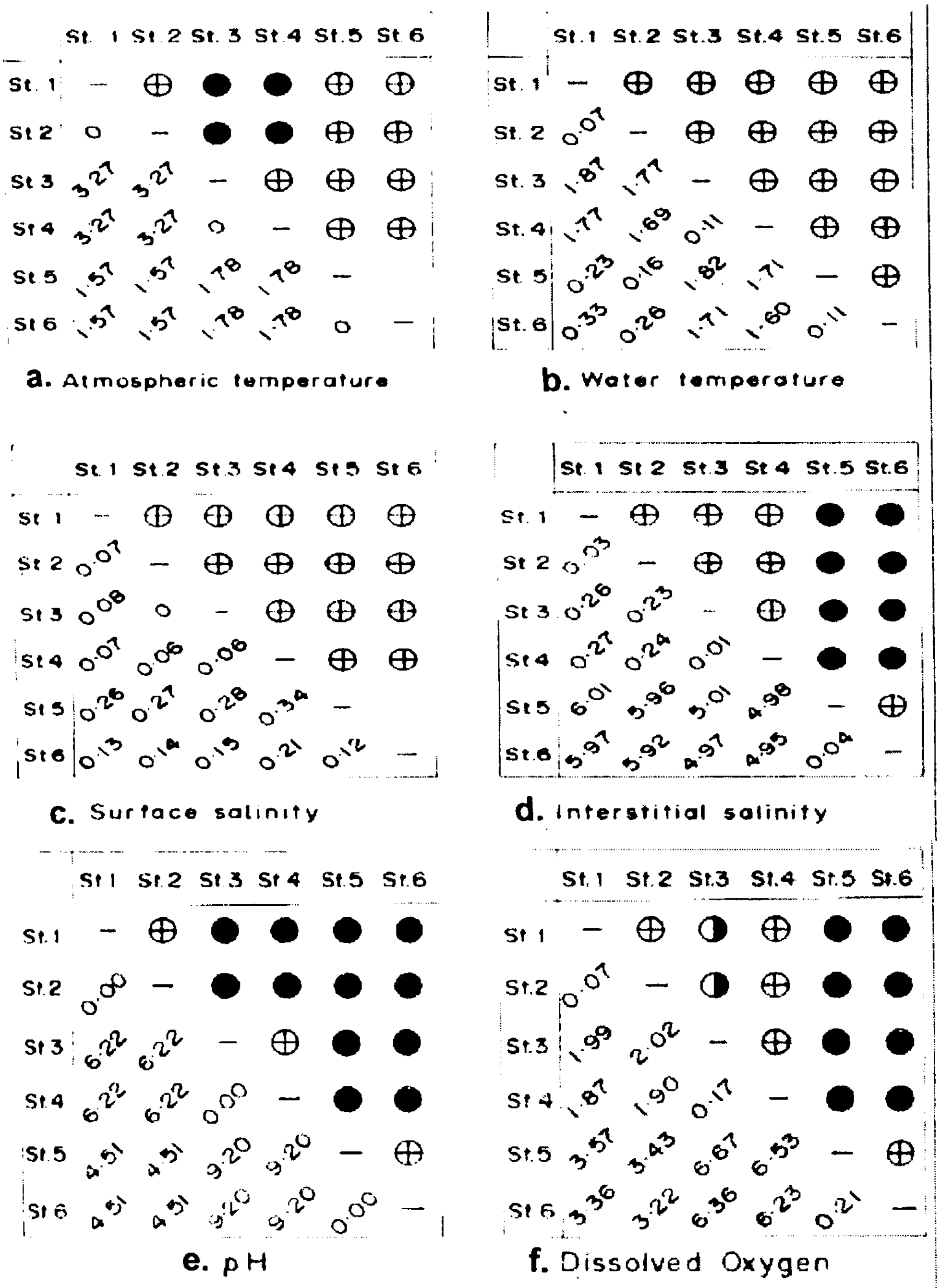
Concentration of interstitial phosphate was nearly 4 times at stations 3 (8.24 μg at /l) and 4 (8.47 μg at /l) and more than 6 times at stations 1, 2, 5 and 6 (13.03 μg at /l (station 1) - 13.81 μg at /l (station 5, 6)) compared to maximum surface phosphate. Temporal variation at station 6 showed a gradual increase in the trend for variations from stations 1and 2 (45.79%) to stations 5 and 6 (56.29%) (Fig. 3. 15. j).

3. 2. 11. Surface nitrite

It showed a reverse form of spatial distribution compared to surface phosphates with least concentration (0.79 μg at /l) at stations 3 and 4 and highest (0.92μg at /l) at stations 5 and 6. Same was the trend for the temporal variation (least variation at stations 3, 4 (71.12%) and highest at stations 5 and 6 (83.58%). Even though the values were not temporally homogeneous, the concentrations at different stations were not significantly different. (P> 0.05) (Fig. 3. 15. k).

3. 2. 12. Interstitial nitrite

Interstitial nitrite was least at station 5 (2.13 μg at /l) and highest (3.17 μg at /l) at station 4. Stations 1 and 2 showed highest temporal variation (C.V.% -79.75%) where as stations 3 and 4, the least



⊕ — t statistic is not significant, $t < 2.074$

● — $t \geq 2.578$, t is significant at 1 % level $P < .01$

◑ — $t \geq 1.96$ & $t < 2.578$, t is significant at 5 % level $P < 0.05$

Fig.3.15 a-f Trellis diagram for comparing between stations based on atmospheric temperature, surface water temperature, surface salinity, interstitial salinity, pH and dissolved oxygen.

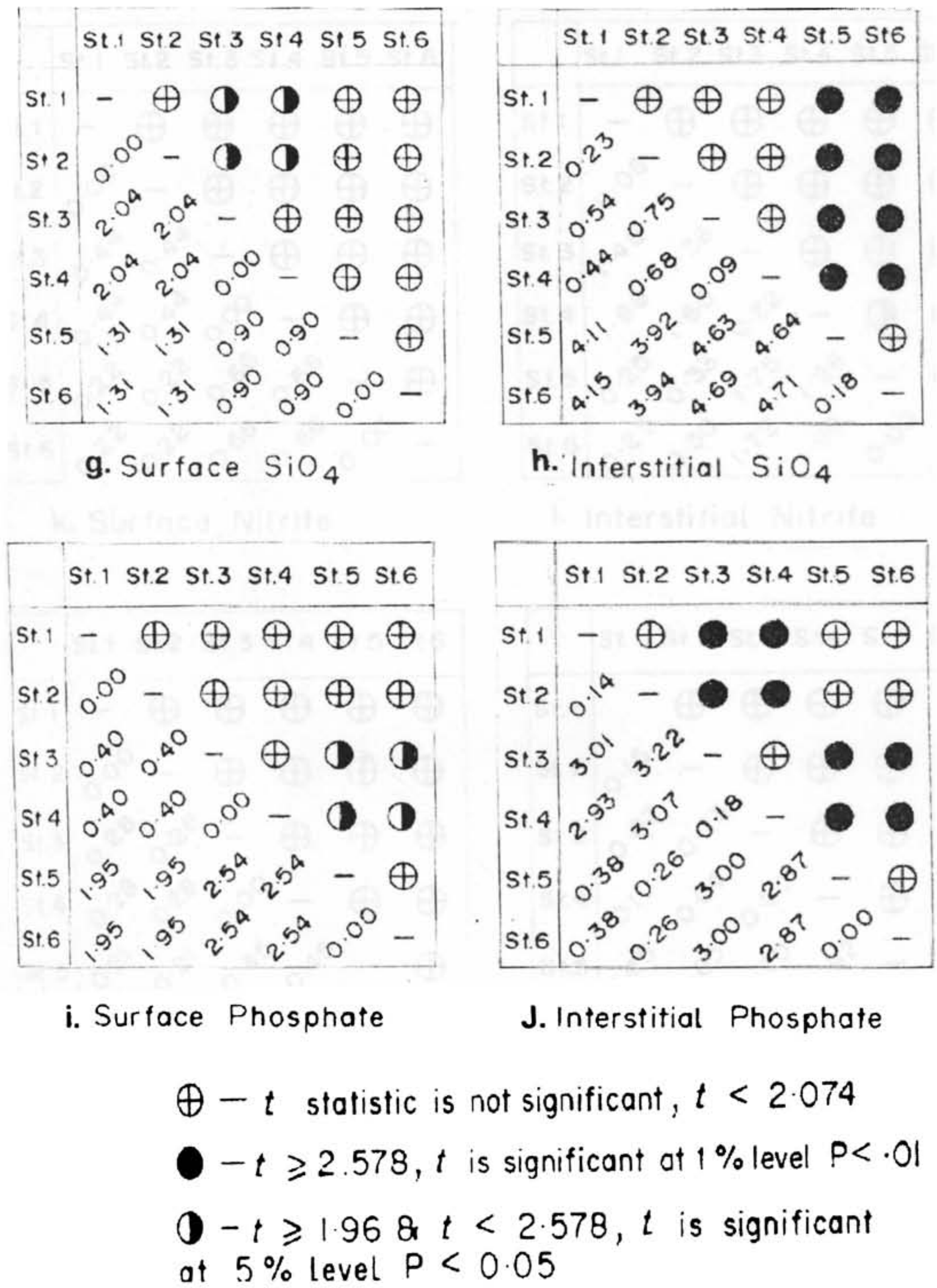


Fig.3.15 contd... g-j Trellis diagram for comparing between stations based on surface silicate, interstitial silicate, surface phosphate and interstitial phosphate.

	St.1	St.2	St.3	St.4	St.5	St.6
St.1	–	⊕	⊕	⊕	⊕	⊕
St.2	0.00	–	⊕	⊕	⊕	⊕
St.3	0.44	0.44	–	⊕	⊕	⊕
St.4	0.44	0.44	0.00	–	⊕	⊕
St.5	0.22	0.22	0.66	0.66	–	⊕
St.6	0.22	0.22	0.66	0.66	0.00	–

k. Surface Nitrite

	St.1	St.2	St.3	St.4	St.5	St.6
St.1	–	⊕	⊕	⊕	⊕	⊕
St.2	0.08	–	⊕	⊕	⊕	⊕
St.3	1.48	1.38	–	⊕	⊕	⊕
St.4	1.68	1.60	0.22	–	◑	⊕
St.5	0.25	0.33	1.75	1.98	–	⊕
St.6	0.25	0.30	1.72	1.95	0.03	–

l. Interstitial Nitrite

	St.1	St.2	St.3	St.4	St.5	St.6
St.1	–	⊕	⊕	⊕	⊕	⊕
St.2	0.00	–	⊕	⊕	⊕	⊕
St.3	0.28	0.28	–	⊕	⊕	⊕
St.4	0.28	0.28	0.00	–	⊕	⊕
St.5	0.21	0.21	0.45	0.45	–	⊕
St.6	0.21	0.21	0.45	0.45	0.00	–

m. Surface Nitrate

	St.1	St.2	St.3	St.4	St.5	St.6
St.1		⊕	⊕	⊕	⊕	⊕
St.2	0.15	–	⊕	⊕	⊕	⊕
St.3	0.07	0.23	–	⊕	⊕	⊕
St.4	0.11	0.04	0.20	–	⊕	⊕
St.5	1.65	1.85	1.70	1.92	–	⊕
St.6	1.53	1.72	1.57	1.78	0.15	–

n. Interstitial Nitrate

⊕ – t statistic is not significant, $t < 2.074$

● – $t \geq 2.578$, t is significant at 1 % level $P < .01$

◑ – $t \geq 1.96$ & $t < 2.578$, t is significant at 5 % level $P < 0.05$

Fig.3.15 contd... k-n Trellis diagram for comparing between stations based on surface nitrite, interstitial nitrate, surface nitrate and interstitial nitrate.

Table 3. 2. Avg. (X), standard deviation (S. D.) and co-efficient of variation (C.V.%) of environmental/ hydrographic parameters at station 1 to 6.

Station 1	X		S.D	C.V. (%)	LCL	UCL
Atmospheric temperature (°C)	29.488	±	1.453	4.926	26.640	32.335
Water temperature (°C)	28.725	±	1.069	3.720	26.631	30.819
Surface salinity (ppt.)	32.200	±	1.954	6.067	28.371	36.029
Interstitial salinity (ppt.)	32.237	±	2.186	6.782	27.952	36.523
pH	8.004	±	0.117	1.463	7.775	8.234
Dissolved oxygen (ml/l)	3.767	±	1.026	27.233	1.756	5.777
Surface silicates (µg at /l)	3.680	±	2.438	66.261	-1.099	8.458
Surface phosphates (µg at /l)	1.881	±	0.979	52.068	-0.039	3.800
Surface nitrites (µg at /l)	0.869	±	0.706	81.309	-0.516	2.253
Surface nitrates (µg at /l)	1.155	±	0.711	61.546	-0.238	2.547
Interstitial silicates (µg at /l)	3.481	±	1.376	39.536	0.784	6.179
Interstitial phosphates (µg at /l)	13.027	±	6.037	46.344	1.194	24.86
Interstitial nitrites (µg at /l)	2.248	±	1.793	79.745	-1.266	5.762
Interstitial nitrates (µg at /l)	2.260	±	1.506	66.624	-0.691	5.211

Station 2						
Atmospheric temperature (°C)	29.488	±	1.453	4.926	26.640	32.335
Water temperature (°C)	28.704	±	1.082	3.770	26.583	30.825
Surface salinity (ppt.)	32.196	±	1.928	5.988	28.417	35.975
Interstitial salinity (ppt.)	32.217	±	2.191	6.801	27.922	36.511
pH	8.004	±	0.117	1.463	7.775	8.234
Dissolved oxygen (ml/l)	3.746	±	1.064	28.399	1.661	5.831
Surface silicates (µg at /l)	3.680	±	2.438	66.261	-1.099	8.458
Surface phosphates (µg at /l)	1.881	±	0.979	52.068	-0.039	3.800
Surface nitrites (µg at /l)	0.869	±	0.706	81.309	-0.516	2.253
Surface nitrates (µg at /l)	1.155	±	0.711	61.546	-0.238	2.547
Interstitial silicates (µg at /l)	3.573	±	1.373	38.440	0.881	6.265
Interstitial phosphates (µg at /l)	13.275	±	6.079	45.792	1.360	25.190
Interstitial nitrites (µg at /l)	2.289	±	1.809	79.029	-1.257	5.835
Interstitial nitrates (µg at /l)	2.325	±	1.472	63.308	-0.560	5.211

LCL – Lower Confidence limit at 95% confidence

UCL – Upper Confidence limit at 95% confidence

Table 3. 2. contd...

Station 3	**X̄**		**S.D**	**C.V. (%)**	**LCL**	**UCL**
Atmospheric temperature (°C)	28.117	±	1.387	4.933	25.398	30.835
Water temperature (°C)	28.146	±	1.036	3.682	26.115	30.177
Surface salinity (ppt.)	32.196	±	1.782	5.535	28.703	35.688
Interstitial salinity (ppt.)	32.050	±	2.605	8.128	26.944	37.156
pH	7.729	±	0.177	2.287	7.383	8.076
Dissolved oxygen (ml/l)	4.254	±	0.571	13.418	3.135	5.373
Surface silicates (µg at /l)	2.490	±	1.365	54.823	-0.186	5.166
Surface phosphates (µg at /l)	1.994	±	0.932	46.728	0.168	3.820
Surface nitrites (µg at /l)	0.786	±	0.559	71.120	-0.310	1.881
Surface nitrates (µg at /l)	1.219	±	0.826	67.753	-0.400	2.837
Interstitial silicates (µg at /l)	3.27	±	1.324	40.423	0.680	5.871
Interstitial phosphates (µg at /l)	8.237	±	4.390	53.293	-0.367	16.841
Interstitial nitrites (µg at /l)	3.050	±	1.941	63.639	-0.754	6.855
Interstitial nitrates (µg at /l)	2.230	±	1.332	59.709	-0.380	4.840

Station 4						
Atmospheric temperature (°C)	28.117	±	1.387	4.933	25.398	30.835
Water temperature (°C)	28.179	±	1.026	3.641	26.168	30.190
Surface salinity (ppt.)	32.163	±	1.777	5.525	28.680	35.645
Interstitial salinity (ppt.)	32.046	±	2.616	8.165	26.918	37.174
pH	7.729	±	0.177	2.287	7.383	8.076
Dissolved oxygen (ml/l)	4.225	±	0.573	13.567	3.102	5.348
Surface silicates (µg at /l)	2.490	±	1.365	54.823	-.186	5.166
Surface phosphates (µg at /l)	1.994	±	0.932	46.728	.168	3.820
Surface nitrites (µg at /l)	0.786	±	0.559	71.120	-.310	1.881
Surface nitrates (µg at /l)	1.219	±	0.826	67.753	-.400	2.837
Interstitial silicates (µg at /l)	3.310	±	1.256	37.938	.849	5.771
Interstitial phosphates (µg at /l)	8.467	±	4.409	52.070	-.174	17.109
Interstitial nitrites (µg at /l)	3.174	±	1.939	61.104	-.627	6.975
Interstitial nitrates (µg at /l)	2.307	±	1.328	57.559	-.296	4.910

LCL – Lower Confidence limit at 95% confidence

UCL – Upper Confidence limit at 95% confidence

Table 3. 2. contd...

Station 5	**X̄**		**S.D**	**C.V. (%)**	**LCL**	**UCL**
Atmospheric temperature (°C)	28.838	±	1.362	4.723	26.168	31.507
Water temperature (°C)	28.658	±	.863	3.013	26.966	30.351
Surface salinity (ppt.)	32.354	±	2.066	6.385	28.305	36.403
Interstitial salinity (ppt.)	28.900	±	1.522	5.266	25.917	31.883
pH	8.196	±	.167	2.037	7.869	8.523
Dissolved oxygen (ml/l)	2.733	±	.933	34.152	.904	4.563
Surface silicates (µg at /l)	2.886	±	1.598	55.368	-.246	6.018
Surface phosphates (µg at /l)	1.435	±	.492	34.295	.471	2.400
Surface nitrites (µg at /l)	0.917	±	.766	83.581	-.585	2.418
Surface nitrates (µg at /l)	1.108	±	.833	75.246	-.526	2.741
Interstitial silicates (µg at /l)	5.377	±	1.729	32.149	1.989	8.765
Interstitial phosphates (µg at /l)	13.814	±	7.775	56.285	-1.425	29.053
Interstitial nitrites (µg at /l)	2.123	±	1.650	77.685	-1.110	5.356
Interstitial nitrates (µg at /l)	1.612	±	1.122	69.612	-.587	3.812

Station 6						
Atmospheric temperature (°C)	28.838	±	1.362	4.723	26.168	31.507
Water temperature (°C)	28.629	±	.873	3.049	26.918	30.340
Surface salinity (ppt.)	32.280	±	2.053	6.361	28.255	36.304
Interstitial salinity (ppt.)	28.917	±	1.528	5.285	25.922	31.913
pH	8.196	±	.167	2.037	7.869	8.523
Dissolved oxygen (ml/l)	2.791	±	.943	33.784	.943	4.640
Surface silicates (µg at /l)	2.886	±	1.598	55.368	-.246	6.018
Surface phosphates (µg at /l)	1.435	±	.492	34.295	.471	2.400
Surface nitrites (µg at /l)	.917	±	.766	83.581	-.585	2.418
Surface nitrates (µg at /l)	1.108	±	.833	75.246	-.526	2.741
Interstitial silicates (µg at /l)	5.290	±	1.579	29.842	2.196	8.384
Interstitial phosphates (µg at /l)	13.814	±	7.775	56.285	-1.425	29.053
Interstitial nitrites (µg at /l)	2.140	±	1.644	76.811	-1.082	5.362
Interstitial nitrates (µg at /l)	1.661	±	1.118	67.299	-.530	3.853

LCL – Lower Confidence limit at 95% confidence

UCL – Upper Confidence limit at 95% confidence

(61.10%). The nitrite concentration at station 4 was highly different from that at station 5 ($t_{(46, 5\%)} > 1.96$, $P<0.05$) (Fig. 3. 15. l).

3. 2. 13. Surface nitrate

This also showed a pattern of distribution similar to that of phosphate with respect to average values with least concentration (1.11 μg at /l) at stations 5 and 6 and highest concentration (1.22 μg at /l) at stations 3 and 4. Temporal variations were least at stations 1 and 2 (61.55%) and highest (75.25%) at stations 5 and 6. Stationwise comparison showed no significant difference between stations ($t_{(46, 5\%)} < 1.96$, $P> 0.05$) (Fig. 3. 15. m).

3. 2. 14. Interstitial nitrate

On an average the concentration was almost similar at all stations ranging between (1.61 μg at /l (station 5) and 2.33 μg at /l (station 2) with no significant difference between stations ($t_{(46, 5\%)} < 1.96$, $P> 0.05$). Temporal variations were not very low [C.V.% ranged between 57.56% (station 4) and 69.61% (station 5)] (Fig. 3. 15. n).

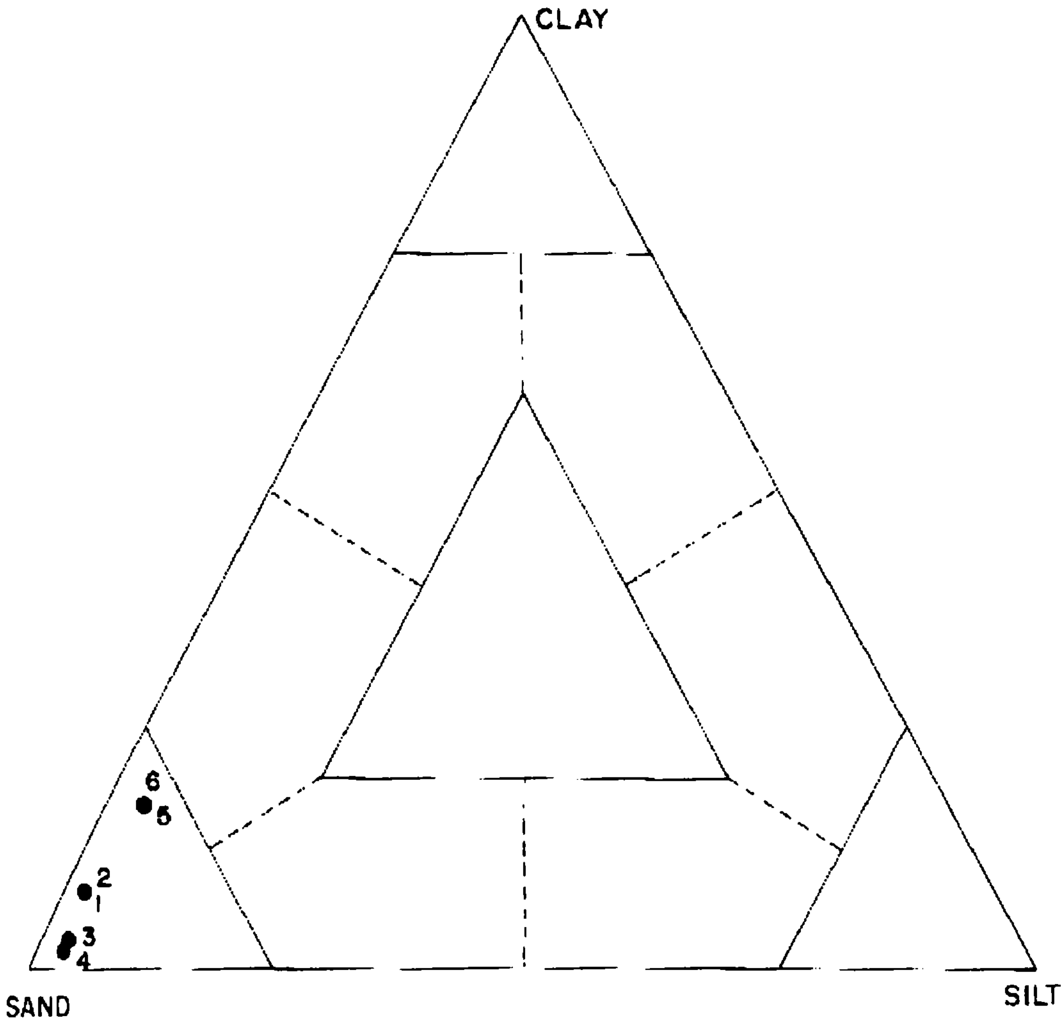
Average ($\overline{X}$) and co-efficient of variation (C.V (%) of environmental/hydrographic parameters at Station 1 to 6 were given in Table 3. 2.

3. 3. Sediment characteristics

3. 3. 1. Sand/ silt/clay fraction

The sediments were analysed for sand, silt and clay fractions, during the study period. At all areas, the substratum was predominated by sand followed by clay and silt in comparatively smaller proportions (Fig. 3. 16).

Monthly sampling revealed that at area 1, the range of sand, silt and clay fraction (%) was 89.26 (March 2001) to 96.15 (December 2000), 1.08



1- station 1	**2- station 2**	**3- station 3**
4- station 4	**5- station 5**	**6- station 6**

Fig. 3. 16. Trellis diagram showing sandy nature of sediment at all stations

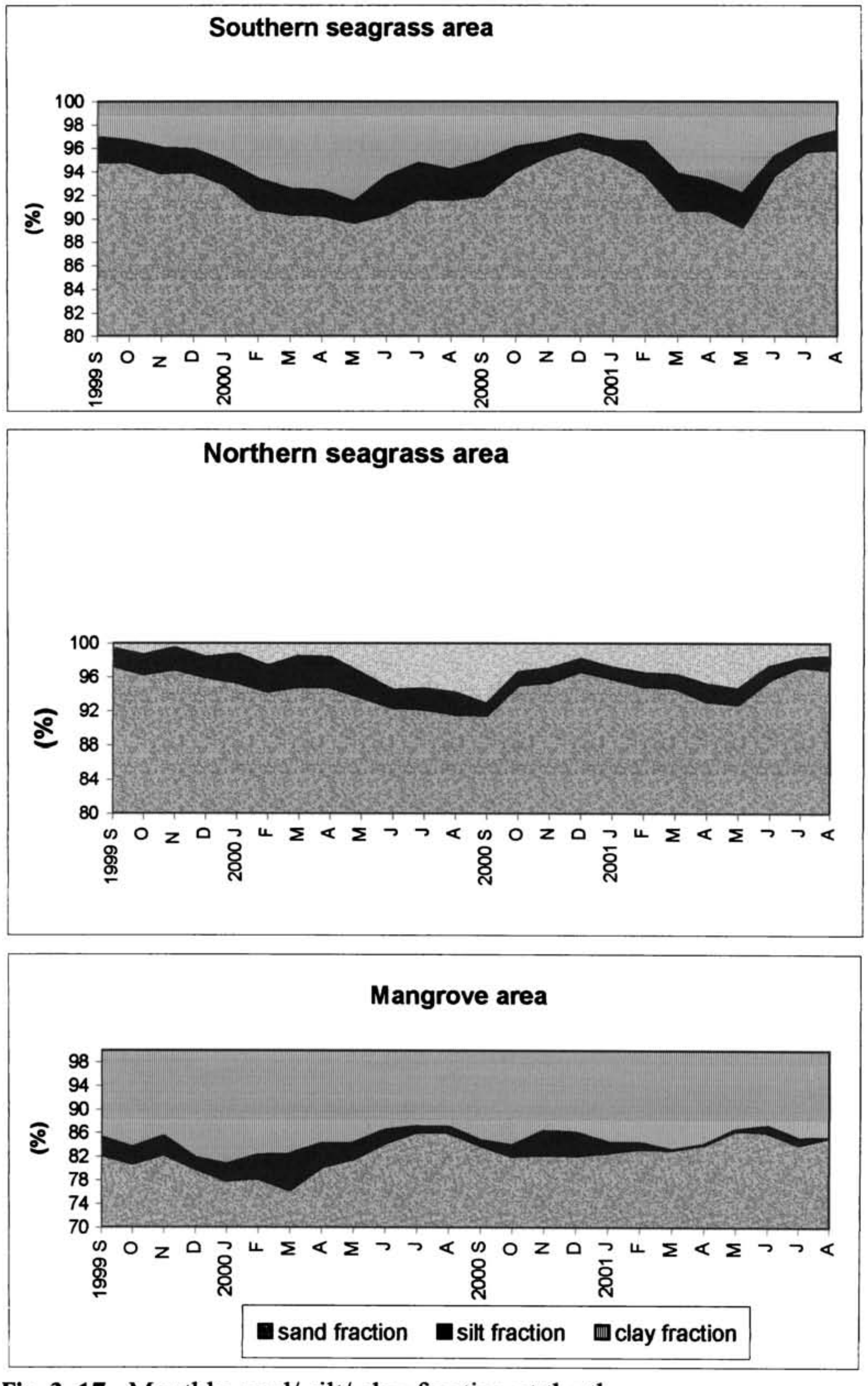


Fig. 3. 17. Monthly sand/ silt/ clay fraction at the three areas

Table 3. 3. Season wise sand/ silt/clay fraction at the three areas

			Sand (%)			Silt (%)			Clay (%)	
Year	**Season**	**area 1**	**area 2**	**area 3**	**area 1**	**area 2**	**area 3**	**area 1**	**area 2**	**area 3**
1999	post-mon	94	96	82	2	3	3	4	1	15
2000	pre-mon	90	94	78	2	4	6	8	2	16
	monsoon	91	91	86	3	1	1	6	8	13
	post-mon	95	96	82	1	1	4	4	3	14
2001	pre-mon	90	92	83	3	2	0	7	6	17
	monsoon	95	96.5	85	1.5	1.5	1	3.5	2	14

Table 3. 4. Season wise organic content (%) at the three areas

Year	**Season**	**area1**	**area 2**	**area 3**
1999	post-monsoon	1.2	0.56	2.8
2000	pre-monsoon	1.5	0.28	2.8
	monsoon	2.06	0.64	2.2
	post-monsoon	1.12	0.32	4.4
2001	pre-monsoon	1.58	0.48	2.8
	monsoon	1.04	0.74	3.2

(December 2000) to 3.19 (June 2000) and 2.48 (August 2001) to 8.56 (May 2000) respectively. At area 2 the range of sand fraction was 91.43 (2000 September) to 97.26 (1999 September). Silt % did not vary significantly at different stations. The observed clay % at station 2 was slightly less than that of area 1. At area 3, mangrove zone, the sand % showed a minimum value of 76.3 (2000 March) to a maximum of 86.4 (March 2001). The monthly values observed at area 3 were comparatively different from the other areas and the clay % showed monthly higher values in the range 12. 8 (June 2001) - 19.3 (2000 January) (Fig.3. 17)

At area 1, the highest value for sand was observed in monsoon and post-monsoon seasons (95-96%) and slightly less in pre-monsoon (90%). Silt percentage remained almost the same during all seasons, showing little variations. In both years comparatively higher percentage of clay was observed in pre-monsoon season. Sand/ silt/ clay fractions of area 2 were almost similar but comparatively more sandy than area 1. Monsoon showed slightly lower values of clay at station 3. Seasonal variations in the sediment structure is given in Table 3. 3.

3. 3. 2. Organic carbon

The organic content of the soil was analysed and found that the monthly range of values (%) at area 1, area 2 and area 3 were 0.90 to 1.95, 0.30 to 0.76 and 2.1 to 4.25 respectively (Fig. 3. 18).

Eventhough significant seasonal pattern in distribution of organic content was not noticed at the study areas (Table 3. 4), annual variations were observed.

3. 4. Rain fall

Rainfall data showed monthly as well as slight annual variations at Minicoy (Fig. 3. 19). The monsoon months of both years showed

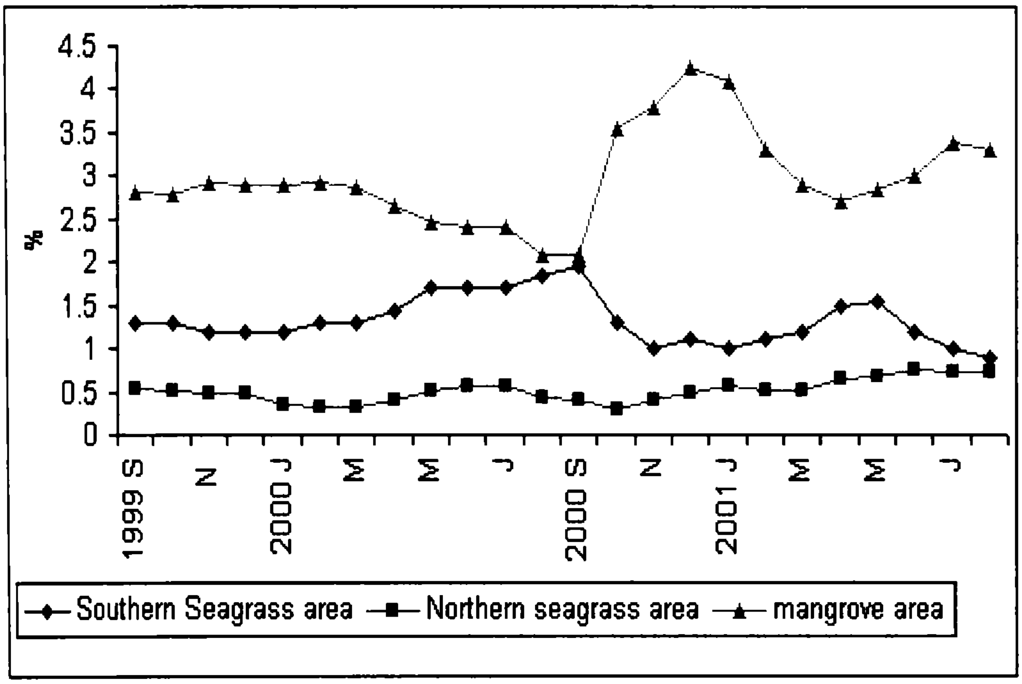


Fig. 3. 18. Monthly organic carbon content at the three areas

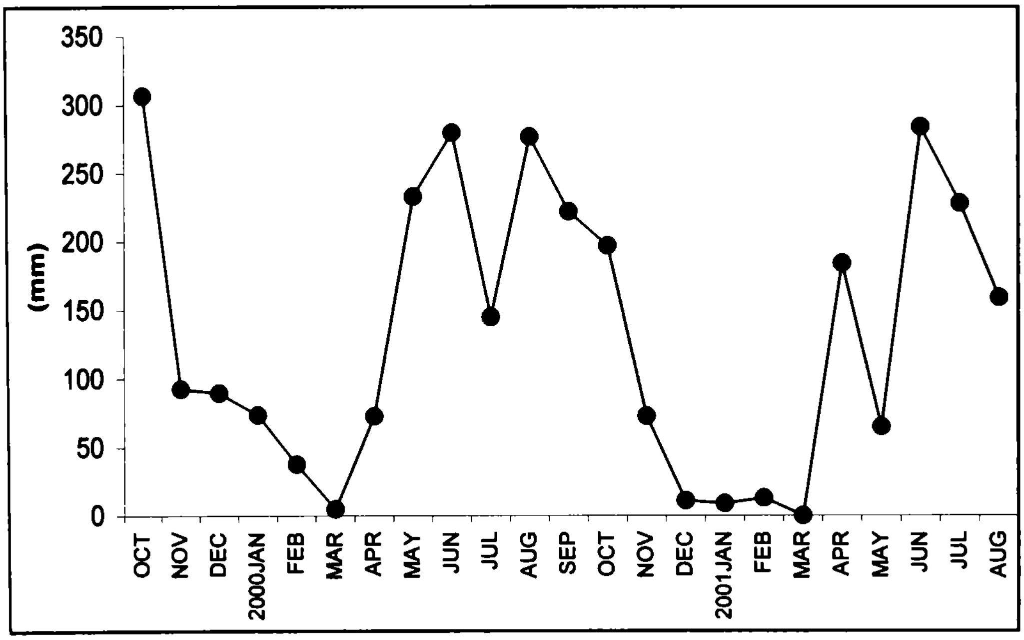


Fig. 3. 19. Rain fall pattern of Minicoy Island, Lakshadweep

highest rainfall and the pre-monsoon recorded the least. During the 1st year the month of May showed a comparatively higher value than that of 2nd year May indicating the onset of early monsoon during the first year.

Chapter. 4

BOTTOM FAUNA

4. 1. Composition and Distribution

The macrobenthic fauna in the study area showed great diversity in seagrass stations and less diversity in mangrove ecosystems. Distinct differences were found in the population density as well as qualitative composition of the various taxa in different areas.

Eight major groups identified were gastropods, bivalves, polychaetes, other worms (all worms except polychaetes), crabs, other crustaceans (including shrimps, amphipods, isopods, stomatopods, tanaeids, etc.), echinoderms and sponges. Altogether under gastropoda there were 58 species under 27 genera, bivalves of 12 species under 7 genera, 'other worms' of 7 species under 6 genera, polychaetes of 27 species under 14 genera, crabs of 24 species under 11 genera, other crustaceans of 19 species under 13 genera, echinoderms of 11 species under 7 genera and sponges of 2 species under 2 genera constituting a grand total of 160 species (Table 4. 1).

Total number of species found at each station was 137 (station 1), 137 (station 2), 74 (station 3), 62 (station 4), 18 (station 5) and 16 (station 6).

Table 4. 1. Occurrence % of different species at different stations (no. of times occurred/ 24 sampling months)x100

SPECIES	**st. 1**	**st. 2**	**st. 3**	**st. 4**	**st. 5**	**st. 6**
GASTROPODS						
Punctacteon amakusaensis	0.0	16.7	12.5	0.0	0.0	0.0
Marania lirata	16.7	8.3	0.0	0.0	0.0	0.0
Cerithium corallium	91.7	91.7	41.7	58.3	95.8	100.0
Cerithium alveolum	54.2	62.5	41.7	45.8	0.0	0.0
Cerithium dialeucum	16.7	33.3	8.3	8.3	0.0	0.0
Cerithium rarimaculatum	4.2	4.2	0.0	0.0	25.0	8.3
Cerithium scabridum	87.5	62.5	45.8	58.3	20.8	16.7
Cerithium rostratum	33.3	25.0	37.5	50.0	0.0	0.0
Cerithium nesioticum	29.2	41.7	66.7	79.2	0.0	0.0
Clypeomorus corallium	12.5	4.2	0.0	0.0	0.0	0.0
Rhinoclavis sinensis	8.3	12.5	4.2	12.5	0.0	0.0
Pyrene sp.	70.8	66.7	87.5	91.7	25.0	12.5
Pyrene vulpecula	16.7	25.0	12.5	16.7	0.0	0.0
Metanachis marquesa	16.7	12.5	25.0	25.0	0.0	0.0
Conus catus	8.3	29.2	33.3	4.2	0.0	0.0
Conus ebraeus	20.8	4.2	0.0	0.0	0.0	0.0
Coralliophila costularis	29.2	45.8	12.5	8.3	0.0	0.0
Cyprea annulus	12.5	8.3	0.0	0.0	0.0	0.0
Cyprea arabica	16.7	12.5	0.0	0.0	0.0	0.0
Cyprea moneta	62.5	33.3	16.7	0.0	0.0	0.0
Cyprea teres	16.7	8.3	0.0	0.0	0.0	0.0
Cyprea tigris	12.5	12.5	0.0	0.0	0.0	0.0
Mazescala japonica	0.0	4.2	0.0	0.0	0.0	0.0
Niso heizensis	0.0	12.5	16.7	8.3	0.0	0.0
Persternis pilsbryi	12.5	0.0	0.0	0.0	0.0	0.0
Littorina undulata	12.5	20.8	20.8	0.0	95.8	95.8
Strigatella litterata	0.0	4.2	0.0	0.0	0.0	0.0
Drupella sp.	4.2	8.3	0.0	4.2	0.0	0.0
Nassarius distortus	0.0	4.2	0.0	0.0	0.0	0.0
Niotha stigmaria	4.2	16.7	8.3	12.5	0.0	0.0
Zeuxis sp.	12.5	0.0	0.0	0.0	0.0	0.0
Polinices flemengium	16.7	0.0	25.0	8.3	0.0	0.0
Natica rufa	8.3	12.5	0.0	0.0	0.0	0.0

Table 4. 1. contd....

SPECIES	st. 1	st. 2	st. 3	st. 4	st. 5	st. 6
Smaragdia viridis	75.0	83.3	70.8	70.8	16.7	8.3
Smaragdia soverbiana	79.2	87.5	58.3	62.5	8.3	20.8
Vittina variegata	0.0	8.3	16.7	4.2	0.0	0.0
Terebralia palustris	0.0	0.0	0.0	0.0	100.0	100.0
Agatha virgo	4.2	0.0	0.0	0.0	0.0	0.0
Agatha lepidule	4.2	0.0	0.0	0.0	0.0	0.0
Pyrgulina pupula	0.0	4.2	20.8	4.2	0.0	0.0
Cymatium neobaricum	0.0	8.3	8.3	0.0	0.0	0.0
Cymatriton nicobaricum	0.0	0.0	8.3	0.0	0.0	0.0
Cinctiscala sp.	4.2	12.5	0.0	0.0	0.0	0.0
Decorifer insignis	8.3	8.3	0.0	0.0	0.0	0.0
Casmeria ponderisai	0.0	12.5	0.0	4.2	0.0	0.0
Strombus canarium	20.8	4.2	16.7	0.0	0.0	0.0
Strombus mutabilis	33.3	33.3	25.0	0.0	0.0	0.0
Cinguloterebra hedleyana	8.3	29.2	8.3	8.3	0.0	0.0
Margarites helicina	20.8	25.0	0.0	0.0	25.0	29.2
Truncatella pfeifferi	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified 129	4.2	8.3	4.2	4.2	0.0	0.0
Dolabella rumphii	37.5	41.7	0.0	0.0	0.0	0.0
Polycera sp.	12.5	16.7	0.0	0.0	0.0	0.0
Gymnodoris ceylonica	4.2	25.0	0.0	0.0	0.0	0.0
Elysia sp.	29.2	4.2	0.0	0.0	0.0	0.0
Smargdinella canaliculata	25.0	16.7	0.0	0.0	0.0	0.0
diala lauta	4.2	0.0	0.0	0.0	0.0	0.0
Dolabrifera dolabrifera	4.2	0.0	0.0	0.0	0.0	0.0
BIVALVES						
Lunulicardia auricula	12.5	0.0	0.0	0.0	0.0	0.0
Cardium asiaticum	20.8	4.2	12.5	0.0	0.0	0.0
Corculum impressum	12.5	8.3	0.0	0.0	0.0	0.0
Ctena delicatula	33.3	33.3	8.3	0.0	0.0	0.0
Mactra cuneata	8.3	4.2	0.0	0.0	0.0	0.0
Myadoropsis brevispinious	16.7	29.2	0.0	4.2	0.0	0.0
Lithophaga nigra	20.8	25.0	0.0	0.0	0.0	0.0
Modiolus metcalfei	8.3	16.7	4.2	8.3	0.0	0.0

Table 4. 1. contd....

SPECIES	st.1	st.2	st.3	st.4	st.5	st.6
Pinna muricata	41.7	50.0	0.0	0.0	0.0	0.0
Tellina palatum	20.8	12.5	37.5	45.8	0.0	0.0
Gafrarium divarticatum	66.7	58.3	100.0	100.0	0.0	0.0
Periglypta puerpura	12.5	16.7	0.0	0.0	0.0	0.0
WORMS						
Baseodiscus delineatus	33.3	20.8	41.7	41.7	0.0	0.0
Golfingia hespera	25.0	25.0	29.2	12.5	0.0	0.0
Phascolosoma nigrescens	12.5	12.5	37.5	45.8	0.0	0.0
Siphonosoma australe	16.7	0.0	16.7	8.3	0.0	0.0
Sipunculus indicus	25.0	16.7	25.0	16.7	0.0	0.0
Siboglinum fiordicum	20.8	8.3	37.5	54.2	0.0	0.0
Hoplonemertean sp.	8.3	20.8	4.2	12.5	0.0	0.0
POLYCHAETE WORMS						
Scoloplos sp.	8.3	4.2	0.0	0.0	0.0	0.0
Eurythoe complanata	12.5	4.2	0.0	33.3	0.0	0.0
Eurythoe mathaii	20.8	12.5	12.5	0.0	0.0	0.0
Notopygos variabilis	16.7	8.3	0.0	4.2	0.0	0.0
Notomastes latericeus	25.0	25.0	16.7	41.7	0.0	0.0
Cirratulus sp.	20.8	8.3	0.0	0.0	0.0	0.0
Marphysa macintoshi	4.2	4.2	12.5	8.3	0.0	0.0
Nematonereis unicornis	20.8	0.0	4.2	0.0	0.0	0.0
Glycera convoluta	29.2	25.0	0.0	0.0	0.0	0.0
Glycera lancadivae	66.7	45.8	8.3	4.2	0.0	0.0
Glycera subaena	16.7	8.3	4.2	0.0	0.0	0.0
Glycera tesselata	29.2	16.7	37.5	50.0	0.0	0.0
Glycera sp.	8.3	0.0	8.3	12.5	0.0	0.0
Goniada emerita	33.3	29.2	12.5	12.5	0.0	0.0
Nephtys dibranchus	33.3	12.5	4.2	0.0	0.0	0.0
Nephtys hombergii	58.3	37.5	4.2	0.0	0.0	0.0
Nephtys inermis	25.0	20.8	12.5	0.0	0.0	0.0
Ceratonereis erythraensis	0.0	8.3	16.7	8.3	0.0	0.0
Nereis kauderni	20.8	4.2	0.0	8.3	0.0	0.0
Nereis trifasciata	37.5	37.5	8.3	0.0	0.0	0.0
Arabella iricolor iricolor	25.0	12.5	8.3	0.0	0.0	0.0

Table 4. 1. contd....

SPECIES	st. 1	st. 2	st. 3	st. 4	st. 5	st. 6
Oenone fulgida	12.5	8.3	0.0	0.0	0.0	0.0
Armandia sp.	20.8	16.7	0.0	0.0	0.0	0.0
Megalomma sp.	8.3	8.3	0.0	0.0	0.0	0.0
Syllis cornuta	25.0	20.8	8.3	8.3	0.0	0.0
Syllis gracilis	16.7	25.0	0.0	0.0	0.0	0.0
Eupolymna nebulosa	12.5	12.5	16.7	29.2	0.0	0.0
CRAB						
Leptoduis sp.	16.7	12.5	0.0	4.2	0.0	0.0
Polydectus cuculifer	8.3	4.2	0.0	0.0	0.0	0.0
Megalopa larva	37.5	37.5	0.0	0.0	0.0	0.0
Calappa hepatica	50.0	33.3	0.0	16.7	0.0	0.0
Diogene sp.	4.2	4.2	4.2	0.0	0.0	0.0
Cardisoma carnifex	0.0	4.2	8.3	0.0	4.2	0.0
Pachygrapsus plicatus	20.8	8.3	0.0	4.2	0.0	0.0
Illyograpsus paludicola	0.0	4.2	0.0	0.0	0.0	4.2
Plagusia sp.	20.8	0.0	0.0	0.0	0.0	0.0
Grapsus sp.	29.2	8.3	4.2	0.0	0.0	0.0
Eriphis sp.	29.2	12.5	20.8	12.5	0.0	0.0
Uca tetragonon	0.0	4.2	0.0	0.0	8.3	16.7
Macrophthalmus boscii	45.8	12.5	8.3	29.2	0.0	0.0
Uca inversa inversa	0.0	0.0	0.0	4.2	4.2	8.3
Tylodipax desigardi	20.8	12.5	0.0	12.5	8.3	0.0
Pilumnus hirtellus	41.7	16.7	33.3	12.5	0.0	0.0
Pinnotheres pisum	25.0	8.3	4.2	4.2	0.0	0.0
Pinnotheres pinnotheres	33.3	16.7	29.2	33.3	0.0	0.0
Thalamita crenata	37.5	20.8	37.5	12.5	8.3	0.0
scylla serrata	0.0	0.0	0.0	0.0	25.0	12.5
Portunus orbitosinus	4.2	12.5	0.0	0.0	0.0	0.0
Macropipus corrugatus	0.0	0.0	0.0	0.0	0.0	0.0
Etisus splendidus	29.2	4.2	0.0	0.0	0.0	0.0
Actaeodes tomentosus	33.3	16.7	29.2	0.0	0.0	0.0
OTHER CRUSTACEANS						
PRAWNS AND SHRIMPS						
Alpheopsis equalis	33.3	12.5	4.2	8.3	0.0	0.0
Alpheus lottini	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. 1. contd....

SPECIES	st. 1	st. 2	st. 3	st. 4	st. 5	st. 6
Alpheus sp.	8.3	4.2	0.0	0.0	0.0	0.0
Metabetaeus minutus	8.3	12.5	0.0	0.0	0.0	0.0
Nikoides maldivensis	0.0	8.3	0.0	0.0	54.2	33.3
AMPHIPODS						
Cymadusa imbroglio	41.7	4.2	37.5	20.8	0.0	0.0
Maera pacifica	33.3	29.2	33.3	25.0	0.0	0.0
Mallacoota insignis	20.8	20.8	0.0	0.0	0.0	0.0
Stenothoe kaia	33.3	29.2	0.0	4.2	0.0	0.0
ISOPODS						
Cirolana sp.	0.0	8.3	0.0	0.0	0.0	0.0
Seychellana expansa	25.0	12.5	4.2	0.0	0.0	0.0
Accalathura borradailei	20.8	8.3	0.0	0.0	0.0	0.0
Paracilicaca setosa	50.0	25.0	0.0	0.0	0.0	0.0
Paraleptospheroma indica	20.8	16.7	0.0	0.0	0.0	0.0
STOMATOPODS						
Gonodactylus.of.smithii	8.3	8.3	0.0	0.0	0.0	0.0
Apseudus sp.	0.0	0.0	0.0	0.0	70.8	58.3
Paratanaeidae sp.	41.7	25.0	0.0	0.0	16.7	4.2
Paranebalia sp.	16.7	16.7	0.0	0.0	0.0	0.0
Siriella brevicaudata	20.8	20.8	0.0	0.0	0.0	0.0
ECHINODERMS						
Linckia multifora	12.5	0.0	0.0	0.0	0.0	0.0
Ophiactis savignyi	29.2	25.0	0.0	8.3	0.0	0.0
Ophicornella sexadia	58.3	41.7	8.3	0.0	0.0	0.0
Ophiocoma scolopendrina	41.7	20.8	0.0	0.0	0.0	0.0
Astropyga radiata	4.2	0.0	0.0	0.0	0.0	0.0
Echinometra mathaei	20.8	12.5	0.0	0.0	0.0	0.0
Echinoneus cyclostomus	16.7	20.8	0.0	0.0	0.0	0.0
Salmacis bicolor	16.7	4.2	0.0	0.0	0.0	0.0
Bohadschia subruba	12.5	4.2	0.0	0.0	0.0	0.0
Holothuria nobilis	4.2	8.3	0.0	0.0	0.0	0.0
Holothuria scabra	12.5	0.0	0.0	0.0	0.0	0.0
SPONGES						
Aaptos cf.chromis	33.3	37.5	0.0	0.0	0.0	0.0
Cinachyrella voeltzkowii	16.7	12.5	0.0	0.0	0.0	0.0

Gastropods

58 species of gastropods belonging to 27 families and 42 genera were recorded from the stations. Of these, 8 species can be considered as rare as they were present in very small numbers in few samples. They were *Mazescala japonica, Nassarius distortus, Strigatella litterata, Agatha virgo, Agatha lepidula, Truncatella pfeifferi, Diala lauta* and *Dolabrifera dolabrifera*. Only 5 species of gastropods were distributed at all stations, they were *Cerithium corallium, Cerithium scabridum, Smaragdia viridis, Smaragdia soverbiana* and *Pyrene* sp.

Maximum number of Gastropod species were recorded from station 2 (49) followed by station 1 (46), station 3 (28) and station 4 (22). Station 5 and 6 had equal number of species (9 spp). Genus *Cerithium*, which included 7 species was the most common genus at all stations except mangroves. At station 5 and 6 the most common species was *Littorina undulata*, a mangrove associated type. *Terebralia palustris*, which was abundantly reported at mangrove station were totally absent at other stations. Soft molluscs were of 7 species, which included both opisthobranchs and phanerobranchs. The most common species of soft mollusc was *Dolabella rumphii*, which produces a violet ink when got irritated. Soft molluscs were limited to station 1 and 2. *Gymnodoris ceylonica*, a beautiful opisthobranch was frequently seen at station 1 and 2. While station 1 and 2 showed maximum species diversity, station 5 and 6 showed the least. Over population of *Littorina undulata* and *Terebralia palustris* has overthrown the presence of other species at Mangrove sites. *Cerithium corallium* showed a very high percentage of occurrence of 62.5%. At station 5 and 6, *Littorina undulata* showed 96% and *Terebralia palustris* showed 100% occurrence, even though it was completely absent at other stations. The highest percentage of occurrence was shown by *Cerithium corallium* (62.5%), *Pyrene* sp. (56.9%), *Smaragdia viridis*

(52.8%), *Smaragdia soverbiana* (50%), *Cerithium scabridum* (45.8%), *Cerithium nesioticum* (36.8%), *Littorina undulata* (24.3%) etc.

Bivalves

Altogether 12 species of bivalves were reported, out of which station 5 and 6 did not show any occurrence of bivalves. Station 3 and 4 showed the presence of only four bivalves and station 1 and 2 showed 12 and 11 species respectively. Out of the 12 species, *Lunulicardia auricula* appeared at station 1 only. *Gafrarium divarticatum* occurred in good numbers at seagrass stations. *Tellina palatum* of different sizes were obtained from all seagrass stations. Even though *Mactra cuneata* were found abundantly at sandy intertidal areas, they were completely absent at seagrass intertidal meadows. *Pinna muricata* was obtained only from station 1 and station 2. Seasonal variations were observed in the occurrence of bivalves. They were totally absent at the mangrove sites.

Among bivalves, the highest percentage of occurrence was shown by *Gafrarium divarticatum* (54.9%). Frequency occurrence of *Tellina palatum* (19.4%), *Pinna muricata* (16%), *Ctena delicatula* (11.8%) were also countable. *Gafrarium divarticatum* showed hundred percent frequency of occurrence at station 3 and 4 but only 71% and 58% at station 1 and 2 respectively. *Tellina palatum* also showed moderate percentage of occurrence at station 3 (37.5%), station 4 (45.8%), station 1 (20.8%) and 2 (12.5%). *Pinna muricata* which showed a frequency occurrence of 46% at station 1 and 50% at station 2 was completely absent at other sites.

'Other Worms'

Worms other than polychaetes were grouped separately and constituted by 7 species. They were totally absent at mangrove stations 5 and 6 and at all other stations (seagrass) they were found distributed more or less evenly (7 spp. each at station 1, 3, 4 and 6 spp. at station 2). Their maximum abundance was seen at station 4 and 3. The major species of this group were *Siboglinum fiordicum*, *Baseodiscus delineatus* and the least abundance was shown by *Phascolosoma nigrescens* and *Siphonosoma australe*. Sipunculid worms were present at all four seagrass stations.

Among 'other worms', the highest percentage of occurrence was shown by *Baseodiscus delineatus* (23.6%) followed by *Siboglinum fiordicum* (20.1%), *Phascolosoma nigrescence* (18.1%) and *Golfingia hespera* (13.9%). *Baseodiscus delineatus* showed frequency occurrence of 33.3%, 20.8%, 41.7%, 41.7% at station 1 to 4 respectively. *Golfingia hespera* showed occurrence of 25%, 25%, 29.2% and 12.5%, *Phascolosoma nigriscence* of 25%, 16.7%, 25%, 16.7% and *Siboglinum fiordicum* of 21%, 8%, 38% and 54% at stations 1 to 4 respectively.

Polychaetes

Twenty-seven species of polychaetes were identified. At station 5 and 6, there was no occurrence of polychaetes. At station 1, 27 species were found, station 2- 25, station 3-19 and at station 4, 11 species. *Glycera* species such as *Glycera lancadivae, Glycera tesselata, Glycera convoluta* predominated at many stations. Along with species of *Glycera, Nephtys* and *Nereis* were abundantly present at station 1 and station 2. At station 4, *Eupolymna nebulosa* was found in large numbers. Though *Sabellid* spp. abounded at some locations, they were rare in the samples taken from seagrass. Polychaetes were often found among the rhizomes of seagrasses along with seaweeds. Swarming of *Nereis* spp. was often encountered in reef areas, but comparatively less in seagrass areas.

Among Polychaetes, the highest percentage of occurrence was shown by *Glycera tesselata* (22.9%), *Glycera lancadivae* (18.8%), *Notomastes latericeus* (18.8%), *Nephtys hombergii* (16%) and *Goniada* *emerita* (15.3%). At station 1 and 2, species such as *Glycera*, *Goniada* and *Nephtys* were found at all seasons, while at station 3 and 4 *Notomastes latericeus* and *Eupolymna nebulosa* were found along with Glyceridae members.

Crabs

Altogether 24 species of crabs were found, out of which 18 were found at station 1, 20 at station 2, 10 at station 3, 11 at station 4, 6 at station 5 and 4 at station 6. The most common species at station 1 were *Calappa hepatica*, *Macrophthalmus boscii* and *Thalamita crenata*. At station 2, dominant species were *Thalamita crenata*, *Pinnotheres* spp. and *Calappa hepatica*. Station 3 showed comparatively lesser abundance of crabs. At station 3, *Thalamita crenata*, *Pinnotheres* spp., *Actaeodes tomentosus*, *Pilumnus hirtellus* etc. dominated. At station 4, *Macrophthalmus boscii, Pinnotheres* spp., *Calappa hepatica* and *Thalamita crenata were* dominated. At station 5 and station 6, the dominant species observed were *Scylla serrata* and *Uca* spp.

Among crabs the highest percentage of occurrence were shown by *Thalamita crenata* (19.4%), *Pinnotheres pinnotheres* (18.8%), *Pilumnus hirtellus* (16.7%), *Calappa hepatica* (16.7%) and *Macrophthalmus boscii* (16%). At station 1, species like *Calappa hepatica, Macrophthalmus boscii, Pilumnus hirtellus* etc. exceeded more than 40% frequency of occurrence. At station 2, no species were represented more than 40% occurrence. At station 3, *Thalamita crenata* showed 41% occurrence.

Other Crustaceans

Shrimps, carridean prawns, amphipods, isopods, stomatopods and tanaeids were included in this group. Four species of prawns, 4 species of amphipods, 5 species of isopods, 1 species of stomatopod, 2 species of tanaeids and 1 paranebalia sp. were reported. The highest diversity of other crustaceans was observed at station 2 (17 spp.) followed by 15 spp. at station 1. The other four stations showed almost even distribution (4 spp. each at both northern seagrass station and 3 spp. each at both mangrove stations).

Shrimp, *Nikoides maldivensis* was often found at mangrove sites. Cariddean prawns were found in seagrass samples intermittently. Amphipods were present abundantly at seagrass beds but absent at mangrove sites. *Maera pacifica* and *Cymadusa imbroglio* were the dominant species of amphipods. The most dominant isopod species was *Paracilicacea setosa*. Isopods and stomatopods were limited to station 1 and station 2. Tanaeids (*Apseudus* sp.) were abundantly found at Mangrove sites. More than 10% frequency of occurrence was shown by *Nikoides maldivensis* (11.1%), *Cymadusa imbroglio* (18.8%), *Maera pacifica* (20%), *Stenothoe kaia* (11%) and *Paracilicacea setosa* (12.5%). Some species showed more than 40% frequency of occurrence at some stations, which included *Nikoides maldivensis* (58.3% at station 5), *Cymadusa imbroglio* (45.8% and 41.7% at station 1 and 3 respectively), *Paracilicacea setosa* (50% at station 1), *Apseudus* sp., (70.8% and 58.3% at station 5 and 6 respectively) and *Paratanaeidae* sp., (41.7% at station 1).

Echinoderms

11 species of Echinoderms were recorded under 8 families. They were abundantly found at station 1 and 2. They showed a diversity of 11 spp. at station 1 and 8 spp. at station 2. The most dominant species were *Ophicornella sexadia, Ophiocoma scolopendrina* and *Ophiactis savignyi.* Holothurians and starfishes were comparatively lesser than the brittle stars at the selected sites. They were showing only meagre presence at station 3 and 4 and completely absent at station 5 and 6.

Some species like *Ophiactis savignyi* (33.3% and 25%), *Ophicornella sexadia* (58.3%and 41.7%), *Ophiocoma scolopendrina* (45.8% and 20.8%), *Echinometra mathai* (25% and 12.5%), and *Echinoneus cyclostomus* (12.5% and 20.8%) showed high percentage of frequency of occurrence at station 1 and 2 respectively. Starfish, *Linckia multifora* showed their presence only at station 1 (12.5%).

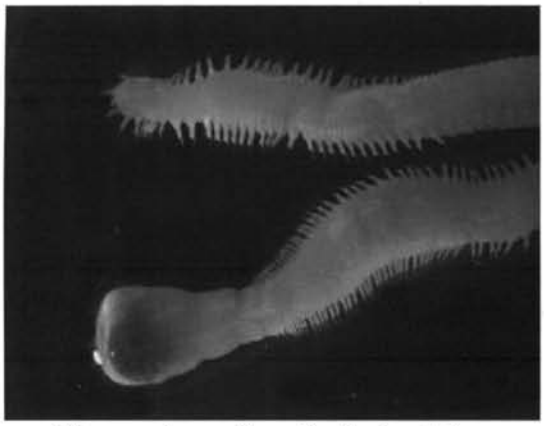
Sponges

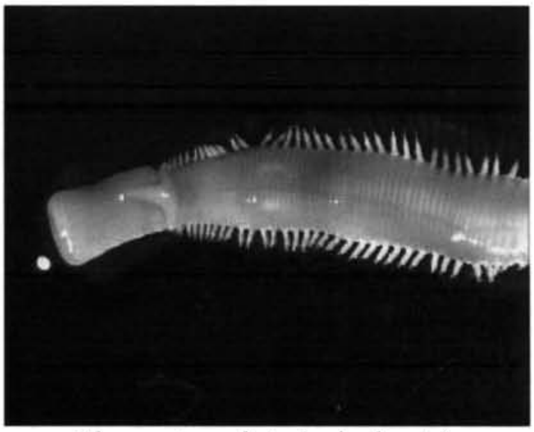
Two species of sponges *Aaptos.cf.chromis* and *Cinachyrella* sp. were frequently found in the benthos samples collected from station 1 and 2. Frequency of occurrence of these two sponges was comparatively higher at station 1 (*Aaptos.cf.chromis* and *Cinachyrella* spp. showed 33.3% and 16.7% respectively) and station 2 (*Aaptos.cf.chromis* and *Cinachyrella* spp. showed 37.5% and 12.5% respectively).

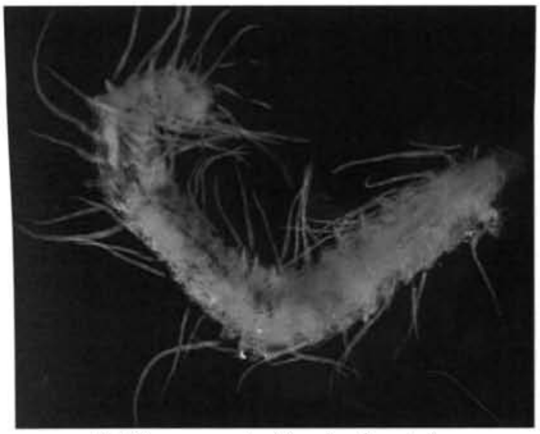
Number of species of major groups found at the three different areas (southern seagrass, northern seagrass and mangrove) are given below:

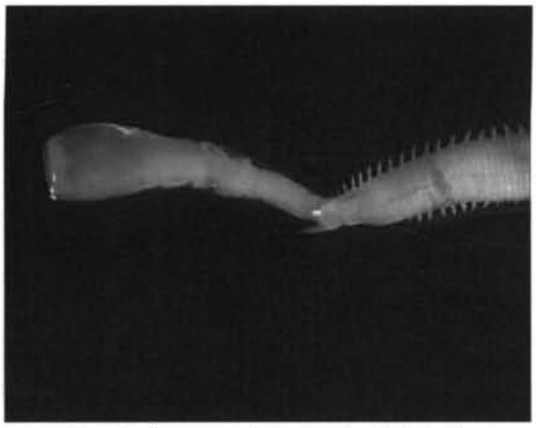
Major groups	S. seagrass	N. seagrass	Mangroves
Gastropods	48	25	9
Bivalves	12	4	-
Polychaetes	25	15	-
Other worms	6	7	-
Crabs	19	11	5
Other crustaceans	16	4	3
Echinoderms	9	1	0
Sponges	2	-	-

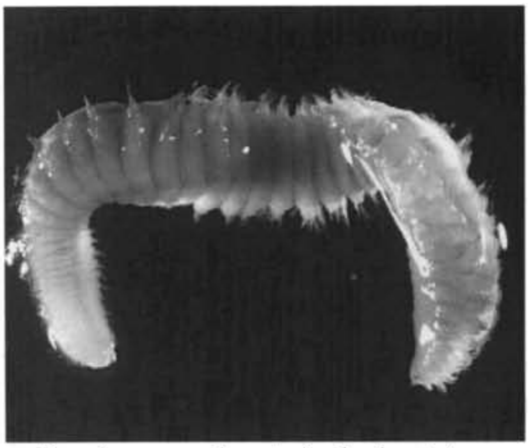
Some of the major benthic macrofauna species collected during the study are given in Plate 4.1, 4. 2 and 4. 3.


Glycera lancadivae (polychaete)


Glycera tesselata (polychaete)


Syllis cornuta ((polychaete)


Goniada maculata (polychaete)


Eurythoe complanata (polychaete)

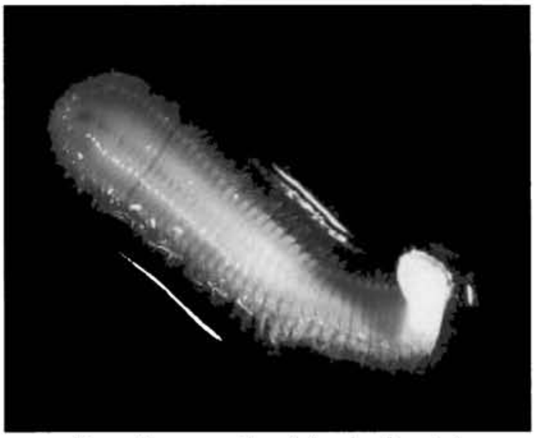
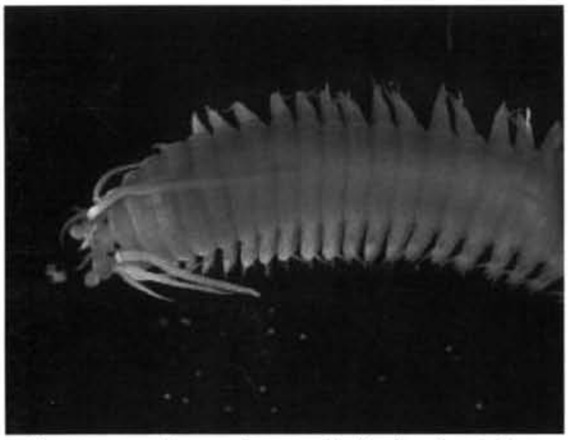
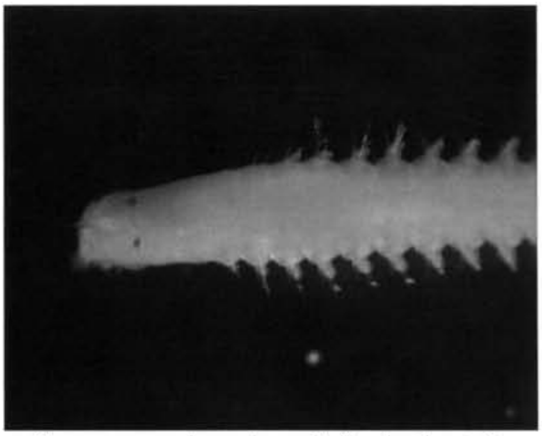

Eurythoe mathaei (polychaete)

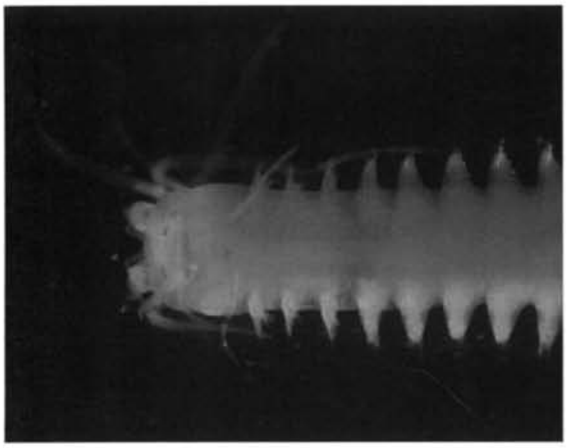
Plate 4.1 Major species of benthic macrofauna obtained from the study area



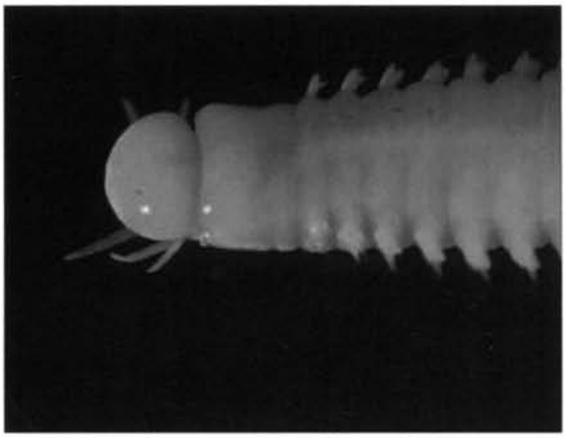
Ceratonereis erythraensis (polychaete)



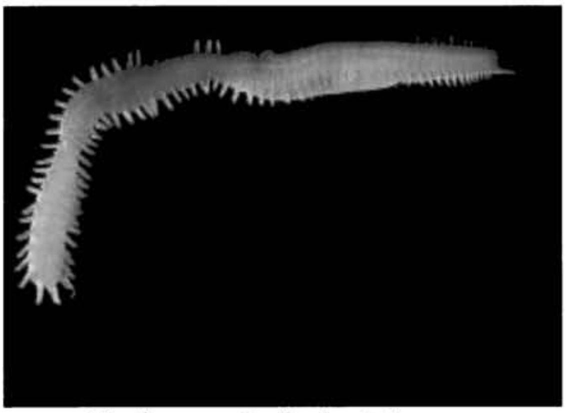
Nematonereis unicornis (polychaete)



Nereis kauderni (polychaete)



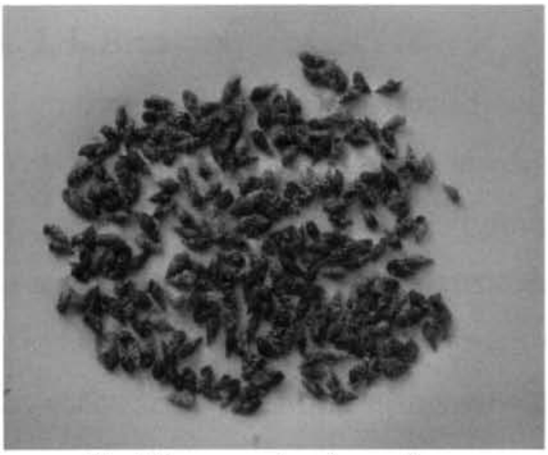
Marphysa macintoshi (polychaete)



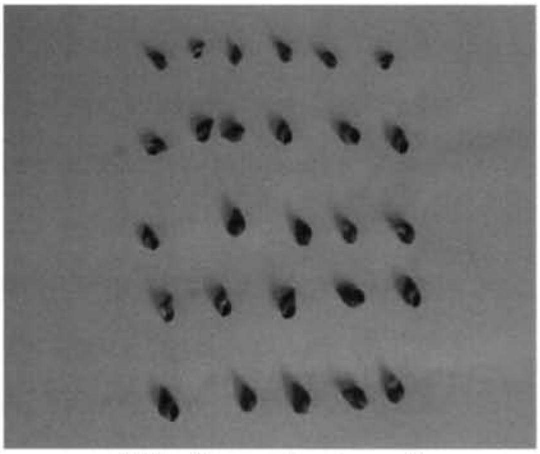
Nephtys sp. (polychaete)

Uca sp. (mangrove crab)

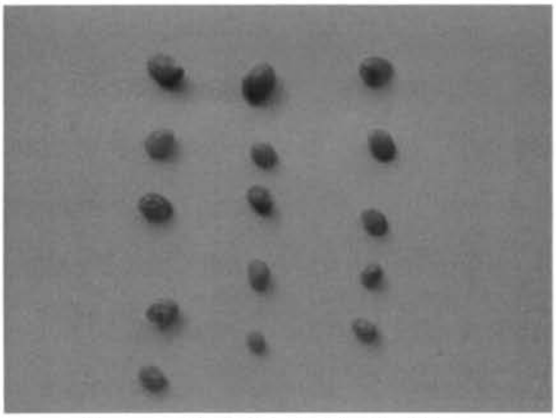
Plate 4. 2 Major species of benthic macrofauna obtained from the study area



Cerithium spp. (gastropod)



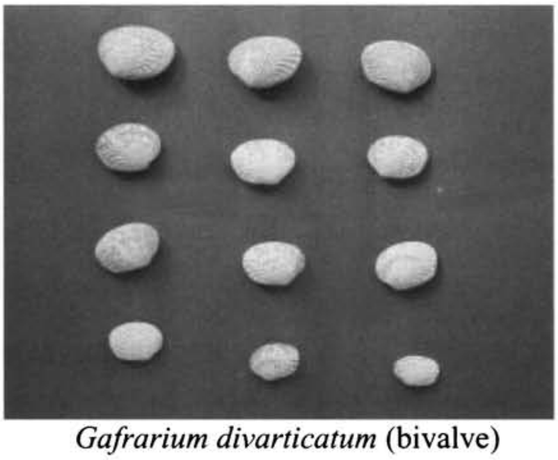
Littorina sp. (gastropod)



Smaragdia spp. (gastropod)

Cyprea moneta (gastropod)

Terebralia palustris (gastropod)



Gafrarium divarticatum (bivalve)

Plate 4. 3 Major species of benthic macrofauna obtained from the study area

4. 2. Standing stock

4. 2. 1. Biomass

Biomass analysis was carried out at all six stations from September 1999 to August 2001. The individuals were classified into major groups i.e., gastropods (group1), bivalves (group 2), worms including polychaetes (group 3), crabs (group 4), other crustaceans (group 5), echinoderms (group 6) and sponges (group 7). Only group wise wet weight biomass analysis was conducted. From the mangrove sites, biomass of mangrove whelk, '*Terebralia palustris*' was separately analysed because of its high biomass. All other gastropods except *Terebralia palustris* were weighed shell-on owing to their smaller size.

Biomass analysis (wet weight) was made group wise, stationwise, season wise and month wise. The yearwise and seasonwise biomass distribution are given in Fig. 4.1 and 4. 2. The monthwise distribution of biomass at each station are given in Fig. 4.3

The gastropods formed major share of biomass at all stations. From the station wise analysis, it was found that stations 1 and 2 showed maximum total average biomass of 184.44 g/m^{2}and 165.61 g/m^2 respectively. The mangrove sites recorded a total average biomass of 118.3 g/m^2 and 101.1 g/m^2 for station 5 and station 6. The lowest total average biomass of 78.7 g/m^2 and 56.5 g/m^2 for station 3 and 4 respectively were recorded at the northern seagrass stations. From the seasonwise analysis, it was found that post-monsoon season contributed major share of total biomass followed by monsoon at all three areas and the lowest total biomass was observed in pre-monsoon season at all three areas.

Stationwise analysis

Station wise average biomass of major groups of benthos (g/m^2) are given in Table 4. 2.

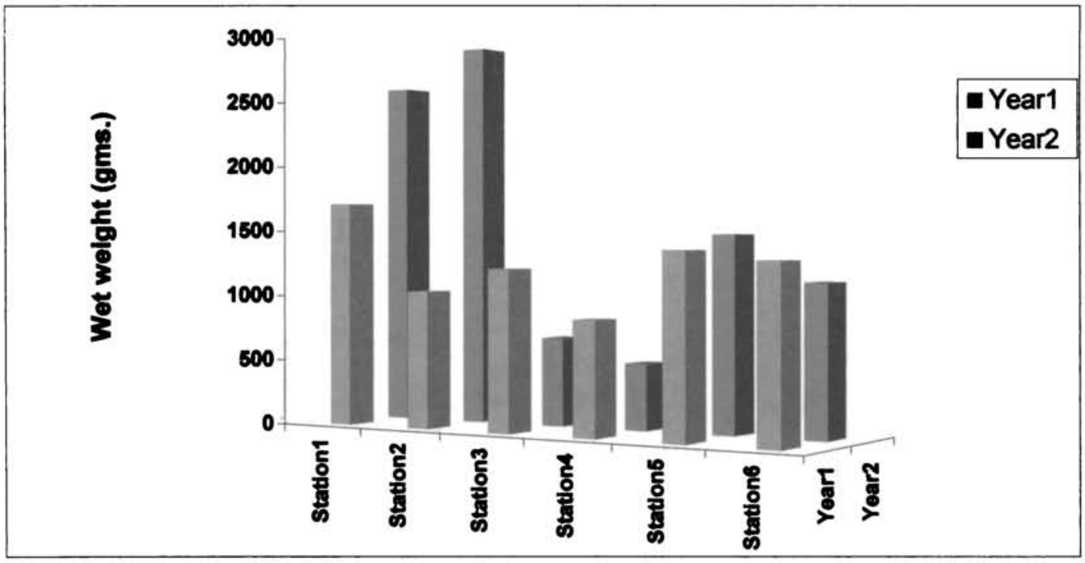


Fig. 4. 1. Yearwise total biomass at different stations

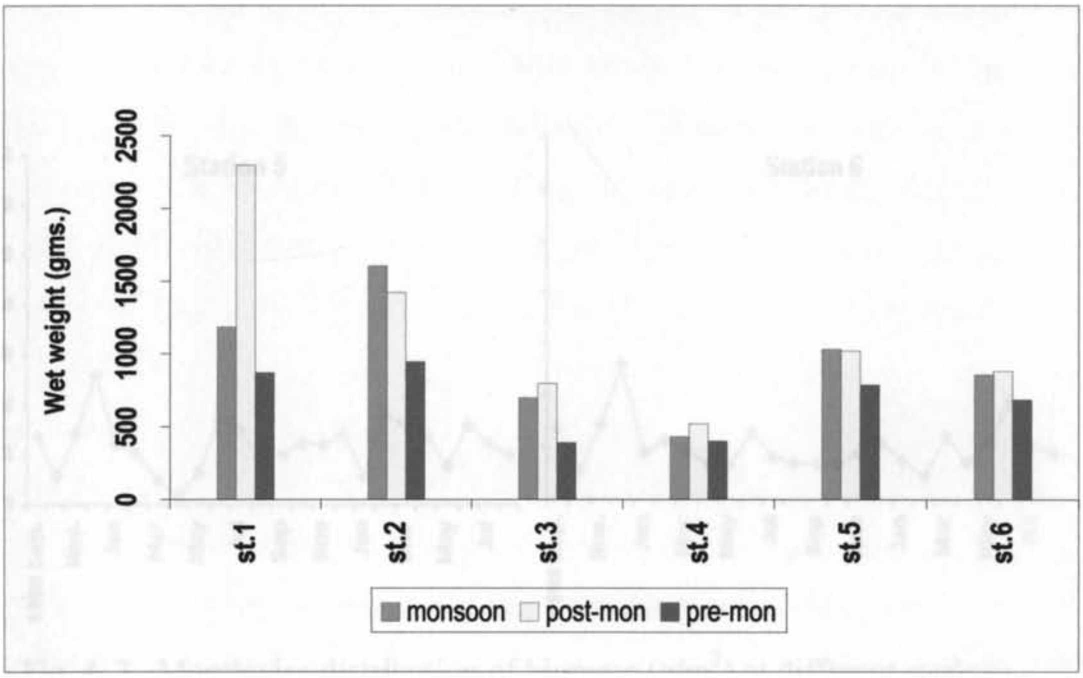


Fig. 4. 2. Seasonwise total biomass at different stations

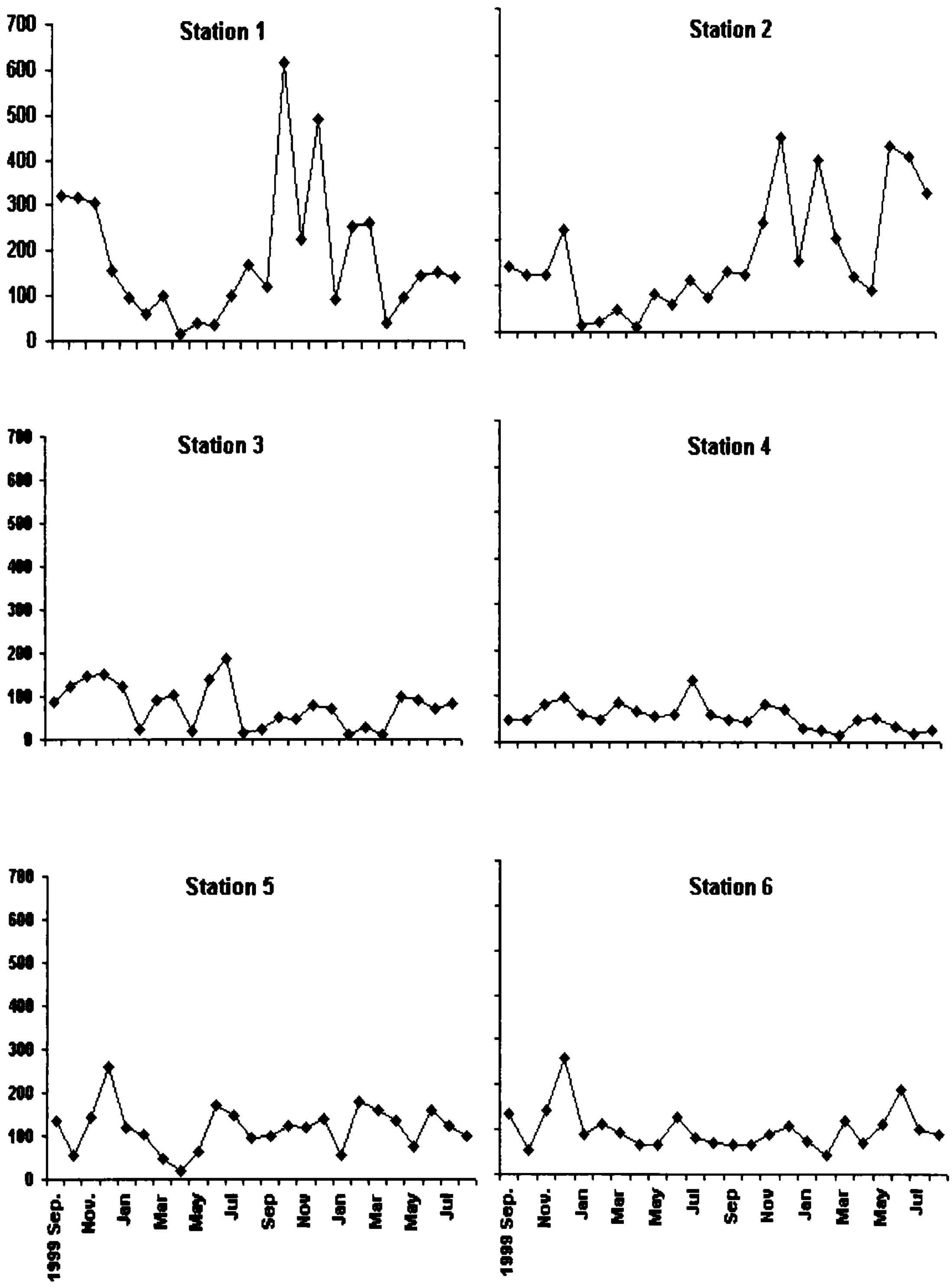


Fig. 4. 3. Monthwise distribution of biomass (g/m^2) at different stations

Station 1

Total biomass for the pre-monsoon season was estimated as 870.9g. For monsoon it came up to 1185.6g and for post-monsoon it was 2298g. Of the total biomass of 4354.6g, Year I contributed 1713g and Year II contributed 2642g. The groups, which shared biomass, were gastropods (4030g), bivalves (268g), worms and polychaetes (18g), crabs (7g), echinoderms (12g) and sponges (4g). Monthly average was estimated as 168 g/m^2 for group 1, 10.5 g/m^2 for group 2, 0.7 g/m^2 for group 3, 0.7 g/m^2 for group 4, 0.28 g/m^2 for group 5, 0.5 g/m^2 for group 6 and 0.18 g/m^2 for group 7. Highest values of biomass were noticed at this station during October, November and December months. Monthly values of biomass ranged from 18 g/m^2 in April 2000 to 615 g/m^2 in October 2000.

Station 2

At station 2, total biomass values for pre-monsoon, monsoon and post-monsoon were 945g, 1608g and 1421g respectively. Of the total biomass of 3974g, Year I contributed 1040g and Year II contributed 2935g. Groupwise break up showed that group 1-7 contributed 3607g, 319g, 10g, 16g, 6g, 9g and 8g respectively. Monthly biomass values ranged from 11g in April 2000 to 421 g in December 2000. Monthly averages were 150.3 g/m^2 (group 1), 13.3 g/m^2 (group 2), 0.4 g/m^2 (group 3), 0.67 g/m^2 (group 4), 0.23 g/m^2 (group 5), 0.37 g/m^2 (group 6) and 0.35 g/m^2 (group 7).

Station 3

Total biomass was 391.7g in pre-monsoon, 699.84g in monsoon and 797.28g in post-monsoon and the grand total came up to 1888.8g. Year wise break up showed that Year I contributed 1217g. and Year II 671g. Item wise contribution was 813g (group 1), 1015.7g (group 2), 29g (group

3), 27g (group 4), 4g (group 5) and 0.16g (group 6). Group 7 was not recorded at this station. Monthly biomass values ranged from 12 g/m^2 in February 2001 to 188 g/m^2 in July 2000. Monthly averages were 33.8 g/m^2 (group 1), 42 g/m^2 (group 2), 1.2 g/m^2 (group 3), 1.11 g/m^2 (group 4) and 0.17 g/m^2 (group 5). Biomass of group 6 was negligible.

Station 4

Biomass values were 403g during pre-monsoon, 432g during monsoon and 520g during post-monsoon with a grand total of 1355.04g. Total biomass for Year I and II were 855.4g and 500g respectively. Group wise contribution was 767g (group 1), 528g (group 2), 33g (group 3), 26g (group 4), 0.64g (group 5) and 0.48g (group 6). Group 7 was not recorded at this site. Biomass values ranged from 14 g/m^2 in March 2001 to 135 g/m^2 in July 2000. Monthly averages were 31.9 g/m^2 (group 1), 22 g/m^2 (group 2), 1.35 g/m^2 (group 3), 1.08 g/m^2 (group 4), 0.03 g/m^2 (group 5) and 0.02 g/m^2 (group 6). Biomass of group 7 was negligible.

Station 5

Total biomass observed was 2840g. Out of which 787g, 1032g and 1021g were contributed by pre-monsoon, monsoon and post-monsoon seasons respectively. Year I contributed 1365g and Year II, 1475g. Bivalves, worms including polychaetes, echinoderms and sponges were not recorded at this station. Group 1 (gastropods), 4 (crabs) and 5 (other crustaceans) contributed 2772g, 53.6g and 14.88g respectively. Monthly biomass values ranged from 18 g/m^2 in April 2000 to 259 g/m^2 in December 1999. Monthly averages of groups were 115.5 g/m^2 (group 1), 2.2 g/m^2 (group 4) and 0.6 g/m^2 (group 5).

Station 6

Total biomass observed was 2426.24g. For pre-monsoon, monsoon and post-monsoon the biomass values were 686.4g, 858g and 882g respectively. Year wise break up showed that Year I and II contributed 1297g and 1129g respectively. During the period of study Group 1 contributed 2365g, group 4, 38g and group 5 23g. Monthly averages were 98.5 g/m^2 (group 1), 1.59 g/m^2 (group 4) and 0.9 g/m^2 (group 5). All other groups were absent at this site. Monthly biomass values ranged from 43 g/m^2 in February 2001 to 259 g/m^2 in December 1999.

Seasonwise analysis

Season wise average biomass values of major groups of benthos (g/m^2) at each area are given in Table 4. 3. In general, a marked seasonal variation in biomass values of the bottom fauna was observed at different areas. The gastropods showed their highest biomass value during post-monsoon season at the southern seagrass as well as mangrove region and during monsoon at the northern seagrass region. They showed their least biomass values during pre-monsoon at both seagrass regions and during monsoon at the mangrove area. The bivalves showed their highest and lowest biomass values at the monsoon and pre-monsoon respectively at southern seagrass area and post-monsoon and pre-monsoon season at northern seagrass area. At the mangrove area the dominating mollusc *Terebralia palustris* showed their highest and lowest abundance during monsoon and pre-monsoon respectively. Crabs and echinoderms showed their highest biomass value during monsoon irrespective of any area and 'other crustaceans' and sponges showed their maximum biomass during pre-monsoon at the two seagrass areas.

Table 4. 2. Station wise avg. biomass of major groups of benthos (g/m^2)

Major groups	area 1		area 2		area 3	
	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6
Gastropods	167.93	150.29	33.89	31.96	115.48	98.53
Bivalves	11.15	13.30	42.32	22.01	0.00	0.00
Worms (incl. polychaetes)	0.73	0.40	1.20	1.35	0.00	0.00
Crabs	0.65	0.67	1.11	1.09	2.23	1.59
Other crustaceans	0.3	0.23	0.17	0.03	0.62	0.97
Echinoderms	0.5	0.37	0.01	0.02	0.00	0.00
Sponges	0.18	0.35	0.00	0.00	0.00	0.00
Total	181.44	165.61	78.70	56.46	118.33	101.09

Table 4. 3. Avg. seasonal biomass of major groups of benthos (g/m^2)

Southern seagrass area	pre-mon	monsoon	post-mon
Gastropods	104.9	154.13	218.29
Bivalves	6.24	17.78	12.65
Worms (incl. polychaetes)	0.72	0.53	0.45
Crabs	0.57	1.07	0.35
Other crustacean	0.52	0.13	0.15
Echinoderms	0.24	0.71	0.35
Sponges	0.33	0.23	0.23
Total	113.52	174.58	232.47
Northern seagrass area	**pre-mon**	**monsoon**	**post-mon**
Gastropods	25.76	38.37	34.64
Bivalves	21.74	29.73	45.03
Worms (incl. polychaetes)	1.18	0.92	1.73
Crabs	0.77	1.65	0.88
Other crustacean	0.17	0.05	0.08
Echinoderms	0.03	0.01	0
Sponges	0	0	0
Total	49.65	70.73	82.36
Mangrove area	**pre-mon**	**monsoon**	**post-mon**
Gastropods except *Terebralia palustris*	57.48	50.08	53.85
Terebralia palustris	31.79	64.19	63.63
Bivalves	0	0	0
Worms (incl. polychaetes)	0	0	0
Crabs	1.73	2.67	1.34
Other crustacean	1.08	1.16	0.14
Echinoderms	0	0	0
Sponges	0	0	0
Total	92.08	118.1	118.96

4. 2. 2 Numerical abundance

Yearwise, groupwise and monthwise contribution to numerical abundance by different stations/areas are given in Fig. 4.4, 4.5 and 4.6.

Gastropods were showing their maximum average monthly abundance (no./0.25m^2) at station 2 (604) followed by station 1 (362), station 6 (250), station 5 (212), station 3 (159) and station 4 (137).

The bivalves were distributed only at the seagrass stations and total numerical abundance of bivalves at each seagrass station was 1524 (25%) at station 1, 1064 (18%) at station 2, 1516 (25%) at station 3 and 1920 (32%) at station 4. *Gafrarium divarticatum* itself recorded an abundance of 1360 at station 1, 796 at station 2, 1364 at station 3 and 1804 at station 4. Bivalves were showing their maximum average monthly abundance (No./ 0.25m^2) at station 4 (80) followed by station 1 (64), station 3 (63) and station 2 (44).

Total abundance of worms at different seagrass stations were 300 at station 1 (18%), 188 at station 2 (11%), 476 at station 3 (29%) and 708 (42%) at station 4. They were totally absent at station 5 and 6. *Siboglinum fiordicum* showed the maximum abundance (164) at station 1, *Baseodiscus delineatus* at station 4 (264) and *Phascolosoma nigrescens* at station 4 (196). The average monthly values (no./0.25m^2) were 12.5, 7.8, 19.8 and 29.5 for stations 1 to 4 respectively.

Total abundance of polychaetes for the entire study period at different seagrass stations were 1132 (38%) at station 1, 564 (19%) at station 2, 668 (22%) at station 3 and 644 (21%) at station 4. They were totally absent at stations 5 and 6. Polychaetes were showing their maximum average monthly abundance at station 1 (47 nos./ 0.25m^2), followed by station 3 (28 nos./0.25m^2), station 4 (27 nos./0.25m^2) and station 2 (24 nos./0.25m^2). *Glycera* spp. predominated in many samples of

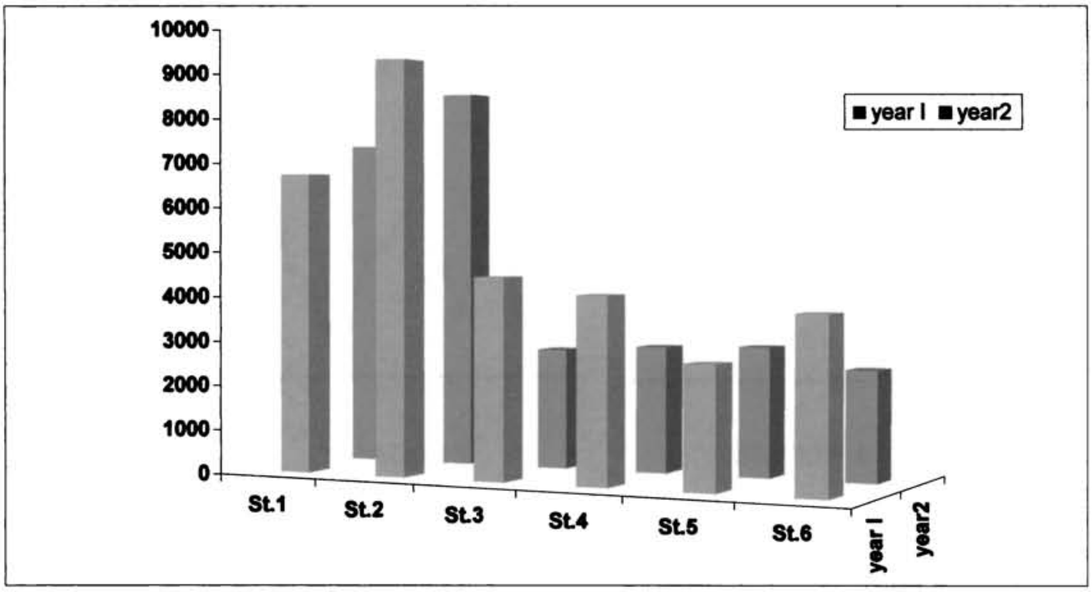


Fig. 4. 4. Yearwise total benthic abundance (nos.) at different stations

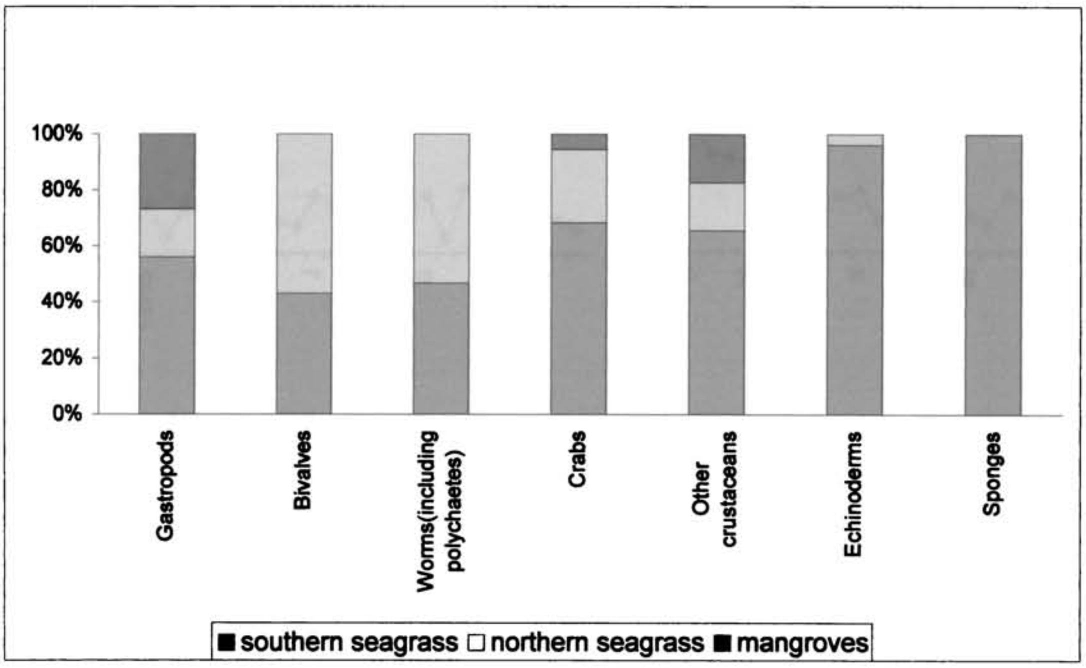


Fig. 4. 5. Areawise share to the numerical abundance of major groups

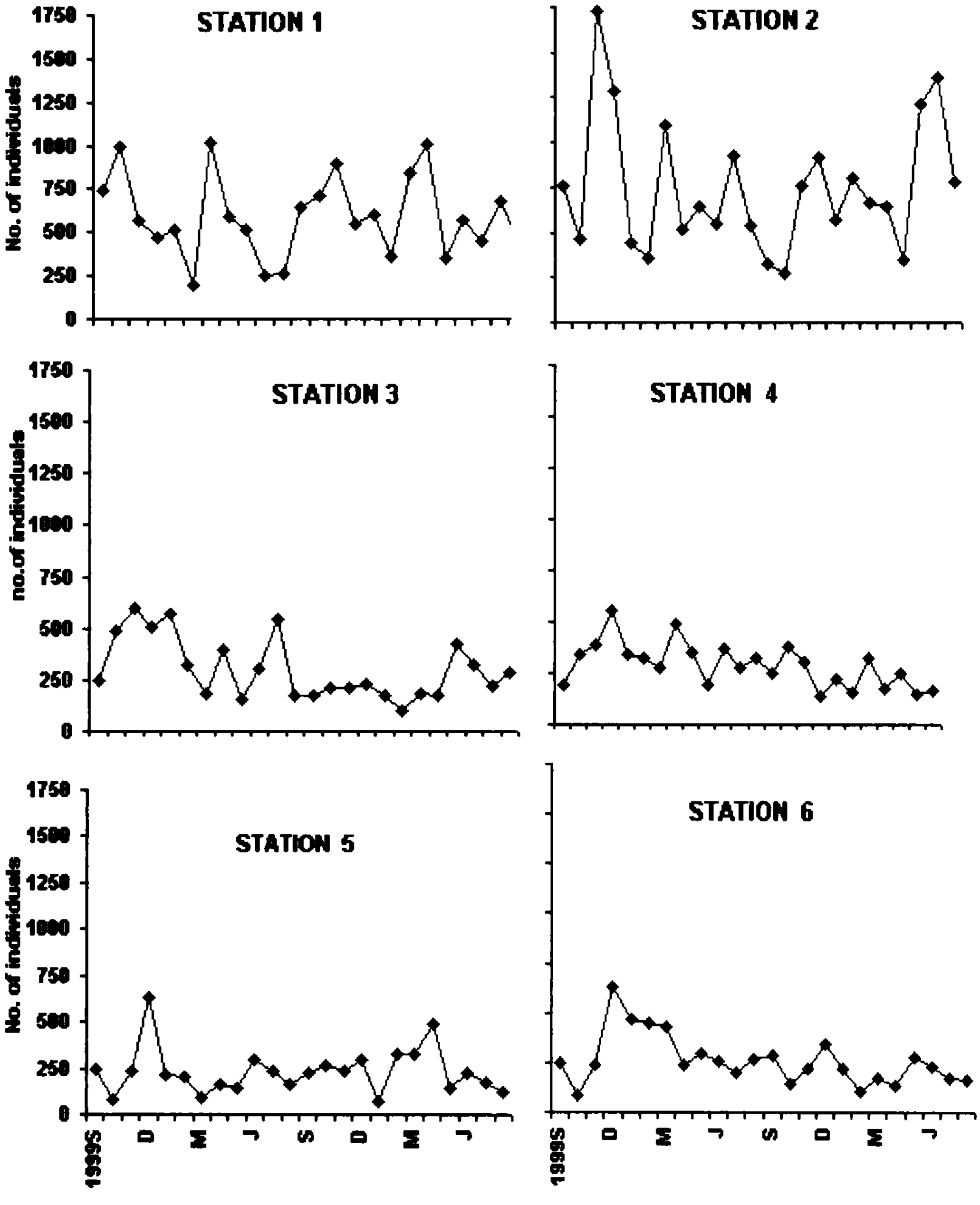


Fig. 4. 6. Monthwise distribution of benthic abundance (no./0.25m^2) at different stations

which the total number of *Glycera lancadivae* itself came up to 208 at station 1 and 96 at station 2. *Glycera tesselata* dominated at station 3 (136), and station 4 (256). *Eurythoe mathaii* was abundant at station 3 (172).

Crabs showed their maximum average monthly abundance (nos./ $0.25m^2$) at station 1 (32), station 2 (18), station 3 (10), station 4 (9), station 5 (2) and station 6 (2).

Crustaceans other than crabs were considered as a single group and referred as 'other crustaceans'. They showed their maximum average monthly abundance (nos./$0.25m^2$) at station 1 (62), station 2 (42), station 3 (20), station 5 (19), station 6 (9) and station 4 (7).

Numerical abundance of echinoderms at different seagrass stations were 260 at station 1, 148 at station 2 and 8 at each station 3 and 4. Numerical abundance of sponges at station 1 and 2 were 48 and 60 respectively. At all other stations, they were completely absent.

Station wise analysis

Contribution (%) of major benthic group at each area is given in Fig. 4.7. Specieswise contribution to the total abundance at each station is given in Table 4. 4.

Station 1

Gastropods contributed 62%, bivalves 11%, other worms 2%, Polychaetes 8%, crabs 5%, other crustaceans 10% and echinoderms 2%.

Among the gastropods, *Cerithium corallium* itself represented 25% of the total. *C. alveolum* 2%, *C. scabridum* 13%, *Pyrene* sp. 2%, *Smaragdia viridis* 2% and *S. soverbiana* 7.5%. All other individuals represented less than 1%. Contribution of *Mazescala japonica*, *Niso heizensis, Vittina variegata, Terebralia palustris, Agatha virgo, A. lepidule,*

Table 4. 4. Specieswise contribution (% of numerical abundance) to total abundance.

Species	St.1	St.2	St.3	St.4	St.5	St.6
GASTROPODS						
Punctacteon amakusaensis	0.03	0.11	0.22	0.00	0.00	0.00
Marania lirata	0.14	0.09	0.00	0.00	0.00	0.00
Cerithium corallium	22.58	29.76	3.94	3.85	10.62	11.61
Cerithium alveolum	3.63	3.12	1.22	1.67	0.00	0.00
Cerithium dialeucum	0.31	0.60	0.50	0.29	0.00	0.00
Cerithium rarimaculatum	0.03	0.07	0.00	0.00	0.43	0.19
Cerithium scabridum	13.89	19.93	6.61	8.10	0.50	0.77
Cerithium rostratum	0.39	1.60	7.05	4.37	0.00	0.00
Cerithium nesioticum	0.82	5.79	3.00	4.02	0.00	0.00
Clypeomorus corallium	0.06	0.02	0.00	0.00	0.00	0.00
Rhinoclavis sinensis	0.06	0.20	0.06	0.23	0.00	0.00
Pyrene sp.	2.25	1.87	11.83	12.70	0.93	0.38
Pyrene vulpecula	0.65	0.47	1.50	0.46	0.00	0.00
Metanachis marquesa	0.39	0.27	1.00	3.85	0.00	0.00
Conus catus	0.14	0.38	0.50	0.06	0.00	0.00
Conus ebraeus	0.17	0.02	0.00	0.00	0.00	0.00
Coralliophila costularis	0.51	0.80	0.17	0.23	0.00	0.00
Cyprea annulus	0.08	0.04	0.00	0.00	0.00	0.00
Cyprea arabica	0.08	0.07	0.00	0.00	0.00	0.00
Cyprea moneta	0.51	0.27	0.33	0.00	0.00	0.00
Cyprea teres	0.11	0.04	0.00	0.00	0.00	0.00
Cyprea tigris	0.08	0.07	0.00	0.00	0.00	0.00
Mazescala japonica	0.00	0.02	0.00	0.00	0.00	0.00
Niso heizensis	0.00	0.36	1.50	0.46	0.00	0.00
Persternia pilsbryi	0.08	0.00	0.00	0.00	0.00	0.00
Littorina undulata	0.28	1.36	1.33	0.00	59.37	66.52
Strigatella litterata	0.00	0.02	0.00	0.00	0.00	0.00
Drupella sp.	0.03	0.04	0.00	0.06	0.00	0.00
Nassarius distortus	0.00	0.02	0.00	0.00	0.00	0.00
Niotha stigmaria	0.03	0.40	0.17	0.52	0.00	0.00
Zeuxis sp.	0.34	0.00	0.00	0.00	0.00	0.00
Polinices flemengium	0.25	0.00	1.44	0.11	0.00	0.00
Natica rufa	0.06	0.07	0.00	0.00	0.00	0.00

Table 4. 4. contd...

Species	**St.1**	**St.2**	**St.3**	**St.4**	**St.5**	**St.6**
Smaragdia viridis	2.47	2.83	5.00	2.53	0.43	0.19
Smaragdia soverbiana	7.84	6.97	2.72	2.59	0.14	0.64
Vittina variegata	0.00	0.78	0.50	0.06	0.00	0.00
Terebralia palustris	0.00	0.00	0.00	0.00	18.03	14.99
Agatha virgo	0.00	0.00	0.00	0.00	0.00	0.00
Agatha lepidule	0.00	0.00	0.00	0.00	0.00	0.00
Pyrgulina pupula	0.00	0.09	0.72	0.23	0.00	0.00
Cymatium neobaricum	0.00	0.04	0.11	0.00	0.00	0.00
Cymatriton nicobaricum	0.00	0.00	0.11	0.00	0.00	0.00
Cinctiscala sp.	0.39	0.16	0.00	0.00	0.00	0.00
Decorifer insignis	0.11	0.07	0.00	0.00	0.00	0.00
Casmeria ponderisai	0.00	0.07	0.00	0.06	0.00	0.00
Strombus canarium	0.20	0.02	0.17	0.00	0.00	0.00
Strombus mutabilis	0.20	0.20	0.28	0.00	0.00	0.00
Cinguloterebra hedleyana	0.14	0.49	0.33	0.57	0.00	0.00
Margarites helicina	0.39	0.38	0.00	0.00	0.57	0.70
Truncatella pfeifferi	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified 129	0.51	0.18	0.61	0.34	0.00	0.00
SOFT MOLLUSCS						
Dolabella rumphii	0.34	0.22	0.00	0.00	0.00	0.00
Polycera sp.	0.08	0.09	0.00	0.00	0.00	0.00
Gymnodoris ceylonica	0.03	0.02	0.00	0.00	0.00	0.00
Elysia sp.	0.31	0.09	0.00	0.00	0.00	0.00
Smargdinella canaliculata	0.20	0.13	0.00	0.00	0.00	0.00
diala lauta	0.00	0.00	0.00	0.00	0.00	0.00
Dolabrifera dolabrifera	0.00	0.00	0.00	0.00	0.00	0.00
BIVALVES						
Lunulicardia auricula	0.08	0.00	0.00	0.00	0.00	0.00
Cardium asiaticum	0.37	0.04	0.17	0.00	0.00	0.00
Corculum impressum	0.11	0.04	0.00	0.00	0.00	0.00
Ctena delicatula	0.42	0.33	0.44	0.00	0.00	0.00
Mactra cuneata	0.06	0.02	0.00	0.00	0.00	0.00
Myadoropsis brevispinious	0.17	0.20	0.00	0.17	0.00	0.00
Lithophaga nigra	0.14	0.13	0.00	0.00	0.00	0.00
Modiolus metcalfei	0.06	0.09	0.06	0.11	0.00	0.00

Table 4. 4. contd...

Species	St.1	St.2	St.3	St.4	St.5	St.6
Pinna muricata	0.34	0.29	0.00	0.00	0.00	0.00
Tellina palatum	0.14	0.07	1.44	1.38	0.00	0.00
Gafrarium divarticatum	8.74	4.43	18.93	25.92	0.00	0.00
Periglypta puerpura	0.08	0.27	0.00	0.00	0.00	0.00
WORMS						
Baseodiscus delineatus	0.37	0.25	1.22	3.79	0.00	0.00
Golfingia hespera	0.17	0.20	0.67	0.34	0.00	0.00
Phascolosoma nigrescens	0.08	0.07	2.22	2.82	0.00	0.00
Siphonosoma australe	0.08	0.00	0.33	0.34	0.00	0.00
Sipunculus indicus	0.14	0.09	0.61	0.40	0.00	0.00
Siboglinum fiordicum	1.15	0.29	1.33	2.13	0.00	0.00
Hoplonemertean sp.	0.11	0.16	0.22	0.34	0.00	0.00
POLYCHAETE WORMS						
Scoloplos sp.	0.06	0.02	0.00	0.00	0.00	0.00
Eurythoe complanata	0.28	0.02	0.56	1.84	0.00	0.00
Eurythoe mathaii	0.14	0.07	2.39	0.00	0.00	0.00
Notopygos variabilis	0.20	0.04	0.00	0.23	0.00	0.00
Notomastes latericeus	0.17	0.13	0.39	1.21	0.00	0.00
Cirratulus sp.	0.14	0.09	0.00	0.00	0.00	0.00
Marphysa macintoshi	0.03	0.04	0.33	0.52	0.00	0.00
Nematonereis unicornis	0.11	0.00	0.11	0.00	0.00	0.00
Glycera convoluta	0.28	0.16	0.00	0.00	0.00	0.00
Glycera lancadivae	1.46	0.53	0.22	0.11	0.00	0.00
Glycera subaena	0.22	0.13	0.50	0.00	0.00	0.00
Glycera tesselata	0.22	0.09	1.89	3.68	0.00	0.00
Glycera sp.	0.06	0.00	0.33	0.29	0.00	0.00
Goniada emerita	0.25	0.20	0.17	0.34	0.00	0.00
Nephtys dibranchus	0.20	0.07	0.06	0.00	0.00	0.00
Nephtys hombergii	1.38	0.25	0.11	0.00	0.00	0.00
Nephtys inermis	0.25	0.11	0.22	0.00	0.00	0.00
Ceratonereis erythraensis	0.22	0.09	0.56	0.17	0.00	0.00
Nereis kauderni	0.28	0.04	0.00	0.17	0.00	0.00
Nereis trifasciata	1.07	0.42	0.50	0.00	0.00	0.00
Arabella iricolor iricolor	0.17	0.09	0.11	0.00	0.00	0.00

Table 4. 4. contd…

Species	St.1	St.2	St.3	St.4	St.5	St.6
Oenone fulgida	0.17	0.07	0.00	0.00	0.00	0.00
Armandia sp.	0.11	0.09	0.00	0.00	0.00	0.00
Megalomma sp.	0.06	0.04	0.00	0.00	0.00	0.00
Syllis cornuta	0.20	0.13	0.22	0.17	0.00	0.00
Syllis gracilis	0.11	0.13	0.22	0.00	0.00	0.00
Eupolymna nebulosa	0.11	0.07	0.39	0.52	0.00	0.00
CRAB						
Leptoduis sp.	0.22	0.09	0.00	0.06	0.00	0.00
Polydectus cuculifer	0.06	0.02	0.00	0.00	0.00	0.00
Megalopa larva	0.31	0.31	0.00	0.00	0.00	0.00
Calappa hepatica	0.82	0.25	0.00	0.34	0.00	0.00
Diogene sp.	0.03	0.02	0.06	0.00	0.00	0.00
Cardiosoma carnifex	0.00	0.02	0.11	0.00	0.07	0.00
Pachygrapsus plicatus	0.17	0.04	0.00	0.11	0.00	0.00
Illyograpsus paludicola	0.00	0.02	0.00	0.00	0.00	0.06
Plagusia sp.	0.14	0.00	0.00	0.00	0.00	0.00
Grapsus sp.	0.25	0.04	0.06	0.00	0.00	0.00
Eriphis sp.	0.20	0.07	0.39	0.17	0.00	0.00
Uca tetragonon	0.00	0.02	0.00	0.00	0.14	0.26
Macrophthalmus boscii	0.93	0.09	0.11	0.80	0.00	0.00
Uca inversa inversa	0.00	0.00	0.00	0.06	0.07	0.13
Tylodipax desigardi	0.11	0.07	0.00	0.29	0.14	0.00
Pilumnus hirtellus	0.45	0.09	0.39	0.29	0.00	0.00
Pinnotheres pisum	0.17	0.04	0.06	0.06	0.00	0.00
Pinnotheres pinnotheres	0.25	0.47	0.72	0.63	0.00	0.00
Thalamita crenata	0.76	0.49	0.94	0.34	0.14	0.00
scylla serrata	0.00	0.00	0.00	0.00	0.43	0.19
Portunus orbitosinus	0.03	0.07	0.00	0.00	0.00	0.00
Macropipus corrugatus	0.00	0.00	0.00	0.00	0.00	0.00
Etisus splendidus	0.22	0.02	0.00	0.00	0.00	0.00
Actaeodes tomentosus	0.28	0.11	0.44	0.00	0.00	0.00
OTHER CRUSTACEANS						
PRAWNS AND SHRIMPS						
Alpheopsis equalis	0.25	0.09	0.06	0.11	0.00	0.00
Alpheus lottini	0.00	0.00	0.00	0.00	0.00	0.00

Table 4. 4. contd...

Species	St.1	St.2	St.3	St.4	St.5	St.6
Alpheus sp.	0.06	0.02	0.00	0.00	0.00	0.00
Metabetaeus minutus	0.06	0.07	0.00	0.00	0.00	0.00
Nikoides maldivensis	0.00	0.09	0.00	0.00	1.57	0.89
AMPHIPODS						
Cymadusa imbroglio	2.42	0.22	4.22	1.09	0.00	0.00
Maera pacifica	4.39	3.43	2.33	1.09	0.00	0.00
Mallacoota insignis	0.28	0.31	0.00	0.00	0.00	0.00
Stenothoe kaia	1.10	0.27	0.00	0.06	0.00	0.00
ISOPODS						
Cirolana sp.	0.03	0.11	0.00	0.00	0.00	0.00
Seychellana expansa	0.17	0.09	0.17	0.00	0.00	0.00
Accalathura borradailei	0.14	0.11	0.00	0.00	0.00	0.00
Paracilicacea setosa	0.45	0.16	0.00	0.00	0.00	0.00
Paraleptosphaeroma indica	0.14	0.09	0.00	0.00	0.00	0.00
STOMATOPODS						
Gonodactylus.of.smithii	0.06	0.04	0.00	0.00	0.00	0.00
Apseudus sp.	0.03	0.00	0.00	0.00	5.92	2.42
Paratanaeidae sp.	0.67	0.22	0.00	0.00	0.50	0.06
Paranebalia sp.	0.11	0.09	0.00	0.00	0.00	0.00
Siriella brevicaudata	0.14	0.18	0.00	0.00	0.00	0.00
ECHINODERMS						
Linckia multifora	0.08	0.00	0.00	0.00	0.00	0.00
Ophiactis savignyi	0.25	0.13	0.00	0.11	0.00	0.00
Ophicornella sexadia	0.62	0.31	0.11	0.00	0.00	0.00
Ophiocoma scolopendrina	0.34	0.11	0.00	0.00	0.00	0.00
Astropyga radiata	0.03	0.00	0.00	0.00	0.00	0.00
Echinometra mathaei	0.17	0.07	0.00	0.00	0.00	0.00
Echinoneus cyclostomus	0.08	0.11	0.00	0.00	0.00	0.00
Salmacis bicolor	0.11	0.02	0.00	0.00	0.00	0.00
Bohadschia subruba	0.06	0.02	0.00	0.00	0.00	0.00
Holothuria nobilis	0.03	0.04	0.00	0.00	0.00	0.00
Holothuria scabra	0.06	0.00	0.00	0.00	0.00	0.00
SPONGES						
Aaptos cf.chromis	0.22	0.27	0.00	0.00	0.00	0.00
Cinachyrella voeltzkowii	0.11	0.07	0.00	0.00	0.00	0.00

Pyrgulina pupula., *Cymatium neobaricum*, *Casmeria ponderisai* and *Truncatella pfeifferi* were very less at this station. Among bivalves, *Gafrarium divarticatum* contributed 90% of individuals followed by *Cardium asiaticum* and *Pinna muricata*. *Siboglinum fiordicum* contributed major share of individuals in the category of "other worms", *Uca* spp. and *Scylla serrata* were not found at station 1. However *Calappa hepatica* formed the major share of crabs followed by *Thalamita crenata*. Carridean prawns formed 90% of other crustaceans, the major share contributed by *Alpheopsis equalis* and *Alpheus* sp. In seagrass beds, amphipods flourished seasonally and they contributed 7% of total individuals. The major species involved were *Maera pacifica, Cymadusa imbroglio, Stenothoe kaia* and *Mallacoota insignis*. Isopods formed only 1 % of total individuals. Major share of isopods were *Paracilicacea setosa* and *Paraleptospheroma indica*. Echinoderms contributed 2% of the total individuals, of which major share was contributed by *Ophiocornella sexadia* and *Ophiocoma scolopendrina*. Sponge *Aaptos cf. chromis* was found in almost all seagrass samples.

Station 2

The spectrum of various taxa at station 2 comprised of gastropods (81%), bivalves (6%), other worms (1%), polychaetes (3%), crabs (2%), other crustaceans (6%) and echinoderms (1%).

All *Cerithium* spp. together contributed 90% of gastropods. *Smaragdia* spp., *Pyrene* spp. and *Littorina* sp. contributed the major share of rest. Opisthobranchs and lamellibranchs were found in seagrass beds occasionally. *Gafrarium divarticatum* formed the major share of bivalves. Worms other than polychaetes were present only in minor quantities. Polychaete species like *Glycera, Nereis,* and *Nephtys* were present in considerable number while the other species of this group were less. Except *Thalamita crenata, Calappa hepatica* and *Actaeodes tomentosus* all other crabs contributed very little to the abundance. Amphipods dominated among other crustaceans, contributed even 4 % of total individuals while isopods, prawns, stomatopods, etc. together contributed only 1%. Echinoderms showed less abundance when compared to station 1 and some species were found absent at this station during the period of study.

Station 3

The share of numerical abundance of each group at station 3 comprised of gastropods (53%), bivalves (21%), other worms (7%), polychaetes (9%), crabs (3%), and other crustaceans (7%).

Of the 53% gastropods, *Cerithium* spp. contributed 21% and *Smaragdia* spp. 7%. Soft molluscs were not recorded from this station. Of the 21 % bivalves, major share was sponsored by the single species *Gafrarium divarticatum. Tellina palatum* contributed 5 %. Many species present at station 1 and station 2 were not recorded from this site. Percentage of worms was higher at this station. *Phasolosoma nigrescens*, *Siboglinum fiordicum*, *Baseodiscus delineatus* etc. were present comparatively in good numbers. Polychaetes were present in good numbers, even though occurrence of polychaetes were less. *Eurythoe mathaei* contributed 25% of total polychaetes from this region. *Glycera* spp., *Notomastes latericeus, Marphysa* sp., *Nephtys* spp., *Syllis* spp. and *Eupolymna* sp. dominated the sample. Out of a crab population of 4%, *Thalamita crenata, Calappa hepatica* and *Actaeodes tomentosus* dominated the samples. Many species of prawns, amphipods, isopods, stomatopods, and echinoderms recorded from other sites were not found at this site, except *Alphaeopsis equalis, Cymadusa imbroglio, Maera pacifica and Seychellana ecpansa*. Stomatopods were not recorded at this station. Only a single species of echinoderm namely *Ophiactis savignyi* has appeared at this station.

Station 4

At station 4 gastropods contributed 48%, bivalves 28%, other worms 10%, polychaetes 9%, crabs 3%, and other crustaceans 2%.

Out of 48% of gastropods, *Cerithium* spp. contributed 20%. *Pyrene* spp. contributed 12% and *Smaragdia* spp. 5%. Out of a total of 58 species gastropods recorded, only 23 species were found at this station. Only 4 species of bivalves were present at this station, of which *Gafrarium divarticatum* alone contributed 26% of the total individuals. *Tellina* spp. contributed 1% only. *Baseodiscus delineatus* dominated among worms forming around 4% of total abundance. *Phascolosoma nigrescens* and *Siboglinum fiordicum* formed 2% each of total abundance. In the case of polychaete worms, some members like *Glycera* spp. dominated. Abundance of *Notomastes* spp. and *Eurythoe complanata* were comparatively higher at this station. Eleven species of crabs were recorded at this station, the dominating ones were *Macrophthalmus boscii, Tylodipax desigardii, Pilumnus hirtellus, Pinnotheres* spp., *Thalamita crenata and Calappa hepatica.* Among echinoderms, only *Ophiactis savignyi* was recorded at this station.

Station 5

At this station, 91% of individuals were gastropods, 1% crabs and 8% other crustaceans.

Only 9 species of gastropods were recorded, out of which *Littorina undulata* formed about 59% of total abundance. *Terebralia palustris* formed 18% and *Cerithium corallium* 10%. All other species showed less than 1% abundance. Bivalves, worms, polychaetes, echinoderms and sponges were not recorded from this station. Six species of crabs were found, out of which *Scylla serrata* showed the highest abundance. *Uca* spp. and *Tylodipax desigardii* also were rarely represented. *Nikoides*

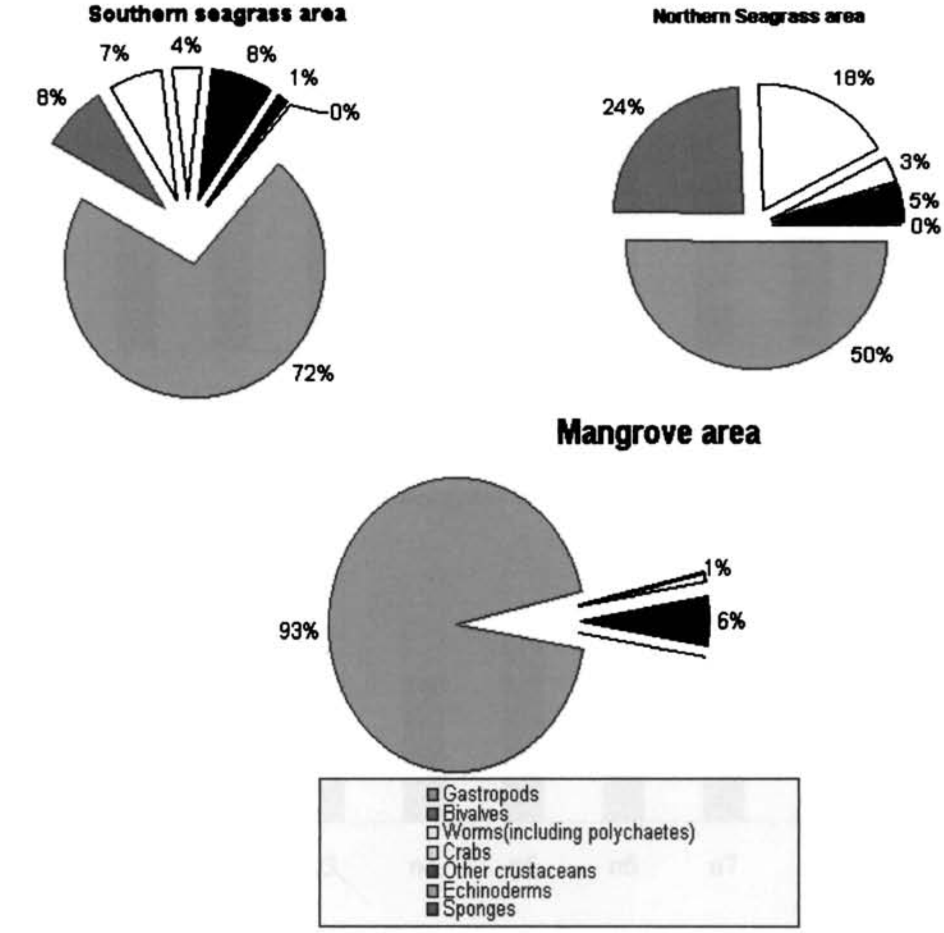


Fig. 4. 7. Groupwise share to numerical abundance at different areas

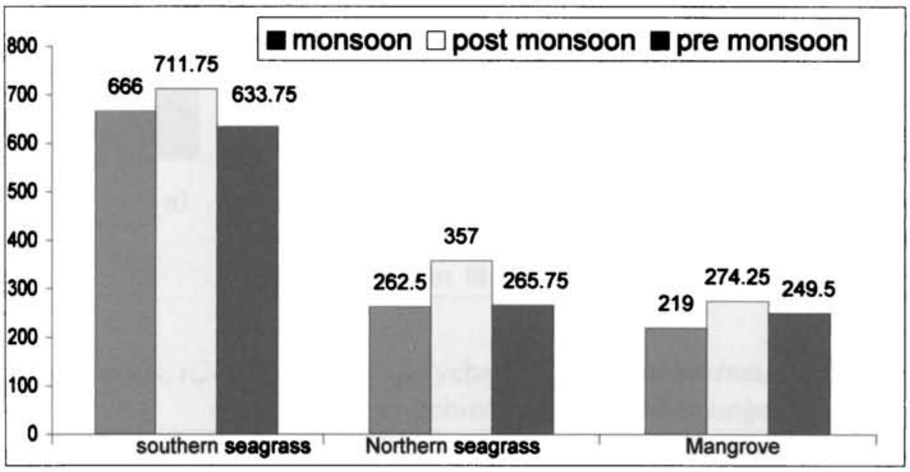
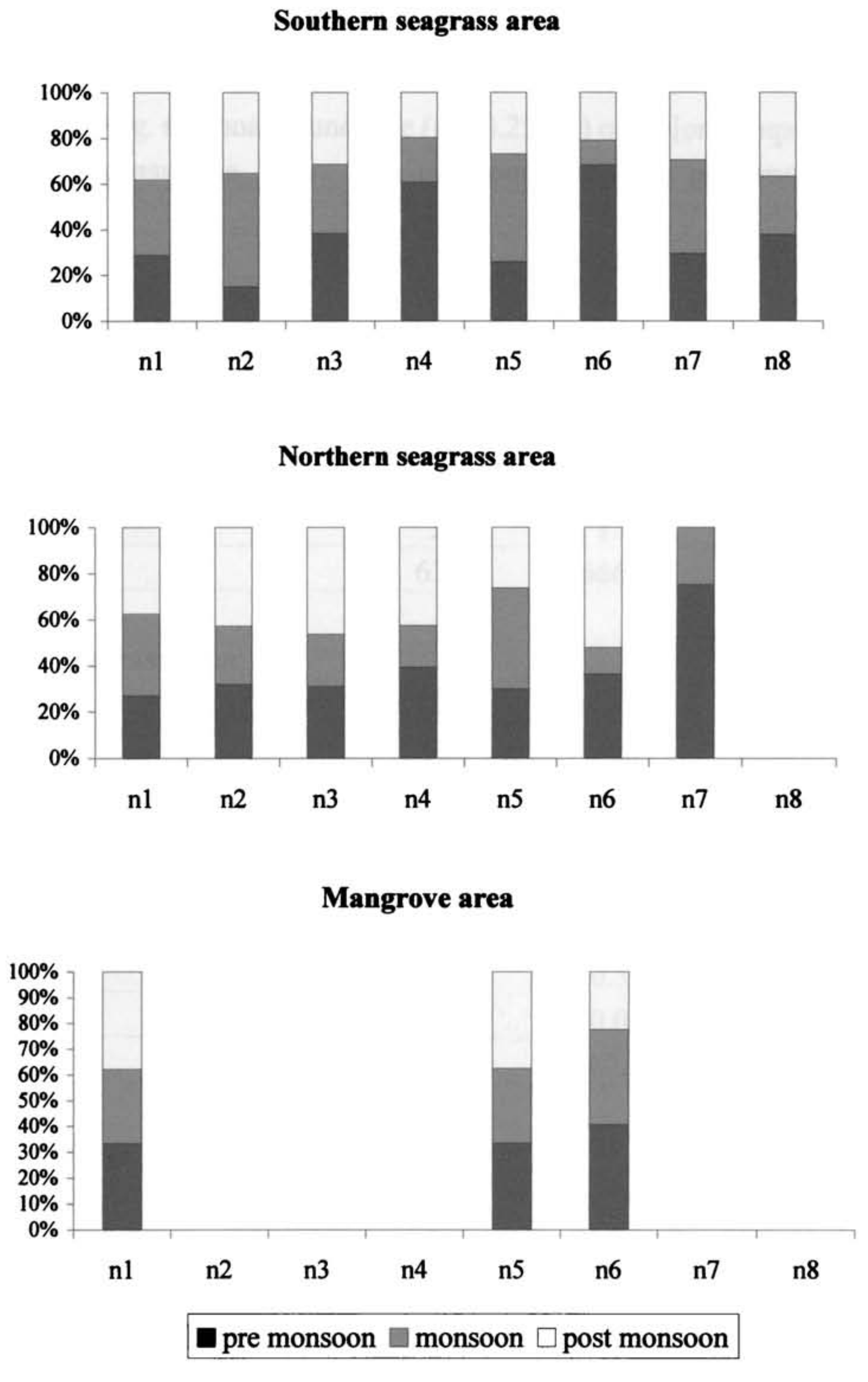


Fig. 4. 8. Avg. seasonal abundance (no./0.25m^2) at different areas



n1-gastropods, n2- bivalves, n3-polychaetes, n4-other worms, n5-crabs, n6-other crustaceans, n7-echinoderms and n8-sponges

Fig. 4. 9. Seasonwise distribution of numerical abundance of major groups at different areas

Table 4. 5. Avg. seasonal abundance (no./0.25 m^2) of major groups

Southern seagrass area	**pre-monsoon**	**monsoon**	**post-monsoon**
Gastropods	415.0	482.5	553.0
Bivalves	24.0	80.8	57.0
Polychaetes	18.5	6.0	6.0
worms(excluding polychaetes)	40.5	32.3	33.3
Crabs	19.3	35.3	20.0
Other crustaceans	106.5	17.0	32.5
Echinoderms	7.5	10.5	7.5
Sponges	2.6	1.8	2.5
Total	633.8	666.0	711.8
Northern seagrass area			
Gastropods	119.3	158.3	166.8
Bivalves	68.3	54.5	92.0
Polychaetes	25.3	18.8	38.0
worms(excluding polychaetes)	29.0	13.5	31.5
Crabs	8.5	12.5	7.5
Other crustaceans	14.8	4.8	21.3
Echinoderms	0.8	0.3	0.0
Sponges	0.0	0.0	0.0
Total	265.8	262.5	357.0
Mangrove Area			
Gastropods	230.8	202.0	262.8
Bivalves	0.0	0.0	0.0
Polychaetes	0.0	0.0	0.0
Worms (excluding polychaetes)	0.0	0.0	0.0
Crabs	2.0	1.8	2.3
Other crustaceans	16.8	15.3	9.3
Echinoderms	0.0	0.0	0.0
Sponges	0.0	0.0	0.0
Total	238.0	209.0	254.5

maldivensis showed 2% abundance. *Apseudus* sp. and *Paratanaeidae* sp. were also found in almost all samples.

Station 6

At this station, 96% of individuals were gastropods, 1% crabs and the rest 3% were of other crustaceans. Abundance of *Littorina undulata* came up to 66% and *Terebralia palustris* 15%. Four species of crabs were found at this station. Numerical abundance of all other individuals was almost similar to that at station 5.

Season wise analysis

The average seasonal values of numerical abundance of major groups as well as major areas are given in Table 4.5 and Fig. 4. 8. The seasonwise contribution to major groups is given in Fig. 4. 9. In the southern seagrass area, gastropods showed a highest seasonal average of 553 nos./0.25m^2 during post-monsoon and the lowest during pre-monsoon (415 nos./0.25m^2). Bivalves, crabs and echinoderms showed their highest abundance at monsoon and other crustaceans showed a very high abundance at the pre-monsoon season. In the northern seagrass area, most of the major groups like gastropods, bivalves, polychaetes and other crustaceans showed their highest average seasonal abundance values at the post-monsoon season. The total abundance at mangrove areas showed the highest value in post-monsoon.

4. 2. 2. 1. Three-way ANOVA

Three way ANOVA applied on the benthic data showed that there was significant difference between stations and abundance of various benthic groups. Station-group interaction was high indicating a location specificity for the benthic groups. Station month interaction was also high.

Students t test was applied to see which of the stations were significantly different. Three way ANOVA for comparing between stations, months and benthic groups and first order interaction effects between these three factors are given in Table 4. 6.

Comparison of stations based on biomass:

Regarding the distribution of major groups of benthic organisms, highest average wet weight biomass was observed for gastropods (shell-on) at station 1 ($\overline{X}$-167.927 g/m2) and least at station 4 ($\overline{X}$-31.96 g/m2) with maximum variation at station 1 (83.11%) and least at station 6 (67.19%). Bivalves were absent at stations 5 and 6 and maximum at station 3 ($\overline{X}$-42.32 g/m2) and least biomass at station 1 ($\overline{X}$-11.147 g/m2) with maximum variation (128.71%). Worms were also absent at stations 5 and 6 and maximum biomass at station 4 ($\overline{X}$-1.353 g/m^2) with highest variation over time (157.29%) and least at station 2 ($\overline{X}$- 0.400 g/m^2) and least variation with distribution over time was observed at station 1 (68.97%). Biomass of Crabs was highest at station 5 ($\overline{X}$-2.233 g/m2) and least at station 1 ($\overline{X}$-0.653 g/m^2) with least variation (71.37%), and highest temporal variation was observed at station 4 (205.87%). Other crustaceans have maximum biomass at station 6 ($\overline{X}$-0.967 g/m^2) with maximum variation, 253.53%. Least biomass was at station 4 ($\overline{X}$-0.027 g/m^2) and least variation was at station 1 (91.49%). Echinoderms and Sponges were absent at stations 5 and 6 with very stray occurrence at other stations ($\overline{X}$-0.007-0.5 g/m^2 for echinoderms and 0.035-0.347 g/m^2 for sponges). Average total biomass was maximum at station 1 ($\overline{X}$-181.440 g/m^2) and least average biomass was at station 4 ($\overline{X}$-56.48 g/m^2) with least temporal variation at station 5 (42.879%) and maximum at station 1 (79.928%) (Table 4. 7).

Table 4. 6. Three way ANOVA for comparing between stations, months and benthic groups and first order interaction effects between these three factors

Source	Sum of squares	D O F	Mean Sum of squares	F Ratio
(A) Stations	126890.0	5	(25378.0)	44.685 **
(B) Groups	2137510.0	8	(267189)	9.793 **
(C) Months	127698.0	23	5652.098	3.281 *
AxB	2989080.0	53	56397.74	
BxC	2657300.0	215	12359.53	
AxC	592078.0	143	4140.406	
AB interaction		40	18117.0	14.354**
BC interaction		184	2130.91	1.688
AC interaction		115	2934.69	2.325*
Error	1161150.0	920	1262.12	
Total		1295		

* Calculated F is significant at 5% level (P<0.05)

** Calculated F is significant at 1% level (P<0.01)

Table 4.7. Avg. (X), standard deviation (S. D.) and co-efficient of variation (C.V.%) of benthic biomass (wet wt. g/m^2)at station 1 to 6.

Station 1	$\overline{X}$		**S.D**	**C.V. (%)**	**LCL**	**UCL**
Gastropods	167.927	±	139.563	83.110	-105.617	441.471
Bivalves	11.147	±	14.346	128.705	-16.972	39.265
Worms (Inc. polychaetes)	0.733	±	0.506	68.971	-0.258	1.725
Crabs	0.653	±	0.466	71.370	-0.261	1.567
Other crustaceans	0.300	±	0.274	91.490	-0.238	0.838
Echinoderms	0.500	±	0.362	72.333	-0.209	1.209
Sponges	0.180	±	0.267	148.102	-0.343	0.703
Total	181.440	±	143.928	79.326	-100.660	282.100

Station 2	$\overline{X}$		**S.D**	**C.V. (%)**	**LCL**	**UCL**
Gastropods	150.287	±	116.938	77.810	-78.912	379.485
Bivalves	13.300	±	13.736	103.278	-13.623	40.223
Worms (Inc. polychaetes)	0.400	±	0.355	88.694	-0.295	1.095
Crabs	0.673	±	0.993	147.438	-1.272	2.619
Other crustaceans	0.233	±	0.537	229.978	-0.818	1.285
Echinoderms	0 .367	±	0.290	79.148	-0.202	0.935
Sponges	0.347	±	0.473	136.308	-0.580	1.273
Total	165.607	±	122.647	74.059	-74.781	240.388

Station 3	$\overline{X}$		**S.D**	**C.V. (%)**	**LCL**	**UCL**
Gastropods	33.887	±	27.080	79.914	-19.191	86.964
Bivalves	42.320	±	43.219	102.125	-42.390	127.030
Worms (Inc. polychaetes)	1.200	±	1.350	112.480	-1.446	3.846
Crabs	1.113	±	1.348	121.057	-1.528	3.755
Other crustaceans	0.173	±	0.269	155.186	-0.354	0.701
Echinoderms	0.007	±	0.032	479.583	-0.056	0.069
Sponges	0.000	±	0.000	479.583	0.000	0.000
Total	78.700	±	49.048	62.323	-17.434	96.134

LCL – Lower Confidence limit at 95% confidence
UCL – Upper Confidence limit at 95% confidence

Table 4. 7. contd...

Station 4	$\overline{X}$		S.D	C.V. (%)	LCL	UCL
Gastropods	31.960	±	20.887	65.353	-8.978	72.898
Bivalves	22.013	±	15.429	70.088	-8.227	52.254
Worms (Inc. polychaetes)	1.353	±	2.129	157.290	-2.819	5.525
Crabs	1.087	±	2.237	205.871	-3.298	5.471
Other crustaceans	0.027	±	0.060	223.607	-0.090	0.144
Echinoderms	0.020	±	0.070	351.188	-0.118	0.158
Sponges	0.000	±	0.000	351.188	0.000	0.000
Total	56.460	±	26.726	47.337	4.076	52.384
Station 5	$\overline{X}$		**S.D**	**C.V. (%)**	**LCL**	**UCL**
Gastropods	55.807	±	37.500	67.196	-17.694	129.307
Terebralia palustris	59.673	±	29.053	48.688	2.729	116.618
Bivalves	0.000	±	0.000	48.688	0.000	0.000
Worms (Inc. polychaetes)	0.000	±	0.000	48.688	0.000	0.000
Crabs	2.233	±	3.035	135.875	-3.714	8.181
Other crustaceans	0.620	±	1.189	191.721	-1.710	2.950
Echinoderms	0.000	±	0.000	191.721	0.000	0.000
Sponges	0.000	±	0.000	191.721	0.000	0.000
Total	118.333	±	50.740	42.879	18.882	99.451
Station 6	$\overline{X}$		**S.D**	**C.V. (%)**	**LCL**	**UCL**
Gastropods	51.800	±	21.155	40.840	10.336	93.264
Terebralia palustris	46.733	±	30.559	65.390	-13.162	106.628
Bivalves	0.000	±	0.000	65.390	0.000	0.000
Worms (Inc. polychaetes)	0.000	±	0.000	65.390	0.000	0.000
Crabs	1.593	±	2.622	164.532	-3.545	6.732
Other crustaceans	0.967	±	2.451	253.530	-3.837	5.770
Echinoderms	0.000	±	0.000	253.530	0.000	0.000
Sponges	0.000	±	0.000	253.530	0.000	0.000
Total	101.093	±	46.422	45.920	10.105	90.988

LCL – Lower Confidence limit at 95% confidence
UCL – Upper Confidence limit at 95% confidence

Comparison of stations based on numerical abundance:

Mean Gastropod abundance was maximum at station 2 ($\overline{X}$-604.33/0.25m^2) and least at station 4 ($\overline{X}$ 137.33). At the other stations average gastropod abundance ranged between 158.8 (station 3) and 362.7 (station 1). Seasonal variations in the gastropod distribution was highest at station 5 (220.62%) and least variation with respect to seasons was at station 6 (202.95%) (Table 4. 8).

Bivalves were occurring only at station 1 ($\overline{X}$-63.5), station 2 (least abundance $\overline{X}$-44.3), station 3 ($\overline{X}$- 63.17) and station 4 (highest abundance $\overline{X}$-80). Bivalves were negligible/ absent at stations 5 and 6. This reveals group specificity for some locations. Worm's distribution was similar to that of gastropods and bivalves, occurring only at stations 1 to 4 with maximum average abundance of 29.5 at station 4 with highest spatial variation (C.V.% = 791 at station 1) and totally absent at stations 5 and 6. Polychaetes were distributed with maximum average abundance at station 1 ($\overline{X}$- 47.17) and found negligibly absent at stations 5 and 6. Crabs were distributed more or less with same average abundance at stations 3 and 4 and having maximum abundance at station1. Stations 1 & 5 and stations 2 & 5 showed high differences in the abundance of crabs ($P<.05$). High variation was observed for crustaceans other than crabs at different stations with highest abundance at station 1 ($\overline{X}$- 63) followed by station 2 ($\overline{X}$-41.8) and least abundance at station 4 ($\overline{X}$- 6.8). Seasonal variations were also found high at all stations for this group. In respect of the remaining two benthic groups, stations 1& 2 and 3 & 4 the difference was not very high. Echinoderms were high at Sts. 1 and 2 and least at station 3 to 6 ($P<0.01$). Based on total benthic abundance, stations 1 and 2 were highly different from stations 3 and 4 and so also at station 6 ($P<0.05$). In terms

a. Gastropods

	St.1	St.2	St.3	St.4	St.5	St.6
St.1	–	⊕	●	●	●	●
St.2	0.46	–	●	●	●	●
St.3	4.52	4.65	–	⊕	◑	◑
St.4	4.62	4.78	0.27	–	◑	●
St.5	3.72	3.69	2.27	2.66	–	⊕
St.6	3.95	3.97	2.50	3.20	0.45	–

b. Bivalves

	St.1	St.2	St.3	St.4	St.5	St.6
St.1	–	⊕	●	◑	●	●
St.2	0.52	–	●	◑	●	●
St.3	3.28	3.07	–	◑	●	●
St.4	2.47	2.02	2.12	–	●	●
St.5	3.71	4.63	4.69	6.83	–	⊕
St.6	3.71	4.63	4.69	6.83	0.00	–

c. Worms

	St.1	St.2	St.3	St.4	St.5	St.6
St.1	–	●	⊕	⊕	●	●
St.2	2.59	–	●	◑	●	●
St.3	1.56	2.75	–	⊕	●	●
St.4	1.36	2.12	0.29	–	●	●
St.5	6.10	4.22	4.07	2.94	–	⊕
St.6	6.10	4.22	4.07	2.94	0.00	–

d. Crabs

	St.1	St.2	St.3	St.4	St.5	St.6
St.1	–	⊕	⊕	⊕	◑	⊕
St.2	0.09	–	⊕	⊕	◑	⊕
St.3	1.55	1.26	–	⊕	⊕	⊕
St.4	0.91	0.81	0.05	–	⊕	⊕
St.5	2.47	2.34	1.62	1.46	–	⊕
St.6	1.69	1.57	0.78	0.71	0.77	–

⊕ – t statistic is not significant, $t < 2{\cdot}074$

● – $t \geq 2.578$, t is significant at 1 % level $P < {\cdot}01$

◑ – $t \geq 1{\cdot}96$ & $t < 2{\cdot}578$, t is significant at 5 % level $P < 0{\cdot}05$

Fig.4. 10. a-d Trellis diagram for comparing between stations based on numerical abundance of gastropods, bivalves, worms (including polychaetes) and crabs.

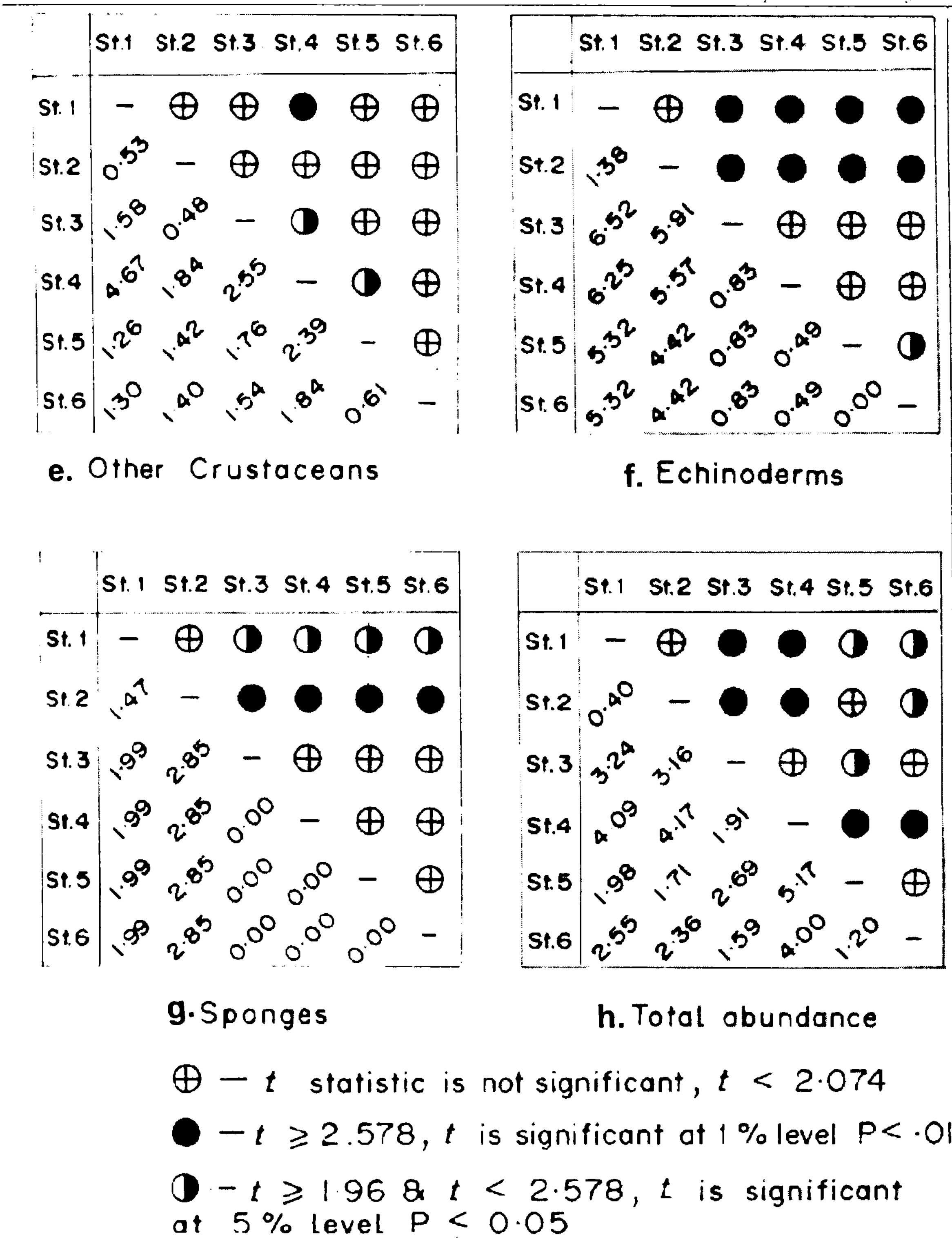


Fig. 4. 10 e-h Trellis diagram for comparing between stations based on numerical abundance of other crustaceans, echinoderms, sponges and all groups together.

Table 4. 8. Avg. (X), standard deviation (S. D.) and co-efficient of variation (C.V.%) of benthic numerical abundance (no./0.25m^2) at station 1 to 6.

	Station1			Station 2		
Groups	X	S.D.	C.V. (%)	X	S.D.	C.V. (%)
Gastropods	362.7	194.4	214.412	604.33	323.8	214.288
Bivalves	63.5	68.52	431.628	44.332	63.36	571.672
Worms	12.5	24.72	791.044	7.832	9.344	477.128
Polychaetes	47.17	22.06	187.08	23.5	9.612	163.632
Crabs	29.5	16.24	220.208	17.668	17.24	390.344
Other crustaceans	63	76.072	483	41.832	92.66	885.964
Echinoderms	10.83	4.24	156.532	6.168	3.46	224.44
Sponges	2.2	2.308	461.88	2.5	2.784	445.42

	Station3			Station 4		
Groups	X	S.D.	C.V. (%)	X	S.D.	C.V. (%)
Gastropods	158.8	83.528	210.348	137.33	74.98	218.392
Bivalves	63.17	52.876	334.84	80	50.58	252.916
Worms	19.83	18.708	377.296	29.5	25.61	347.22
Polychaetes	27.87	36.96	531.148	26.832	29.06	433.232
Crabs	9.832	8.944	363.772	9.168	8.444	368.476
Other crustaceans	20.33	24.6	483.96	6.832	9.964	583.328
Echinoderms	0.332	1.104	1326.65	0.332	1.104	1326.65
Sponges	0.332	1.104	1326.65	0.332	1.104	1326.65

	Station5			Station 6		
Groups	X	S.D.	C.V. (%)	X	S.D.	C.V. (%)
Gastropods	212.8	117.39	220.62	250.83	127.3	202.948
Bivalves	0.168	0.8	1918.33	0.168	0.8	1918.33
Worms	0.168	0.8	1918.33	0.168	0.8	1918.33
Polychaetes	0.168	0.8	1918.33	0.168	0.8	1918.33
Crabs	2.332	2.808	481.496	1.668	2.284	548.452
Other crustaceans	18.67	25.024	536.236	8.832	7.744	350.68
Echinoderms	0.168	0.8	1918.33	0.168	0.8	1918.33
Sponges	0.168	0.8	1918.33	0.168	0.8	1918.33

Table 4. 9. Avg. (X), standard deviation (S. D.) and co-efficient of variation (C.V.%) of benthic numerical abundance (no./0.25m^2) from 1999 Sep.-2001 Aug.

		Station 1			Station 2	
Months	**X**	**S.D.**	**C.V.(%)**	**X**	**S.D.**	**C.V.(%)**
1999 SEP	89	154.4	693.928	94.5	209.76	887.876
OCT	123.5	215.848	699.1	58	89.976	620.536
NOV	68.5	115.04	671.756	216.5	477.3	881.844
DEC	63	110.336	700.804	160.5	385.628	961.068
2000 JAN	59.5	89.832	603.912	55.5	90.12	649.52
FEB	27.5	28.668	416.964	44.5	90.696	815.244
MAR	125	179.072	573.032	136.5	202.736	594.096
APR	78	102.196	524.08	65	124.592	766.716
MAY	60	66.844	445.62	80.5	188.896	938.616
JUN	34.5	35.66	413.468	68	142.66	839.18
JUL	34	44.812	527.184	116.5	265.092	910.188
AUG	80.5	138.572	688.548	67.5	124.152	735.716
SEP	89	156.624	703.928	41.5	84.64	815.796
OCT	111.5	217.608	780.66	34.5	74.724	866.372
NOV	67.5	124.392	737.148	95	219.896	925.884
DEC	76	145.916	767.988	114	268.52	942.184
2001 JAN	46	78.512	682.704	71	153.436	864.436
FEB	106.5	189.196	710.6	99.5	169.5	681.4
MAR	125	252.332	807.46	82.5	176.532	855.916
APR	46.5	39.492	339.732	80.5	187.42	931.272
MAY	69	138.836	804.836	43	86.872	808.124
JUN	51	71.128	557.856	151	376.896	998.4
JUL	86	101.608	472.592	170.5	338.336	793.752
AUG	56.5	53.232	376.872	98	213.86	872.896

Table 4. 9. contd...

	Station 3			Station 4		
Months	**X**	**S.D.**	**C.V.(%)**	**X**	**S.D.**	**C.V.(%)**
1999 SEP	32	45.388	567.34	24.5	55.008	898.072
OCT	61.5	77.328	502.952	43	94.716	881.072
NOV	74.5	79.244	425.476	49	61.116	498.896
DEC	63.5	87.028	548.204	69.5	64.712	372.448
2000 JAN	71.5	110.912	620.492	43	53.208	494.952
FEB	40.5	40.468	399.696	40	34.06	340.588
MAR	22.5	29.32	521.272	35	58.948	673.704
APR	49	54.98	448.832	61.5	82.192	534.592
MAY	19.5	28.384	582.272	44	57.028	518.42
JUN	37.5	48.7	519.472	24	31.368	522.812
JUL	67.5	100.648	596.424	46	77.768	676.252
AUG	21.5	30.064	559.3	35	44.124	504.284
SEP	21.5	35.94	668.668	41	71.936	701.828
OCT	27	35.54	526.5	31.5	41.544	527.52
NOV	26.5	44.94	678.364	48	57.584	479.872
DEC	28.5	30.164	423.328	38	51.612	543.304
2001 JAN	22	30.596	556.256	17.5	28.208	644.78
FEB	13	18.948	582.992	27.5	36.9	536.756
MAR	22.5	34.636	615.776	20	22	440
APR	22	31.748	577.256	40	83.5	834.984
MAY	53	98.688	744.804	21.5	32.368	602.212
JUN	40.5	84.816	837.688	31.5	51.516	654.152
JUL	28	52.384	748.332	18.5	34.288	741.388
AUG	36	69.972	777.46	21.5	32.12	597.596

Table 4. 9. contd...

	Station 5			Station 6		
Months	**X**	**S.D.**	**C.V.(%)**	**X**	**S.D.**	**C.V.(%)**
1999 SEP	31.5	73.032	927.396	32	72.828	910.356
OCT	11	19.26	700.412	11.5	19.02	661.556
NOV	30.5	74.752	980.344	30.5	74.752	980.344
DEC	79	209.016	1058.3	79	209.016	1058.3
2000 JAN	26.5	65.632	990.692	58.5	153.272	1048
FEB	25	61.732	987.732	56.5	142.02	1005.452
MAR	12	23.324	777.46	53.5	140.04	1047.044
APR	21	49.668	946.076	29.5	78.048	1058.3
MAY	18.5	45.996	994.536	36.5	90.752	993.688
JUN	36.5	92.12	1009.512	32.5	85.988	1058.3
JUL	29	63.96	882.22	25.5	63.052	989.076
AUG	20	44.544	890.844	34	85.464	1005.452
SEP	28	66.724	953.192	36	90.796	1008.848
OCT	33	87.308	1058.3	17.5	46.3	1058.3
NOV	29	66.596	918.564	28	69.6	994.268
DEC	37	91.996	994.536	43.5	107.728	990.62
2001 JAN	9.5	23.66	996.168	27	65.596	971.812
FEB	41	104.016	1014.776	13	34.396	1058.3
MAR	41	104.016	1014.776	21	52.564	1001.224
APR	61.5	119.532	776.132	16.5	36.684	889.32
MAY	18	43.176	959.424	34.5	91.28	1058.3
JUN	28	62.864	898.072	29	70.872	977.56
JUL	21.5	53.924	1003.228	21	55.56	1058.3
AUG	16	32.124	803.12	20	45.652	913.016

of numerical abundance, stations can be graded as st.1> st.2> st.5> st.6> st.3> and st.4. Fig. 4.10 a-h is the Trellis diagram for comparing between stations based on numerical abundance of major groups.

At station 1, the month of March 2000 showed highest average abundance ($\overline{X}$-125) followed by October 1999 ($\overline{X}$-123.5). The least average abundance was seen in July 2000 ($\overline{X}$-34). At station 2 the highest abundance was in 1999 November ($\overline{X}$-216.5) and least was in October 2000 ($\overline{X}$-34.5). Station 3 showed the highest abundance in 2000 January ($\overline{X}$-71.5) and least abundance in February 2001 ($\overline{X}$-13). At station 4 the highest abundance was in 1999 December ($\overline{X}$-69.5) and the lowest abundance was in 2001 January ($\overline{X}$-17.5). The highest abundance ($\overline{X}$-61. 5) was reported from station 5 during April 2001 and station 6 during 2000 January ($\overline{X}$-58.5) (Table 4. 9).

4. 2. 2. 2. Community structure

Species richness

Based on average diversity indices computed for each station, it was noticed that there was a steady decrease for species richness index from station 1 to station 6 with a gradual increase in temporal variation even though overall variation was less (<36.26%) except at station 2, where coefficient of variation was the least for species richness (15.49%).

Species concentration

Species concentration index decreased from station 1 to station 2 and after that again increased and following the second peak, it steadily decreased from station 3 onwards to station 6. Maximum concentration was at station 1 (0.843). Temporal variation also showed the same trend with average concentration factor with maximum temporal variation at station 6 (C.V.%- 26.696) and least temporal variation or high consistency with respect to seasons for species concentration factor at station 3 (C.V.% - 9.388).

Species diversity

Shannon weaver diversity was maximum (3.649) at station 1 and least at station 6 (1.453). Spatial distribution showed a positively skewed curve, for diversity as that for concentration with bimodal pattern the first mode at station 1 and second at station 3, whereas for richness, a steep steady decreasing pattern with rate of change of 4.396 per station was observed. Temporal variation was least at Station 1 and Station 3 (<13.9482%) showing high consistency in the diversity, during the study period at these two stations and maximum variation at station 6 (28.3285%) showing high fluctuation in the number of species and abundance at station 6, during the period of 2 years.

Species dominance

Dominance was least at station 2 (0.47) and maximum at station 3 (0.8034). Pattern of distribution was same as that of diversity and concentration with two modal values, one at station 1 and other at station 3. Temporal variation was maximum at station 2 (87.62%) and least at station 3, (13.052%) implying that dominance remained almost same for all the months, while at station 2, the least dominance was highly varying from period to period.

Species evenness

Uniformity in the distribution was high at station 3 (1.6669) and least at station 2 (0.6923) with least variation at station 3 (29.98%) and maximum variation at station 2 (49.98%). Evenness was least at station 2

Table 4. 10. Community structure indices on the average.

Station	Richness Index	Concentration Index	Diversity Index	Dominance Index	Evenness Index
Station 1					
$\bar{X}$	26.176	0.843	3.649	0.594	1.361
σ	5.674	0.067	0.504	0.349	0.674
C.V.%	21.678	7.929	13.948	58.775	49.559
Station 2					
$\bar{X}$	20.450	0.702	2.778	0.470	0.692
σ	3.168	0.122	0.523	0.412	0.346
C.V.%	15.493	17.417	18.829	87.617	49.978
Station 3					
$\bar{X}$	14.049	0.829	3.173	0.801	1.667
σ	3.242	0.078	0.438	0.105	0.500
C.V.%	23.075	9.388	13.799	13.052	29.978
Station 4					
$\bar{X}$	12.522	0.813	3.039	0.772	1.629
σ	3.121	0.085	0.492	0.113	0.521
C.V.%	24.923	10.443	16.195	14.699	31.989
Station 5					
$\bar{X}$	5.175	0.579	1.709	0.754	0.944
σ	1.321	0.106	0.354	0.156	0.306
C.V.%	25.533	18.273	20.714	20.713	32.384
Station 6					
$\bar{X}$	4.198	0.500	1.453	0.641	0.853
σ	1.522	0.133	0.412	0.182	0.338
C.V.%	36.259	26.696	28.329	28.331	39.667

(0.692) and maximum at station 3 (1.667). Indices at different stations are shown in Table 4. 10.

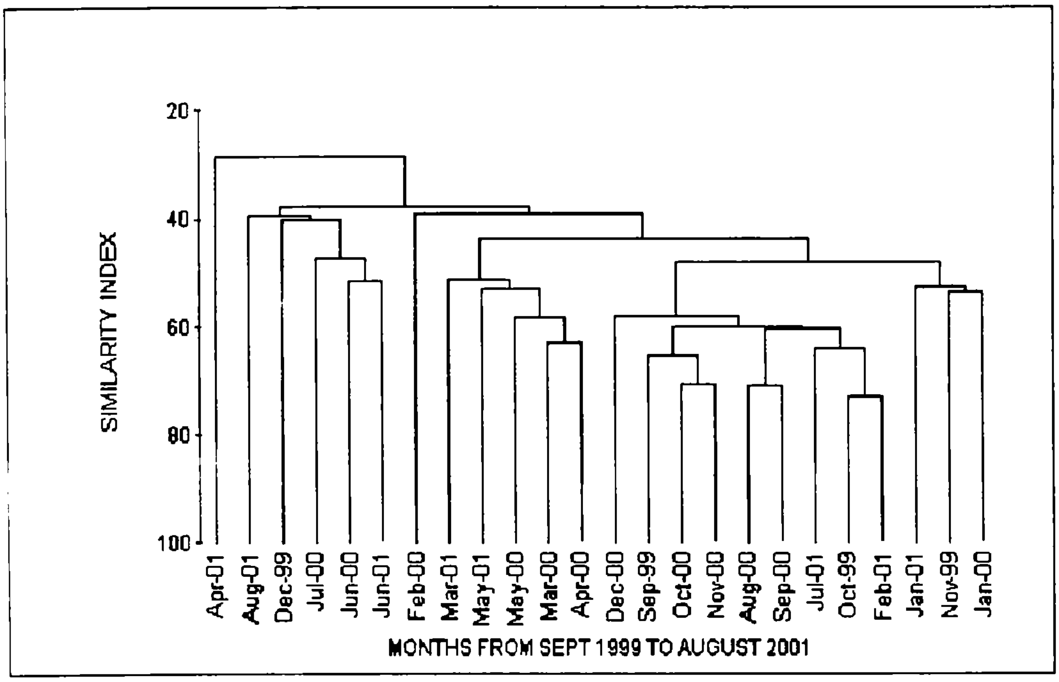
4. 2. 2. 3. Similarity Index

Similarity with respect to months

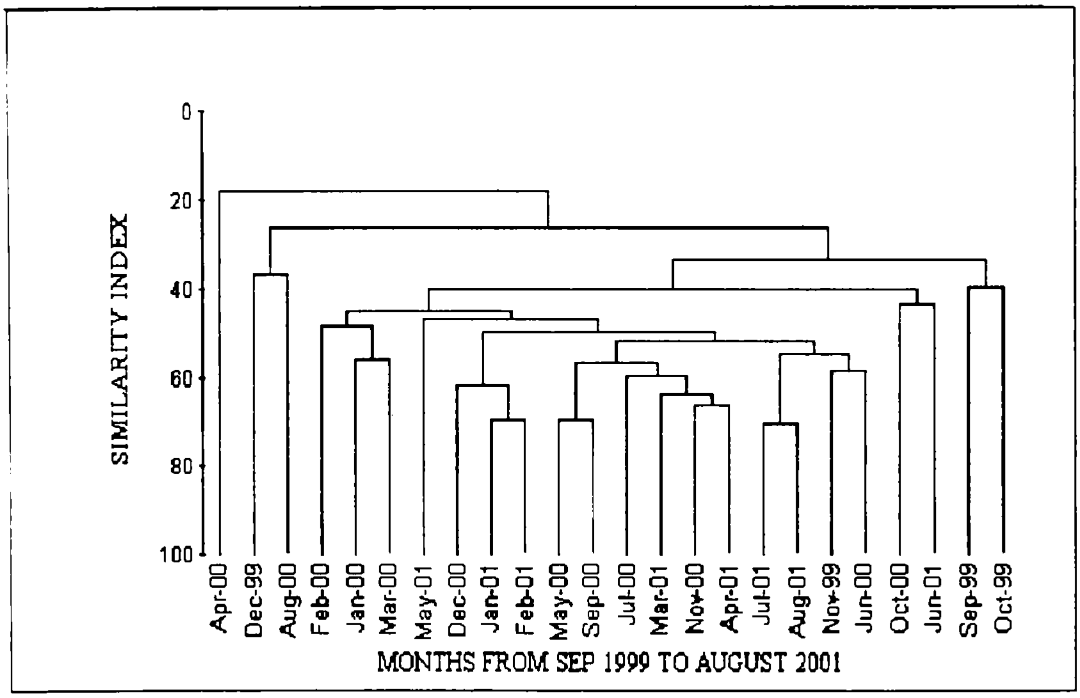
Benthic data collected from stations 1-6 for a period of 24 months was subjected to cluster analysis. Bray Curtis Similarity index (PRIMER 5) was used to study similarity between months using normalised data of log (x+1) transformed data of benthos.

At station 1 with 40% similarity, four distinct clusters of months were obtained. Cluster 1 included months June and July 2000 and June 2001. Cluster 2 contained February, March, April and May of 2000 and March and May of 2001. Cluster 3, the biggest cluster, included the months September, October 1999, August, September, October, November, December 2000 and February, July 2001 and 4th cluster contained November 1999, January 2000 and 2001. Thus cluster 1 was the monsoon season, cluster 2, the pre-monsoon and cluster 3, the end of monsoon and beginning of post-monsoon season and cluster 4 the end of post-monsoon season thus depicting that there were benthic species in station 1, which occur, specifically in these delineated seasons (Fig. 4. 11.a).

At station 2, four clusters of months were obtained. Cluster 1 contained January, February and March 2000 which was the end of post-monsoon and beginning of pre-monsoon season, cluster 2 contained December 2000, January, February and May 2001 which include benthic species which has a wide range of occurrence and can tolerate a wide range of environmental conditions. Cluster 3 contained May, July, September, November of 2000 and March and April 2001. This included the benthic species, which can tolerate extreme hot and extreme cold. Cluster 4



a. Station 1



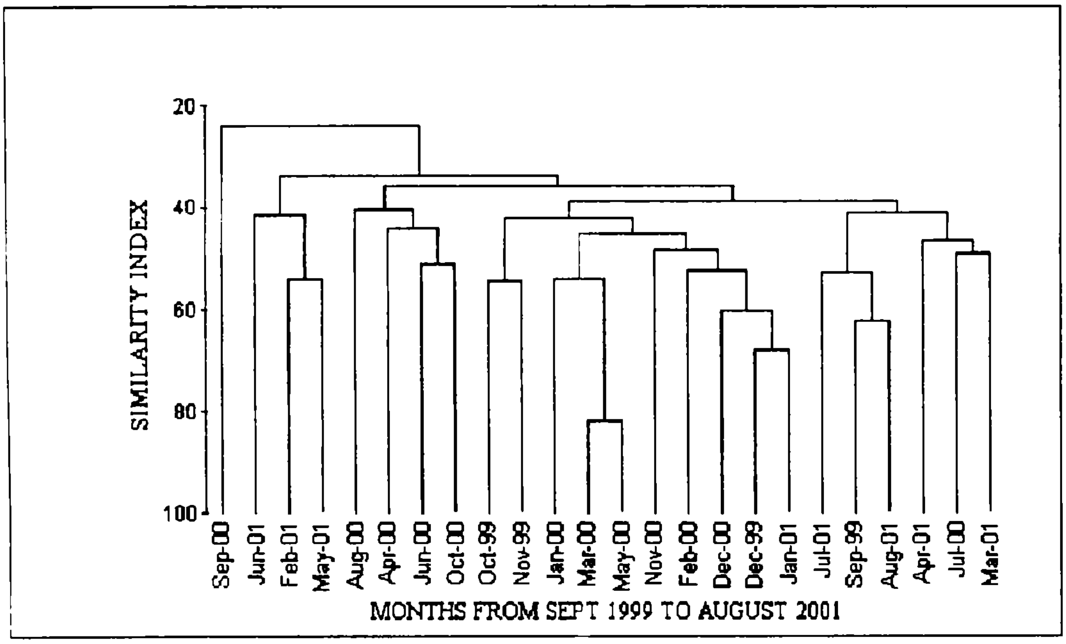
b. Station 2

Fig. 4. 11 Dendrogram for grouping of months at stations 1 and 2

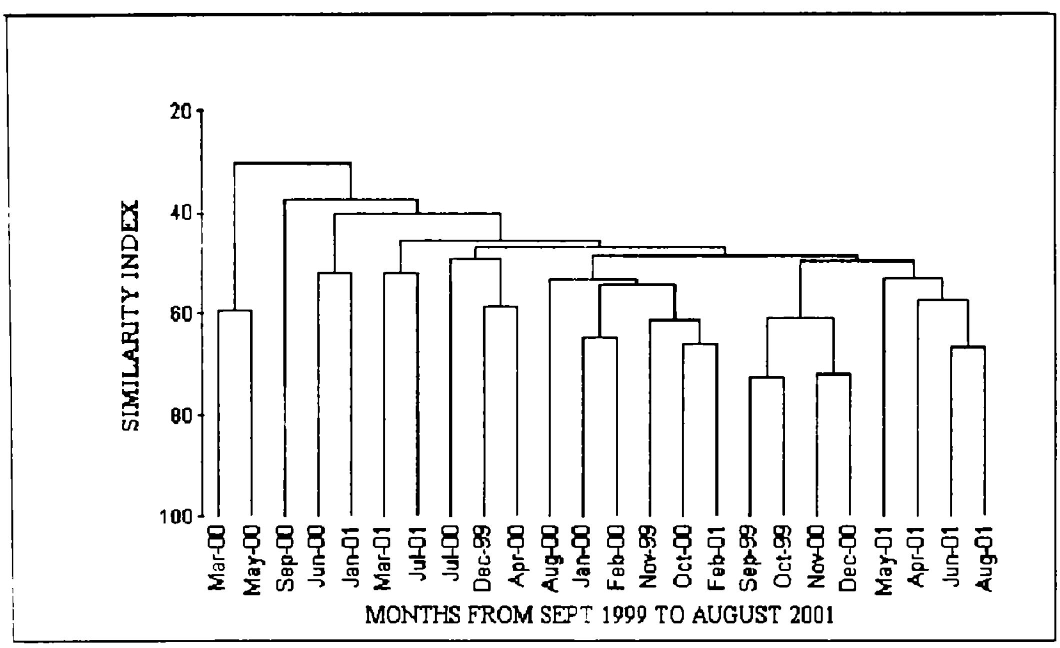
included the months November 1999, June 2000, July and August 2001, which sustained only those benthic species, which can occur exclusively during monsoon period (Fig.4.11.b).

At Station 3, four clusters were obtained. Cluster 1 consisted of February, May and June 2001. Cluster 2 consisted of months April, June, August and October 2000. Cluster 3 consisted of October, November, December 99, January, February, March, May, November, December 2000 and January 2001 which could also be splitted into subclusters of months as October 1999, November 1999, January 2000, March 2000, May 2000 which contained exclusively post-monsoon and pre-monsoon benthic species, which can tolerate the environmental conditions prevailing in post and pre-monsoon seasons. The other subcluster consisted of November 2000, February 2000, December 2000, December 1999 and January 2001, which was post-monsoon of each successive year. Hence for these species, there was a rhythmic occurrence i.e., they occur only during post-monsoon season. Cluster 4 consisted of September 1999 and July, August 2001 which contained species which can tolerate only the conditions prevailing in monsoon season of every year or which can be designated as monsoon species or low salinity tolerating benthic species (Fig. 4.12.a).

At station 4 seven clusters were obtained. Cluster 1 consisted of March and May 2000 (pre-monsoon preferring species), cluster 2 (June 2000 and January 2001) may be opportunistic species because two widely separated months were clustered. Similarly cluster 3 contained March and July 2001. Cluster 4 contained December 1999 and April, July 2000 showing a wide range of period being clustered together, may probably be persisting opportunistic species, cluster 5 was more of a unique nature containing November 1999, January, February, August and October 2000 and February 2001 probably be classified as cool temperature preferring benthic species or monsoon middle and post-monsoon end preferring



a. Station 3



b. Station 4

Fig. 4. 12 Dendrogram for grouping of months at stations 3 and 4

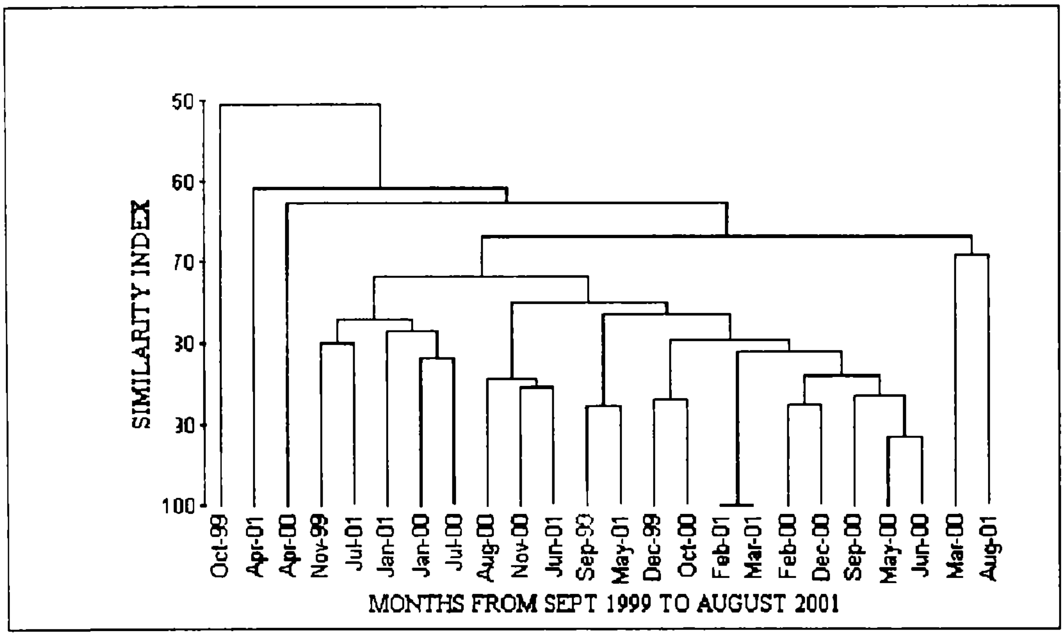
species, cluster 6 contained September and October 1999, November and December 2000 showing a rhythmic occurrence, preferring exclusively monsoon season and cluster 7 consisted of April, May, June and August 2001, more preferably end of pre-monsoon and up to middle end of monsoon (Fig. 4. 12. b).

At station 5, four clusters of months were obtained. Cluster 1 consisted of November 1999, January and July 2000, January and July 2001, which was a combination of monsoon and post-monsoon period. Cluster 2 consisted of August 2000, June and November 2001 i.e. monsoon and beginning of post-monsoon period, cluster 3 (February and March 2001) constituted by highly pre-monsoon and cluster 4 (February, May, June, September and December 2000) of a widely spread combination of period implying occurrence of benthic species which occur periodically with a period of 2 months (Fig. 4. 13. a).

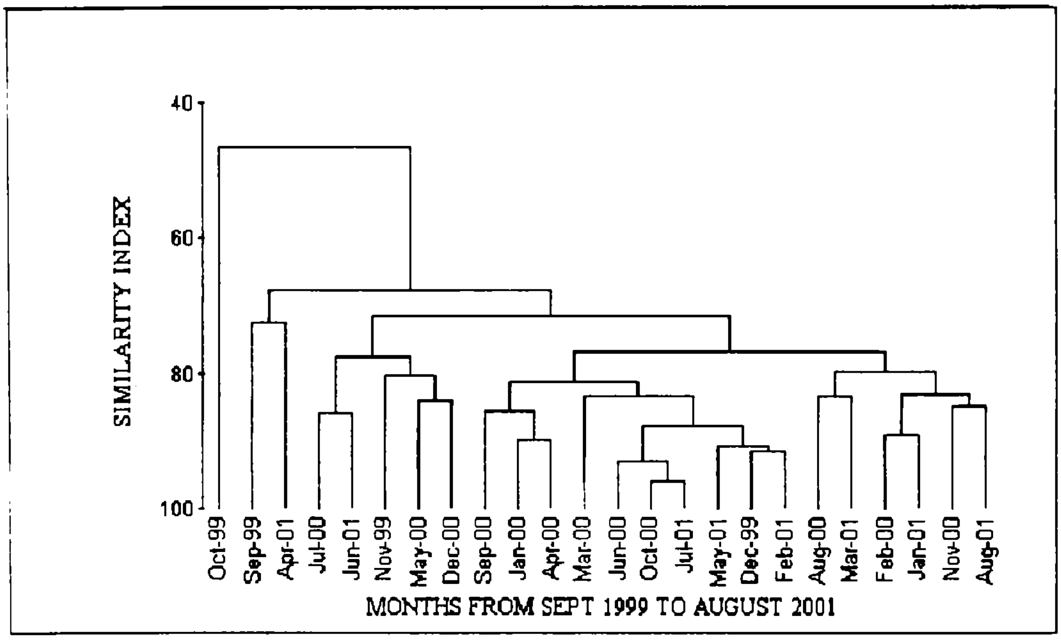
At station 6, 40% similarity included all the months except October 1999 and so also 60% similarities, which included all the months. At 80% similarity, 5 clusters were obtained. Cluster 1 contained (June and July 2001) exactly monsoon months, cluster 2 (November 1999, May and December 2000), a grouping with a period of 5 months, cluster 3 contained January, April and September 2000 with a period of 3 to 4 months, cluster 4 consisted of December 1999, March, June and October 2000, February, May and July 2001 with a period of 3 months, cluster 5 contained February and November 2000, January and August 2001 comprising end of post-monsoon and monsoon specific species (Fig. 4. 13. b).

Similarity with respect to species

At **station 1**, at 40% similarity, 8 clustures were obtained. Cluster 1 contained the species *Nereis trifasciata, Maera pacifica* and *Stenothoe kaia*. Cluster 2 contained *Nephtys inermis, Grapsus* sp. and *Mallacoota*



a. Station 5



b. Station 6

Fig. 4. 13 Dendrogram for grouping of months at stations 5 and 6

insignis. Cluster 3 contained *Cymadusa imbroglio, Ophiactis savignyi, Syllis cornuta, Cerithium alveolum, Eriphis* sp., *Glycera convoluta, Pilumnus hirtellus, Pinnotheres pinnotheres, Pinnotheres pisum and Thalamita crenata*. Cluster 4 contained *Dolabella rumphii, Baseodiscus delineatus, Ophiocoma scolopendrina, Coralliophila costularis* and *Elysia* sp. Cluster 5 contained *Etisus splendidus* and *Goniada emerita*. Cluter 6 contained *Aaptos.cf.chromis, Megalopa larva, Cerithium rarimaculatum* and *Strombus mutabilis*. Cluster 7 contained *Alpheopsis equalis, Actaeodes tomentosus, Macrophthalmus boscii, Ophicornella sexadia, Nephtys hombergii* and *Paratanaeidae* sp. Cluster 8 contained *Ctena delicatula, Cerithium scabridum, Cerithium corallium, Smaragdia soverbiana, Pyrene* sp., *Smaragdia viridis, Cyprea moneta, Paracilicacea setosa, Calappa hepatica, Pinna muricata, Gafrarium divarticatum, Glycera lancadivae* and *Nephtys dibranchus* (Fig. 4. 14).

The species, which showed maximum co-existence at Station 1 were *Pyrene* sp. and *Smaragdia viridis* (85%). These two species together showed co-existence with *Smaragdia soverbiana* at 75% level. More than 70% similarity occurred between *Pinna muricata* and *Gafrarium divarticatum* (75%), *Cyprea moneta* and *Parasilicacea setosa* (70%). *Cerithium scabridum, Cerithium corallium, Smaragdia soverbiana, Pyrene* sp. and *Smaragdia viridis* clustures with more than 60% similarity. Same was the case with species *Cyprea moneta, Parasilicacea setosa, Calappa hepatica, Pinna muricata, Gafrarium divarticatum, Glycera tesselata* and *Nephtys dibranchus* which clustures with more than 60% similarity. *Ophicornella sexadia, Macrophthalmus boscii, Actaeodus tomentosus* and *Alpheus equalis* clustured with more than 60% similarity. *Glycera convoluta, Pilumnus hirtellus, Pinnotheres pinnotheres, Pinnotheres pisum*, and *Thalamita crenata* clustured with more than 50% similarity.

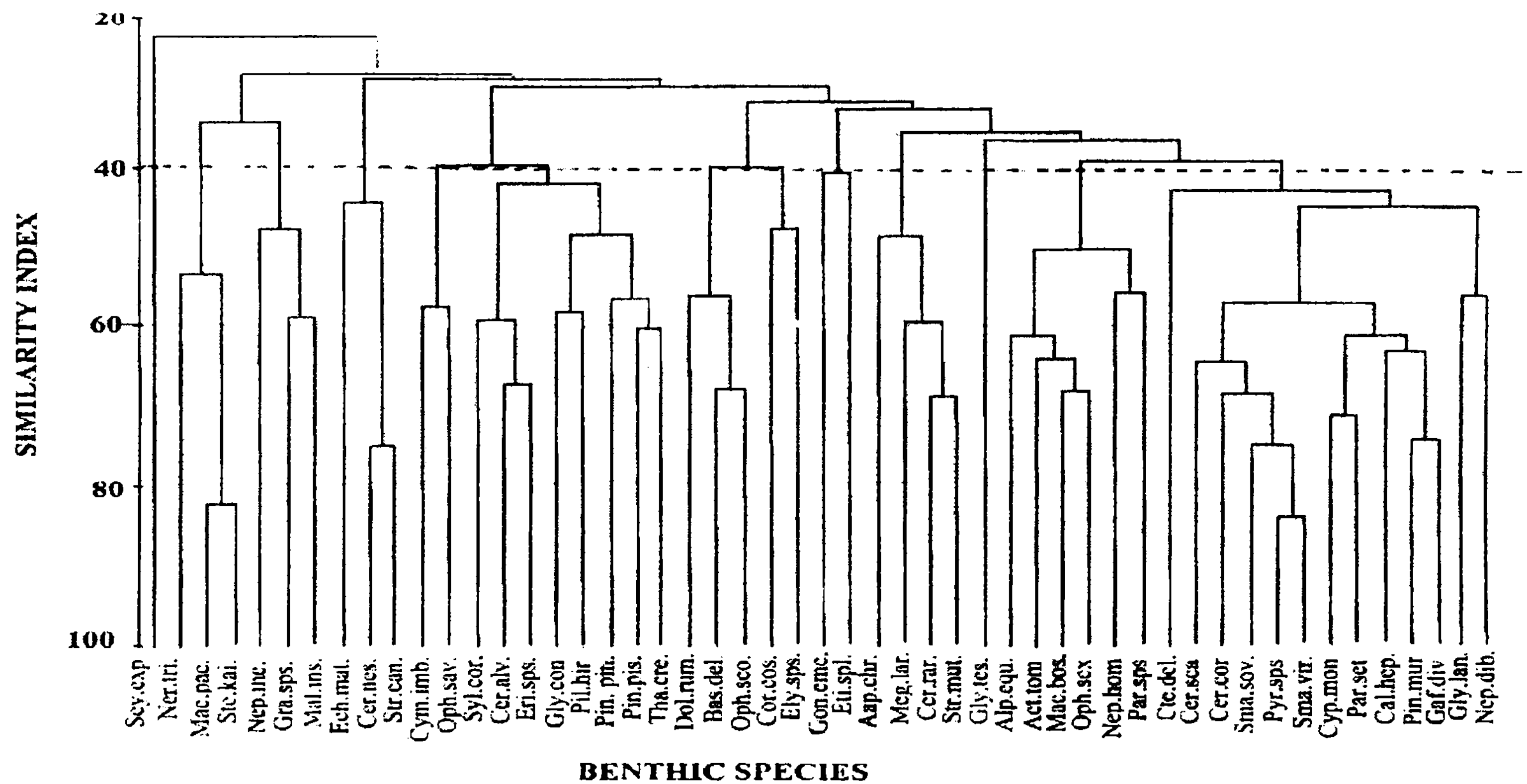


Fig. 4. 14 Dendrogram for grouping of benthic species at station 1

Species listed in dendrogram 4. 14.

Sl. No.	Abbreviation used	Species
1	Sey.exp.	*Seychellana expansa*
2	Ner.tri.	*Nereis trifasciata*
3	Mae.pac.	*Maera pacifica*
4	Ste.kai.	*Stenothoe kaia*
5	Nep.ine.	*Nephtys inermis*
6	Gra.sps.	*Grapsus species*
7	Mal.ins.	*Mallacoota insignis*
8	Ech.mat.	*Echinometra mathaei*
9	Cer.nes	*Cerithium nesioticum*
10	Str.can	*Strombus canarium*
11	Cym.imb.	*Cymadusa imbroglio*
12	Oph.sav.	*Ophiactis savignyi*
13	Syl.cor.	*Syllis cornuta*
14	Cer.alv	*Cerithium alveolum*
15	Eri.sps.	*Eriphis species*
16	Gly.con.	*Glycera convoluta*
17	Pil.hir	*Pilumnus hirtellus*
18	Pin.pin.	*Pinnotheres pinnotheres*
19	Pin.pis.	*Pinnotheres pisum*
20	Tha.cre.	*Thalamita crenata*
21	Dol.rum.	*Dolabella rumphii*
22	Bas.del.	*Baseodiscus delineatus*
23	Oph.sco.	*Ophiocoma scolopendrina*
24	Cor.cos.	*Coralliophila costularis*
25	Ely.sps.	*Elysia sps.*
26	Gon.eme.	*Goniada emerita*
27	Eti.spl.	*Etisus splendidus*
28	Aap.chr.	*Aaptos cf.chromis*
29	Meg.lar.	*Megalopa larva*
30	Cer.ros	*Cerithium rostratum*
31	Str.mut	*Strombus mutabilis*
32	Alp.equ.	*Alpheopsis equalis*
33	Gly.tes.	*Glycera tesselata*
34	Act.tom.	*Actaeodes tomentosus*
35	Mac.bos.	*Macrophthalmus boscii*
36	Ophi.sex.	*Ophicornella sexadia*
37	Nep.hom.	*Nephtys hombergii*
38	Par.sps.	*Paratanaeidae species*
39	Cte.del.	*Ctena delicatula*
40	Cer.sca	*Cerithium scabridum*
41	Cer.cor	*Cerithium corallium*
42	Sma.sov.	*Smargdia soverbiana*
43	Pyr.sps.	*Pyrene sps. 12*
44	Sma.vir.	*Smargdia viridis*
45	Cyp.mon	*Cyprea moneta*
46	Par.set.	*Paracilicaca setosa*
47	Cal.hep.	*Calappa hepatica*
48	Pin.mur.	*Pinna muricata*
49	Gaf.div.	*Gafrarium divarticatum*
50	Gly.lan	*Glycera lancadivae*
51	Nep.dib.	*Nephtys dibranchus*

At **station 2**, only those species, which occurred mainly at least in 20% of the sampled months, were considered by Bray Curtis similarity index. The 50 species which occurred in at least 20% of the sampled months were grouped into 12 clustures at 40% similarity level (Fig. 4. 15). The clustures were

Cluster 1- *Maera pacifica, Stenothoe kaia, Baseodiscus delineatus* and *Syllis cornuta*

Cluster 2- *Malacoota insignis, Hoplonemertean* sp. and *Glycera convoluta*

Cluster 3- *Ophicornella sexadia, Myadoropsis brevispinious* and *Syllis gracilis.*

Cluster 4- *Pyrene vulpecula, Cinguloterebra hedleyana* and *Margarites helicinia*

Cluster 5- *Gymnodoris ceylonica, Cerithium dialeucum* and *Golfingia hespera*

Cluster 6- *Thalamita crenata,Siriella brevicaudata,Cyprea moneta,Nereis trifasciata*

Cluster 7- *Lithophaga nigra, Strombus mutabilis* and *Calappa hepatica*

Cluster 8- *Echinoneus cyclostomus, Nephtys inermis* and *Ophiocoma scolopendrina*

Cluster 9- *Cerithium alveolum, Cerithium scabridum, Aaptos.Cf.chromis, Coralliophila costularis* and *Pyrene* sp.

Cluster10- *Notomastes latericeus, Nephtys hombergii, Glycera lancadivae, Goniada emerita, Dolabella rumphii, Pinna muricata, Ctena delicatula* and *Gafrarium divarticatum.*

Cluster11- Megalopa larva, *Ophiactis savignyi*

Cluster12- *Conus catus, Paratanaeidae* sp.

The pairs of species which showed more than 70% similarity at station 2 include *Maera pacifica* and *Stenothoe kaia*, *Hoplonemertean* sp. and *Glycera convoluta*, *Cinguloterebra hedleyana* and *Margarites helicina*, *Pyrene* sp. and *Cerithium corallium*, *Smaragdia soverbiana* and *Smaragdia viridis*, *Glycera lancadivae* and *Goniada emerita*, *Dolabrifera* sp. and *Pinna muricata*.

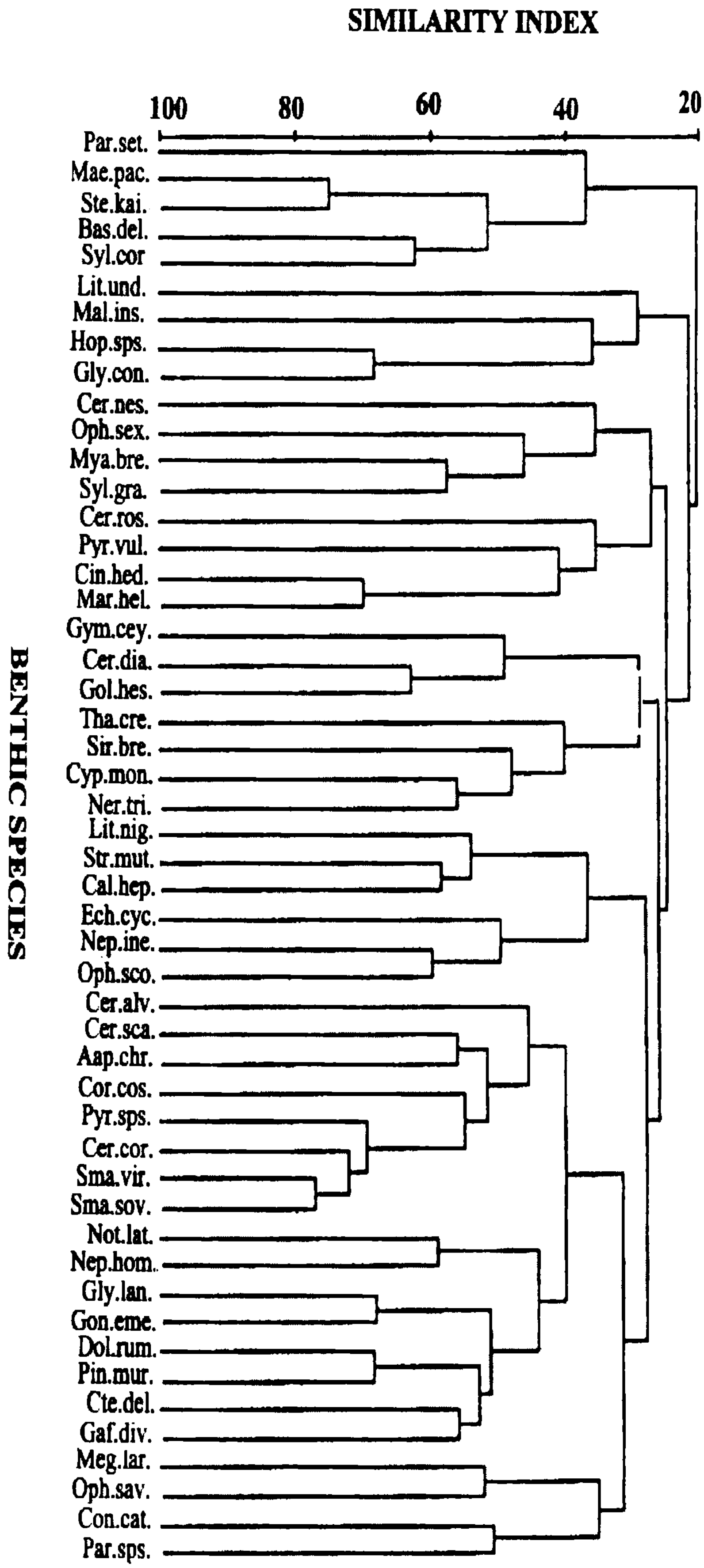


Fig. 4. 15 Dendrogram for grouping of benthic species at station 2

Species listed in dendrogram 4. 15.

Sl. No.	Abbreviation used	Species
1	Par.set.	*Paracilicaca setosa*
2	Mae.pac.	*Maera pacifica*
3	Ste.kai.	*Stenothoe kaia*
4	Bas.del.	*Baseodiscus delineatus*
5	Syl.cor.	*Syllis cornuta*
6	Lit.und	*Littorina undulata*
7	Mal.ins.	*Mallacoota insignis*
8	Hop.sps.	*Hoplonemertean species*
9	Gly.con.	*Glycera convoluta*
10	Cer.nes	*Cerithium nesioticum*
11	Ophi.sex.	*Ophicornella sexadia*
12	Mya.bre.	*Myadoropsis brevispinious*
13	Syl.gra.	*Syllis gracilis*
14	Cer.ros	*Cerithium rostratum*
15	Pyr.vul	*Pyrene vulpecula*
16	Cin.hed.	*Cinguloterebra hedleyana*
17	Mar.hel	*Margarites helicina*
18	Gym.cey.	*Gymnodoris ceylonica*
19	Cer.dia	*Cerithium dialeucum*
20	Gol.hes.	*Golfingia hespera*
21	Tha.cre.	*Thalamita crenata*
22	Sir.bre.	*Siriella brevicaudata*
23	Cyp.mon	*Cyprea moneta*
24	Ner.tri.	*Nereis trifasciata*
25	Lit.nig.	*Lithophaga nigra*
26	Str.mut	*Strombus mutabilis*
27	Cal.hep.	*Calappa hepatica*
28	Ech.cyc.	*Echinoneus cyclostomus*
29	Nep.ine.	*Nephtys inermis*
30	Oph.sco.	*Ophiocoma scolopendrina*
31	Cer.alv	*Cerithium alveolum*
32	Cer.sca	*Cerithium scabridum*
33	Aap.chr.	*Aaptos cf.chromis*
34	Cor.cos.	*Coralliophila costularis*
35	Pyr.sps.	*Pyrene sps. 12*
36	Cer.cor	*Cerithium corallium*
37	Sma.vir.	*Smargdia viridis*
38	Sma.sov.	*Smargdia soverbiana*
39	Not.lat.	*Notomastes latericeus*
40	Nep.hom.	*Nephtys hombergii*
41	Gly.lan	*Glycera lancadivae*
42	Gon.eme.	*Goniada emerita*
43	Dol.rum.	*Dolabella rumphii(violetink)*
44	Pin.mur.	*Pinna muricata*
45	Cte.del.	*Ctena delicatula*
46	Gaf.div.	*Gafrarium divarticatum*
47	Meg.lar.	*Megalopa larva*
48	Oph.sav.	*Ophiactis savignyi*
49	Con.cat.	*Conus catus*
50	Par.sps.	*Paratanaeidae species*

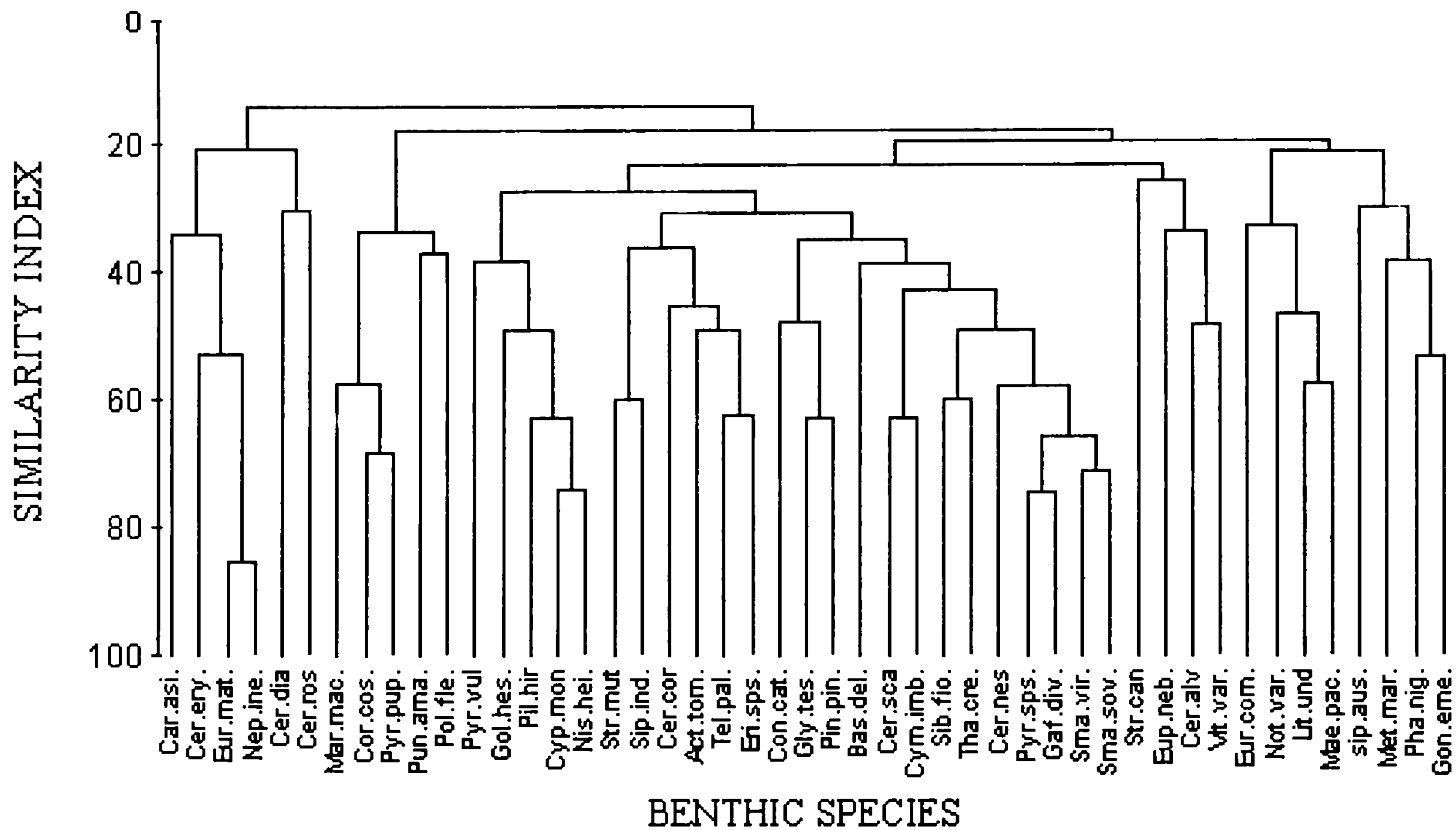


Fig. 4. 16 Dendrogram for grouping of benthic species at station 3

At **station 3,** the species, which occurred in less than 10% of the sampled months, were deleted. The 47 species thus remained were characterized into 10 clustures (Fig. 4.16).

Cluster 1- *Ceratonereis erythraensis*, *Eurythoe mathaii* and *Nephtys inermis*
Cluster 2 - *Marphysa macinoshi, Coralliophila costularis* and *Pyrgulina pupula*
Cluster 3 - *Pyrene vulpecula, Golfingia hespera, Pilumnus hirtellus, Cyprea moneta* and *Niso heizensis.*
Cluster 4 - *Strombus mutabilis* and *Sipunculus indicus*
Cluster 5 - *Cerithium corallium, Actaeodes tomentosus, Tellina palatum* and *Eriphis* sp.
Cluster 6 - *Conus catus, Glycera tesselata* and *Pinnotheres pinnotheres*
Cluster 7 - *Baseodiscus delineatus, Cerithium scabridum, Cymadusa imbroglio, Siboglinum fiordicum, Thalamita crenata, Cerithium nesioticum, Pyrene* sp., *Gafrarium divarticatum, Smaragdia viridis* and *Smaragdia soverbiana.*
Cluster 8 - *Cerithium alveolum* and *Vittina variegata*
Cluster 9 - *Notomastes latericeus, Littorina undulata* and *Maera pacifica*
Cluster 10- *Metanachis marquesa, Phascolosoma nigrescens* and *Goniada emerita*

The similarity analysis confirmed that many pairs of species were showing more than 60% similarity. These pairs include *Eurythoe mathaei* and *Nephtys inermis* (90%), *Cyprea moneta* and *Niso heizensis* (75%), *Pyrene* sp. and *Gafrarium divarticatum* (75%), *Smaragdia viridis* and *Smaragdia soverbiana* (72%), *Strombus mutabilis* and *Sipunculus indicus* (60%), *Glycera tesselata* and *Pinnotheres pinnotheres* (65%), *Tellina palatum* and *Eriphis* sp. (65%).

At **station 4**, the species, which occurred in less than 5% of the

Species listed in dendrogram 4. 16.

Sl. No.	Abbreviation used	Species
1	Car.asi.	*Cardium asiaticum*
2	Cer.ery.	*Ceratonereis erythraensis*
3	Eur.mat.	*Eurythoe mathaii*
4	Nep.ine.	*Nephtys inermis*
5	Cer.dia	*Cerithium dialeucum*
6	Cer.ros	*Cerithium rostratum*
7	Mar.mac.	*Marphysa macintoshi*
8	Cor.cos.	*Coralliophila costularis*
9	Pyr.pup.	*Pyrgulina pupula*
10	Pun.ama.	*Punctacteon amakusaensis*
11	Pol.fle.	*Polinices flemengium*
12	Pyr.vul	*Pyrene vulpecula*
13	Gol.hes.	*Golfingia hespera*
14	Pil.hir	*Pilumnus hirtellus*
15	Cyp.mon	*Cyprea moneta*
16	Nis.hei.	*Niso heizensis*
17	Str.mut	*Strombus mutabilis*
18	Sip.ind.	*Sipunculus indicus*
19	Cer.cor	*Cerithium corallium*
20	Act.tom.	*Actaeodes tomentosus*
21	Tel.pal.	*Tellina palatum*
22	Eri.sps.	*Eriphis species*
23	Con.cat.	*Conus catus*
24	Gly.tes.	*Glycera tesselata*
25	Pin.pin.	*Pinnotheres pinnotheres*
26	Bas.del.	*Baseodiscus delineatus*
27	Cer.sca	*Cerithium scabridum*
28	Cym.imb.	*Cymadusa imbroglio*
29	Sib.fio.	*Siboglinum fiordicum*
30	Tha.cre.	*Thalamita crenata*
31	Cer.nes	*Cerithium nesioticum*
32	Pyr.sps.	*Pyrene sps. 12*
33	Gaf.div.	*Gafrarium divarticatum*
34	Sma.vir.	*Smargdia viridis*
35	Sma.sov.	*Smargdia soverbiana*
36	Str.can	*Strombus canarium*
37	Eup.neb.	*Eupolymna nebulosa*
38	Cer.alv	*Cerithium alveolum*
39	Vit.var.	*Vittina variegata*
40	Eur.com.	*Eurythoe complanata*
41	Not.var.	*Notomastes latericeus*
42	Lit.und	*Littorina undulata*
43	Mae.pac.	*Maera pacifica*
44	sip.aus.	*Siphonosoma australe*
45	Met.mar.	*Metanachis marquesa*
46	Pha.nig.	*Phascolosoma nigrescens*
47	Gon.eme.	*Goniada emerita*

samples, were deleted. The 48 species, which occurred in more than 95% of the sampled months, were grouped in to 11 clusters of species (Fig. 4.17).

Cluster1-*Thalamita crenata, Ceratonereis erythraensis, Alpheopsis equalis* and *Ophiactis savignyi*

Cluster 2- *Rhinoclavis sinensis, Polinices flemengium* and *Glycera* sp.

Cluster 3- *Siphonosoma australe* and *Eupolymna nebulosa*

Cluster 4- *Nereis kaudata* and *Pilumnus hirtellus*

Cluster 5-*Niotha stigmaria* and *Modiolus metcalfei*

Cluster 6 -*Marphysa macintoshi, Eriphis* sp., *Coralliophila costularis* and *Cinguloterebra hedleyana*

Cluster 7- *Tylodipax desigardi, Niso heizensis* and *Syllis cornuta*

Cluster 8- *Calappa hepatica* and *Maera pacifica*

Cluster 9- *Hoplonemertean* sp., *Goniada emerita, Eurythoe complanata* and *Macrophthalmus boscii*

Cluster10-*Cerithium alveolum, Pyrene vulpecula* and *Cymadusa imbroglio*

Cluster11-*Cerithium corallium, Notomastes latericeus, Phascolosoma nigrescens, Siboglinum fiordicum. Glycera tesselata, Cerithium rostratum, Cerithium scabridum, Cerithium nesioticum, Pyrene* sp., *Gafrarium divarticatum, Smaragdia viridis* and *Smaragdia soverbiana.*

Station 4 showed many pairs of close similarity. *Marphysa macintoshi* and *Eriphis* sp. (80%), *Smaragdia viridis* and *Smaragdia soverbiana* (70%), *Niso heizensis* and *Syllis cornuta* (60%), *Hoplonemertean* sp. and *Goniada emerita* (60%), *Macrophthalmus boscii* and *Eurythoe complanata* (60%) come under this. Many other clustures were showing more than 50% similarity, which include *Rhinoclavis sinensis, Polinices flemengium* and *Glycera* spp. Cluster 3 showed more than 70% similarity. The cluster 11 can be subclustered into two. The first sub cluster, which included *Cerithium corallium, Notomastes latericeus,*

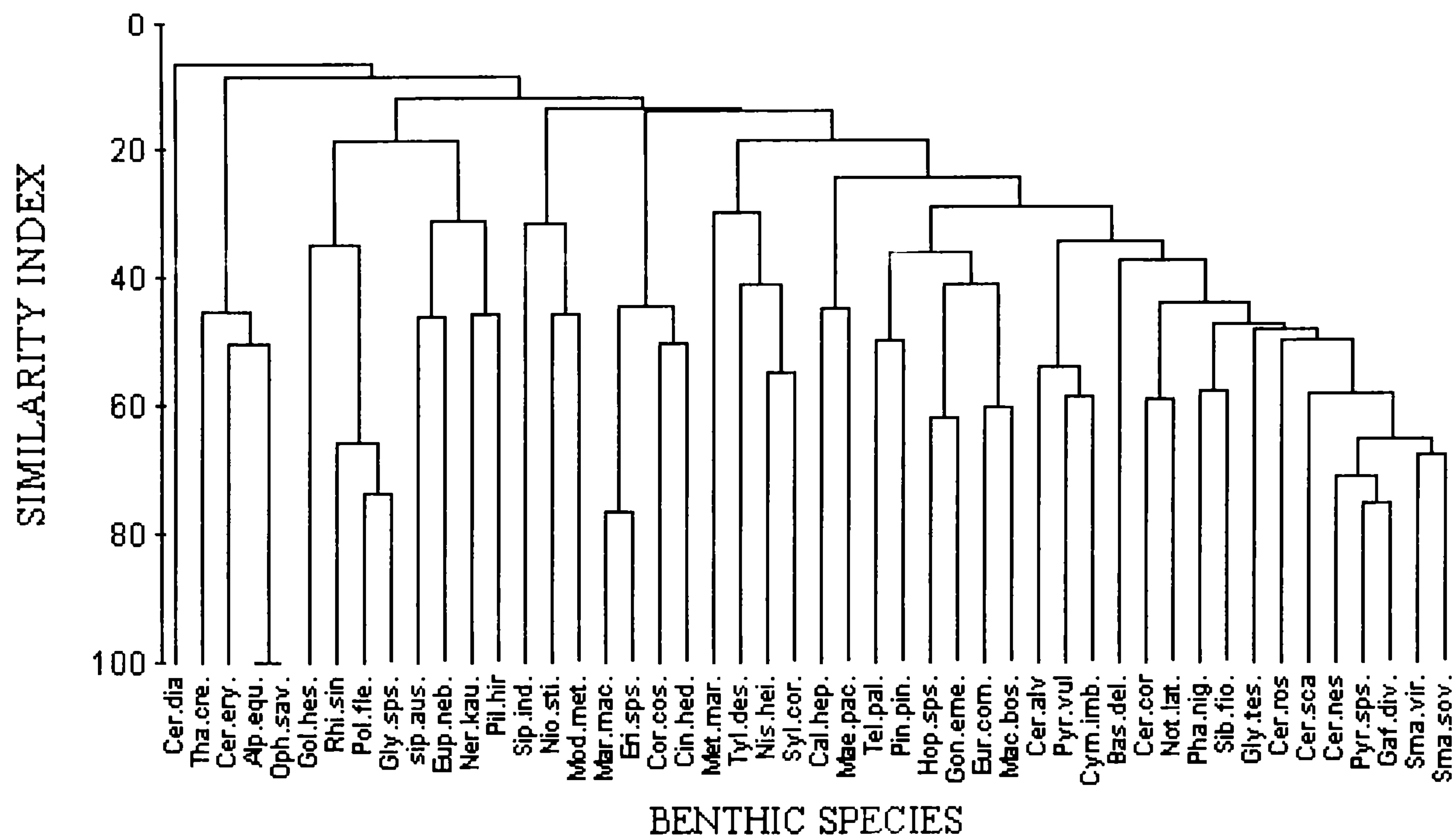


Fig. 4. 17 Dendrogram for grouping of benthic species at station 4

Species listed in dendrogram 4. 17.

Sl. No.	Abbreviation used	Species
1	Cer.dia	*Cerithium dialeucum*
2	Tha.cre.	*Thalamita crenata*
3	Cer.ery.	*Ceratonereis erythraensis*
4	Alp.equ.	*Alpheopsis equalis*
5	Oph.sav.	*Ophiactis savignyi*
6	Gol.hes.	*Golfingia hespera*
7	Rhi.sin	*Rhinoclavis sinensis*
8	Pol.fle.	*Polinices flemengium*
9	Gly.sps.	*Glycera species*
10	sip.aus.	*Siphonosoma australe*
11	Eup.neb.	*Eupolymna nebulosa*
12	Ner.kau.	*Nereis kauderni*
13	Pil.hir	*Pilumnus hirtellus*
14	Sip.ind.	*Sipunculus indicus*
15	Nio.sti.	*Niotha stigmaria*
16	Mod.met.	*Modiolus metcalfei*
17	Mar.mac.	*Marphysa macintoshi*
18	Eri.sps.	*Eriphis species*
19	Cor.cos.	*Coralliophila costularis*
20	Cin.hed.	*Cinguloterebra hedleyana*
21	Met.mar.	*Metanachis marquesa*
22	Tyl.des.	*Tylodipax desigardi*
23	Nis.hei.	*Niso heizensis*
24	Syl.cor.	*Syllis cornuta*
25	Cal.hep.	*Calappa hepatica*
26	Mae.pac.	*Maera pacifica*
27	Tel.pal.	*Tellina palatum*
28	Pin.pin.	*Pinnotheres pinnotheres*
29	Hop.sps.	*Hoplonemertean species*
30	Gon.eme.	*Goniada emerita*
31	Eur.com.	*Eurythoe complanata*
32	Mac.bos.	*Macrophthalmus boscii*
33	Cer.alv	*Cerithium alveolum*
34	Pyr.vul	*Pyrene vulpecula*
35	Cym.imb.	*Cymadusa imbroglio*
36	Bas.del.	*Baseodiscus delineatus*
37	Cer.cor	*Cerithium corallium*
38	Not.lat.	*Notomastes latericeus*
39	Pha.nig.	*Phascolosoma nigrescens*
40	Sib.fio.	*Siboglinum fiordicum*
41	Gly.tes.	*Glycera tesselata*
42	Cer.ros	*Cerithium rostratum*
43	Cer.sca	*Cerithium scabridum*
44	Cer.nes	*Cerithium nesioticum*
45	Pyr.sps.	*Pyrene sps. 12*
46	Gaf.div.	*Gafrarium divarticatum*
47	Sma.vir.	*Smargdia viridis*
48	Sma.sov.	*Smargdia soverbiana*

Phascolosoma nigrescence, Siboglinum fiordicum, Glycera tesselata, Cerithium rostratum and *Cerithium scabridum* showed a similarity more than 60%. The second sub clusture, which included *Cerithium nesioticum,* Pyrene spp., *Gafrarium divarticatum, Smaragdia viridis* and *Smaragdia soverbiana* showed about 68% similarity.

At **station 5,** there were 18 species and can be grouped into 5 clustures (Fig.4.18).

The cluster 1 contained *Cardiosoma carnifex* and *Thalamita crenata* (more than 65% similarity). Cluster 2 contained *Cerithium rarimaculatum* and *Cerithium scabridum* (60% similarity). *Smaragdia soverbiana* and *Tylodipax desigardi* (50% similarity) were included in cluster 3. Cluster 4 contained *Nikoides maldivensis, Apseudus* sp., *Terebralia palustris, Cerithium corallium* and *Littorina undulata* (showing more than 60 % similarity) and the final cluster 5 contained *Margarites helicinia* and *Scylla serrata.*

At this station, between *Cerithium corallium* and *Littorina undulata* 85% of similarity observed and this in turn with *Terebralium palustris* showed 82% similarity.

The 16 species of **station 6** were classified into 5 clustures (Fig. 4.19) of similar species at 40% similarity level. The clustures were

Cluster 1- *Smaragdia viridis, Uca inversa*

Cluster 2- *Cerithium scabridum, Smaragdia soverbiana*

Cluster 3- *Cerithium rarimaculatum, Pyrene* sp. and *Nikoides maldivensis*

Cluster 4-*Apseudus* sp., *Terebralia palustris,Cerithium corallium,Littorina undulata*

Cluster 5- *Margarites helicinia, Uca tetragonon.*

The similarity values observed were, between *Smaragdia viridis* and *Uca inversa* -50%, *Cerithium scabridum* and *Smaragdia soverbiana* -45%.

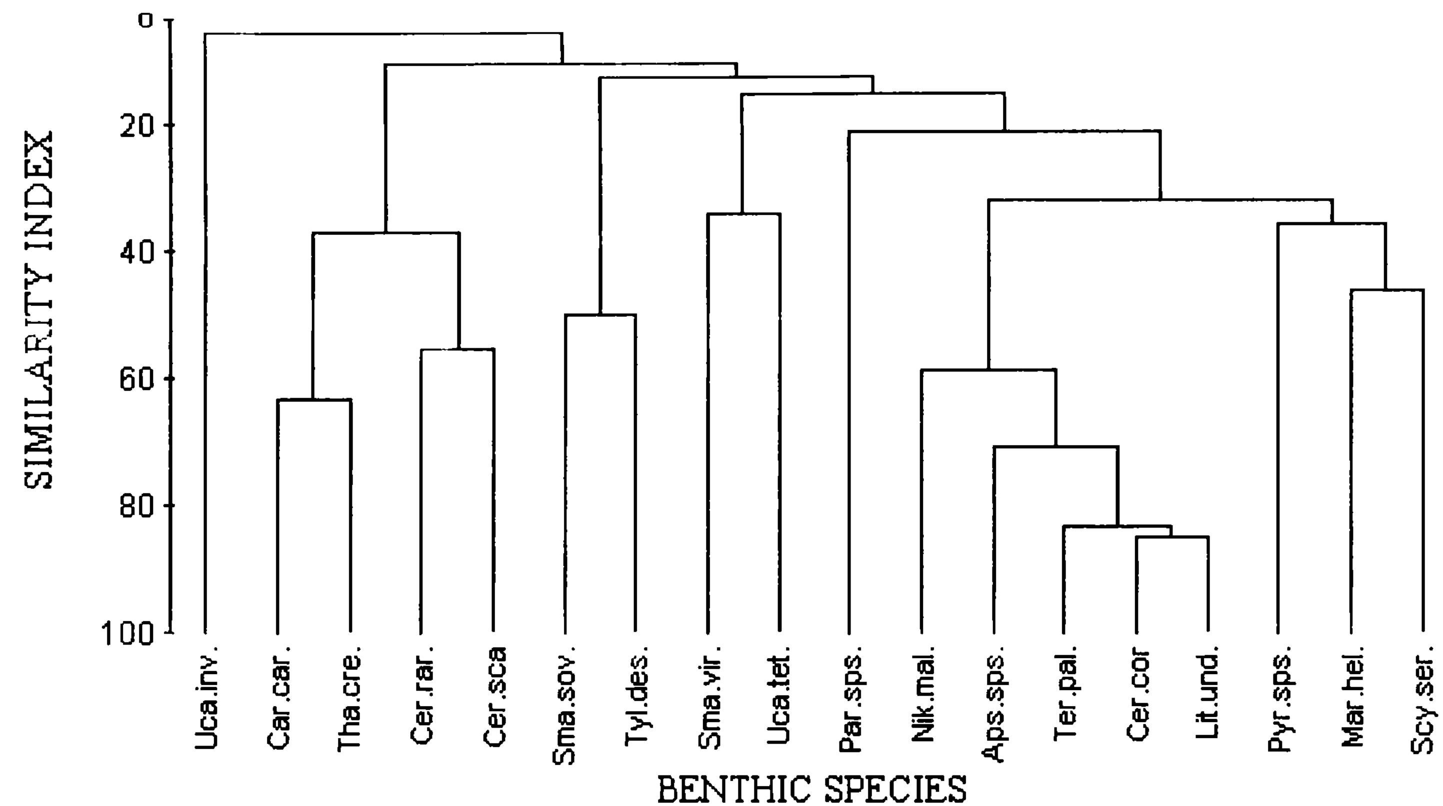


Fig. 4. 18 Dendrogram for grouping of benthic species at station 5

Species listed in dendrogram 4. 18.

Sl. No.	Abbreviation used	Species
1	Uca.inv.	*Uca inversa inversa*
2	Car.car.	*Cardisoma carnifex*
3	Tha.cre.	*Thalamita crenata*
4	Cer.rar.	*Cerithium rarimaculatum*
5	Cer.sca.	*Cerithium scabridum*
6	Sma.sov.	*Smargdia soverbiana*
7	Tyl.des.	*Tylodipax desigardi*
8	Sma.vir.	*Smargdia viridis*
9	Uca.tet.	*Uca tetragonon*
10	Par.sps.	*Paratanaeidae species*
11	Nik.mal.	*Nikoides maldivensis*
12	aps.sps.	*Apseudus species*
13	Ter.pal.	*Terebralia palustris*
14	Cer.cor	*Cerithium corallium*
15	Lit.und.	*Littorina undulata*
16	Pyr.sps.	*Pyrene sps. 12*
17	Mar.hel.	*Margarites helicina*
18	Scy.ser.	*scylla serrata*

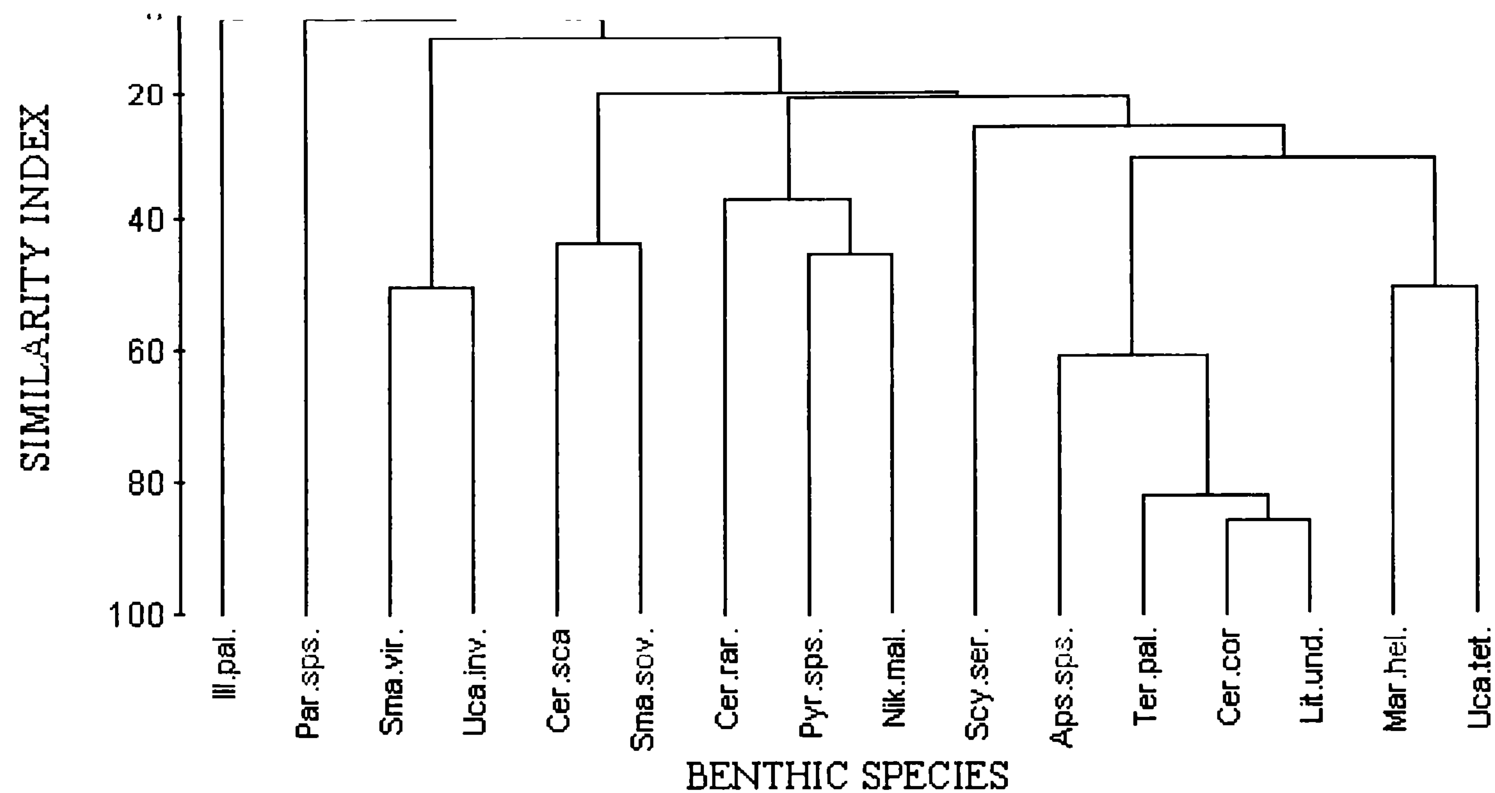


Fig. 4. 19 Dendrogram for grouping of benthic species at station 6

Species listed in dendrogram 4. 19.

Sl. No.	Abbreviation used	Species
1	Ill.pal.	*Illyograpsus paludicola*
2	Par.sps.	*Paratanaeidae species*
3	Sma.vir.	*Smargdia viridis*
4	Uca.inv.	*Uca inversa inversa*
5	Cer.sca.	*Cerithium scabridum*
6	Cer.rar.	*Cerithium rarimaculatum*
7	Sma.sov.	*Smargdia soverbiana*
8	Pyr.sps.	*Pyrene sps. 12*
9	Nik.mal.	*Nikoides maldivensis*
10	Scy.ser.	*scylla serrata*
11	aps.sps.	*Apseudus species*
12	Ter.pal.	*Terebralia palustris*
13	Cer.cor	*Cerithium corallium*
14	Lit.und.	*Littorina undulata*
15	Mar.hel.	*Margarites helicina*
16	Uca.tet.	*Uca tetragonon*

Cerithium corallium, Littorina undulata and *Terebralia palustris* were showed the same pattern like that at station 5.

4. 2. 2. 4. Factor analysis-grouping of months (R-mode) and species (Q-mode)

Station 1

R-mode: Factors 1 and 2 (Table 4. 11) were differential factor groups. Factor 1 comprised of post-monsoon and monsoon season. Pre-monsoon season showed a benthic distribution different from that of the other two seasons. All the factor groups were having high negative factor loadings except factor 4, 5 and 6. This showed that the months contained in factors 1, 2 and 3 were negatively correlated with the months included in factors 4, 5 and 6. Months included in factors 1 and 2 formed the differential factor group periods and they impart with the sufficient information about the benthic temporal distribution at this station. These were the indicator periods and to be given due importance. Deletion of any of these months will lead to reduction in the information gathered. Addition of any of the remaining months will not add to the information about benthic distribution at this station.

Q-mode: 50 species observed at station 1 were classified into 10 significant factor groups ($\lambda>1$). Of these 10 significant factor groups of species, factors 1 to 5 were differential factor groups. The species included in these 5 factor groups constituted about 64% of the total number of species studied at this station. These 32 species were to be given due importance in future studies of benthic species from this area. Factor groups 1, 2, 4 and 6 were having negative factor loadings, which implied that they were favoured by environmental condition unfavourable to the species of other factor groups (Table 4. 12).

Table 4. 11. Station 1-R-mode factor analysis

Factor	Months	%	Maximum factor load	Eigen value	Variance value	Variance %
1	Sep.99	4.58	-0.8132			
	Oct.99	6.04	-0.8021			
	Nov.99	3.53	-0.9038			
	Dec.99	2.85	-0.8686			
	Jul.00	1.83	-0.9683			
	Oct.00	6.25	-0.9665	13.61	9.8732	41.1382*
	Nov.00	3.99	-0.9609			
	Dec.00	4.40	-0.8513			
	Jan.01	2.45	-0.5710			
	Feb.01	5.82	-0.9510			
	May.01	4.21	-0.6616			
	Jun.01	2.85	-0.8856			
2	Mar.00	7.28	-0.8533			
	Apr.00	4.49	-0.8974	3.839	3.581	14.921*
	May.00	3.56	-0.9367			
3	Aug.00	4.46	-0.7030			
	Sep.00	5.2	-0.7375			
	Jul.01	4.77	-0.7458	1.788	3.4799	14.4996
	Aug.01	3.07	-0.8834			
4	Apr.01	1.64	+0.9856	1.330	1.1378	4.7409
5	Jan.00	3.5	+0.7692	1.009	1.4793	6.1637
6	Feb.00	1.02	+0.8982	0.7965	1.1991	4.9963

*Differential factor groups

Table 4. 12. Station 1-Q mode factor analysis

Factor	Species	%	Maximum factor load	Eigen value	Max. value	Variation %
1	*Cerithium corallium*	28.95	-0.6845	16.49	7.1869	14.38*
	Pyrene sp.	2.54	-0.7560			
	Cyprea moneta	0.62	-0.6345			
	Smaragdia viridis	2.79	-0.7332			
	Ctena delicatula	0.5	-0.6485			
	Pinna muricata	0.43	-0.7168			
	Gafrarium divarticatum	10.53	-0.8487			
	Calappa hepatica	1.15	-0.6395			
	Etisus splendidus	0.34	-0.4647			
	Paracilicacea setosa	0.56	-0.5640			
2	*Cerithium scabridum*	15.33	-0.5965	3.91	4.8427	9.68*
	Nereis trifasciata	1.18	-0.8231			
	Maera pacifica	4.83	-0.9585			
	Stenothoe kaia	1.21	-0.8738			
3	*Nephtys hombergii*	1.46	0.6379	3.506	4.8271	9.65*
	Macrophthalmus boscii	0.96	0.6359			
	Actaeodes tomentosus	0.28	0.7399			
	Alpheopsis equalis	0.28	0.8783			
	Seychellana expansa	0.12	0.4668			
	Paratanaeidae sp.	0.74	0.5888			
	Ophicornella sexadia	0.62	0.8621			
4	*Cerithium rostratum*	3.03	-0.5923	3.208	4.0805	8.16*
	Syllis cornuta	0.28	-0.7404			
	Eriphis sp.	0.22	-0.6201			
	Pinnotheres pinnotheres	0.25	-0.5523			
	Thalamita crenata	0.68	-0.8707			
	Cymadusa imbroglio	2.69	-0.7748			

Table 4. 12. contd…

5	*Cerithium alveolum*	0.43	0.7556	2.831	4.5225	9.05*
	Strombus mutabilis	0.28	0.8031			
	Glycera lancadivae	1.67	0.5284			
	Nephtys dibranchus	0.25	0.7407			
	Megalopa larva	0.34	0.5646			
6	*Cerithium nesioticum*	0.93	-0.9098	2.596	3.6388	7.28
	Grapsus sp.	0.28	-0.6981			
	Mallacoota insignis	0.31	-0.8826			
	Ophiactis savignyi	0.34	-0.6230			
7	*Coralliophila costularis*	0.46	0.8246	2.362	3.9247	7.85
	Smargdia soverbiana	8.64	0.5138			
	Dolabella rumphii	0.31	0.7727			
	Baseodiscus delineatus	0.34	0.5982			
	Glycera convoluta	0.22	0.5265			
	Ophiocoma scolopendrina	0.34	0.6403			
8	*Strombus canarium*	0.19	0.6137	2.014	2.5149	5.03
	Elysis sp.	0.37	-0.4706			
	Goniada emerita	0.28	0.7246			
9	*Glycera tesselata*	0.25	0.6832	1.684	2.8214	5.64
	Nephtys inermis	0.25	0.5188			
	Pilumnus hirtellus	0.46	0.7418			
	Pinnotheres pisum	0.15	0.5792			
10	*Echinometra mathaei*	0.12	-0.5556	1.574	1.8171	3.63

* Differential factor groups

Station 2

R-mode: 24 months considered in the study of temporal variation when subjected to R-mode factor analysis, it divided the study period into 6 significant factor groups with factors 1 and 2 constituting the differential factor groups. These two factors were exclusively monsoon and post-monsoon almost excluding pre-monsoon season. From this it become cleared that monsoon and post-monsoon season showed variation in the benthic community structure as well as in its distribution (Table 4. 13).

Q-mode: 49 benthic species collected from station 2 for a period of 24 months were classified into 10 factor groups, which were all statistically significant ($\lambda>1$). Factor groups 1, 5 and 8 were having high negative factor loadings where as the other factor groups have high positive factor loadings implying that the conditions favourable to the former were unfavourable to the latter. Also species included in the same factor group have the same sign implying the co-existence tendency for these species. Factors 1 to 6 were differential factor groups implying that maximum information can be obtained from the species of these factor groups, which was about 71.43% of the total 49 species collected from this station. The remaining 28.57% of the species do not supplement the information already contributed by the differential factor group species (Table 4. 14).

Station 3

R-mode: 24 months data on benthos from station 3 during the period, Sept.1999 to Aug 2001, were subjected to R-mode analysis for grouping months into factors. R-mode analysis after varimax rotation to simple structure classified these periods into 10 factor groups of which only 7 factors were statistically significant ($\lambda>1$). (Table 4. 15)

Q-mode: The factors 1-4 were designated as the differential factor groups. These include the post-monsoon season and monsoon season. Just as at

Table 4. 13. Station 2 R-mode factor analysis

Factor	Months	%	Maximum factor load	Eigen value	Variance value	Variance %
1	Oct.99	2.69	-0.9449	13.26	10.088	42.032*
	Sep.00	1.87	-0.6892			
	Oct.00	1.48	-0.9702			
	Nov.00	4.34	-0.7146			
	Dec.00	5.41	-0.9784			
	Jan.01	3.23	-0.9674			
	Feb.01	4.46	-0.9620			
	May.01	1.72	-0.8412			
	Jun.01	7.15	-0.9663			
	Jul.01	7.93	-0.9292			
	Aug.01	4.71	-0.9558			
2	Sep.99	4.24	-0.9942	5.145	7.591	31.629*
	Nov.99	10.07	-0.9637			
	Jan.00	2.28	-0.8247			
	Feb.00	1.92	-0.9300			
	May.00	3.64	-0.7242			
	Jun.00	2.91	-0.8546			
	Jul.00	5.43	-0.9882			
	Mar.01	3.57	-0.8880			
3	Dec.99	6.79	-0.9809	1.946	1.9391	8.0796
	Aug.99	2.28	-0.9804			
4	Mar.00	5.85	-0.9233	1.394	1.2964	5.4018
5	Apr.00	2.47	-0.9916	0.9388	1.0195	4.2479
6	Apr.01	3.57	-0.8152	0.5804	1.3316	5.5483

* Differential factor groups

Table 4. 14. Station 2 Q -mode factor analysis

Factor	Species	%	Maximum factor load	Eigen value	Variation value	Variation %
1	*Cerithium nesioticum*	6.31	-0.9243	13.77	5.2308	10.67*
	Conus catus	0.41	-0.9001			
	Pyrene vulpecula	3.08	-0.4457			
	Cinguloterebra hedleyana	0.53	-0.6911			
	Margarites helicinia	0.41	-0.7677			
	Myadoropsis brevispinious	0.22	-0.6334			
	Nephtys hombergii	0.27	-0.8192			
2	*Coralliophila costularis*	0.87	0.6078	4.537	4.3021	8.78*
	Smaragdia soverbiana	7.59	0.5710			
	Nereis trifasciata	0.46	0.6484			
	Maera pacifica	3.74	0.9064			
	Stenothoe kaia	0.29	0.8258			
	Ophiactis savignyi	0.15	0.5403			
3	*Cerithium alveolum*	3.4	0.7481	3.897	5.1586	10.53*
	Lithophaga nigra	0.15	0.8044			
	Gafrarium divarticatum	4.83	0.6847			
	Notomastes latericeus	0.15	0.5688			
	Calappa hepatica	0.27	0.7311			
	Echinoneus cyclostomatus	0.12	0.6716			
4	*Cerithium scabridum*	21.7	0.7570	3.113	5.5007	11.23*
	Pyrene vulpecula	0.51	0.7977			
	Strombus mutabilis	0.22	0.6611			
	Ctena delicatula	0.36	0.7247			
	Pinna muricata	0.32	0.6836			
	Glycera lancadivae	0.58	0.7473			
	Goniada emerita	0.22	0.7006			

Table 4. 14. contd...

5	*Cerithium corallium*	32.40	-0.6080	2.926	3.7825	7.72 *
	Littorina undulata	1.48	-0.8841			
	Hoplonemertean sp.	0.17	-0.8083			
	Nephtys inermis	0.12	-0.5670			
	Megalopa larva	0.34	-0.5745			
	Paratanaeidae sp.	0.24	-0.5388			
6	*Cerithium dialeucum*	0.65	0.8657	2.481	2.7474	5.61*
	Gymnodoris ceylonica	0.15	0.5721			
	Golfingia hespera	0.22	0.7918			
7	*Cerithium rostratum*	1.75	0.6788	2.354	2.6012	5.309
	Paraciliaceae setosa	0.17	0.5721			
	Ophiocoma scolopendrina	0.12	0.7918			
8	*Pyrene* sp.	2.04	-0.5634	1.969	3.9049	7.97
	Dolabella rumphii	0.24	-0.5316			
	Syllis cornuta	0.15	-0.7372			
	Mallacoota insignis	0.34	-0.6640			
9	*Syllis gracilis*	0.15	0.5219	1.849	2.7472	5.61
	Thalamita crenata	0.53	0.6493			
	Ophicornella sexadia	0.34	0.5972			
10	*Cyprea moneta*	0.29	0.5763	1.748	2.6629	5.43
	Glycera convoluta	0.17	0.5626			
	Siriella brevicaudata	0.19	0.7975			

* Differential factor groups

station 1 and 2, pre-monsoon season was not in the differential group. This implied that information contributed by the distribution of benthos in this season was not additional, but only contributed to the already gathered information during monsoon and post-monsoon season. Factor loadings of the factors 1, 3 and 4 were highly negative whereas that of 2 was highly positive. The same sign for the elements of a factor implied that these months were highly positively correlated whereas that of 1, 3 and 4 and, that of 2 were negatively correlated or disassociated (Table 4. 16).

47 benthic species collected during a period of 24 months were subjected to Q-mode factor analysis for grouping of these species into associated groups. This analysis classified the 47 species into 10 significant factor groups, all of which statistically significant ($\lambda>1$). First 5 factor groups, which explained about 50% of the total variability, were delineated as the differential factor groups. Species included in these groups were the indicator species. About 70.21% of the benthic species collected were included in the differential factor groups.

Station 4

R-mode: Benthic data collected for 24 months at station 4 was subjected to R-mode analysis for temporal grouping. 24 months of this study were classified into 10 distinct and unique factor groups of which only 4 factors were statistically significant ($\lambda>1$) and of these 4 factors, only the first three were as sub designated as differential factor groups of months. Hence these factors explained about 50% of the temporal variations. The differential factor months were end of post-monsoon and middle to end of monsoon season were more frequent. Factor groups 1 and 3 were having negative factor loadings whereas factors 2 and 4 were having positive factor loadings. Periods of each of the factor groups were highly co-existing indicated by the same sign for all the months of a factor group

Table 4. 15. Station 3 R-mode factor analysis

Factor	Months	%	Maxi factor loading	Eigen value	Variance value	Variance %
1	Nov.99	7.73	-0.8513	11.00	6.0361	25.1504*
	Dec.99	7.09	-0.8646			
	Jan.00	8.38	-0.5684			
	Feb.00	3.81	-0.7784			
	Jun.00	4.22	-0.7814			
	Dec.00	3.34	-0.8329			
	Jan.01	2.58	-0.9181			
2	Sep.99	3.63	0.6500	2.444	3.7781	15.74*
	Apr.00	5.33	0.5490			
	Aug.00	2.23	0.8406			
	Oct.00	2.87	0.7595			
	Nov.00	2.99	0.8465			
3	May.01	5.92	-0.9709	2.182	2.1614	9.006*
	Jun.01	4.69	-0.9802			
4	Oct.99	6.74	-0.5638	1.503	2.6297	10.95*
	Jul.01	3.10	-0.9378			
	Aug.01	3.98	-0.9383			
5	Apr.01	2.52	-0.9383	1.219	1.3605	5.669
6	Mar.00	2.52	-0.8873	1.059	2.0764	8.65
	May.00	2.23	-0.8766			
7	Sep.00	2.46	0.9002	1.0141	1.3466	5.61
8	Jul.00	7.91	-0.6278	0.7381	1.2438	5.18
	Mar.01	2.34	-0.6253			
9	Feb.01	1.41	0.7520	0.5962	1.0016	4.17

* Differential factor groups

Table 4. 16. Station 3 Q-mode factor analysis

Factor	Species	%	Maximum factor load	Eigen value	Variation value	Variation %
1	*Pyrene* sp.	12.48	-0.5488	11.80	4.2136	8.97*
	Smaragdia viridis	5.27	-0.5657			
	Golfingia hespera	0.7	-0.5558			
	Sipunculus indicus	0.64	-0.6305			
	Thalamita crenata	1	-0.7303			
	Actaeodes tomentosus	0.47	-0.6968			
	Maera pacifica	2.46	-0.6074			
2	*Punctacteon amakusaensis*	0.23	-0.8578	5.737	8.0314	17.09*
	Cerithium alveolum	1.29	-0.6951			
	Conus catus	0.53	-0.3980			
	Coralliophila costularis	0.18	-0.7041			
	Polinices flemengium	1.52	-0.9590			
	Smargdia soverbiana	2.87	-0.8847			
	Pyrgulina pupula	0.76	-0.8079			
	Tellina palatum	1.52	-0.7959			
	Marphysa macintoshi	0.35	-0.8701			
	Eriphis sp.	0.41	-0.8293			
	Pinnotheres pinnotheres	0.76	-0.9242			
3	*Cardium asiaticum*	0.18	0.6351	3.750	4.7804	10.17*
	Gafrarium divarticatum	19.98	0.5262			
	Baseodiscus delineatus	1.29	0.6096			
	Eurythoe mathaei	2.52	0.9589			
	Nephtys inermis	0.23	0.8937			
	Ceratonereis erythraensis	0.59	0.8359			
	Cymadusa imbroglio	4.45	0.6867			

Table 4. 16. contd…

4	*Cyprea moneta*	0.35	-0.7945	3.020	4.093	8.71*
	Niso heizensis	1.58	-0.8426			
	Phascolosoma nigrescens	2.34	-0.8398			
	Goniada emerita	0.18	-0.6946			
	Pilumnus hitellus	0.41	-0.5710			
5	*Littorina undulata*	1.41	-0.5294	3.750	4.7804	6.65*
	Notomastes latericeus	0.41	-0.8229			
	Eurythoe complanata	0.59	-0.7646			
6	*Cerithium dialeucum*	0.53	-0.5721	2.495	2.8338	6.03
	Cerithium rostratum	7.44	-0.7611			
	Cerithium nesioticum	3.16	-0.5283			
	Siboglinum fiordicum	1.41	-0.6864			
	Glycera tesselata	1.99	-0.8146			
7	*Strombus canarium*	0.18	-0.7835	2.230	3.0977	6.59
8	*Pyrene vulpecula*	1.58	-0.8888	2.167	2.3157	4.93
	Vittina variegata	0.53	-0.9315			
9	*Metanachis marquesa*	1.05	0.7076	1.954	2.4782	5.27
	Strombus mutabilis	0.29	0.8046			
10	*Cerithium corallium*	4.16	0.7798	1.558	2.5705	5.47
	Siphonosoma australe	0.35	0.8836			

* Differential factor groups

except factor 7 which has two months with opposite signs for factor loadings denoting them as disassociating periods, having species favoured by different environmental conditions (Table 4. 17).

Q-mode: 48 benthic species collected from station 4 for a period of 24 months were subjected to Q-mode factor analysis for grouping of species and thereby to determine the indicator species. Q-mode analysis divided the 48 benthic species into 10 significant ($\lambda>1$) factor groups of which first 7 factor groups formed the differential factor groups. About 79.16% of the species were designated as the differential benthic species. At this station all the factor groups explained almost the same amount of variability in the benthic distribution [6.011% (factor 6)- 9.938% (factor 4] implying that almost all the species contribute to the total variability especially the species of factors 1 to 6 were very important and their contribution was validated by their designated label as differential species. These species are to be considered in any future study, deletion of any of these 79% of the species will lead to loss of information (Table 4. 18).

Station 5

R-mode: Benthic species collected for a period of 24 months at station 5 were subjected to R-mode factor analysis for grouping of months. This analysis divided the 24 months into 2 main factor groups, which explained a total variability of 94.05%, and factor 1 was the differential factor group and this factor contained months from Dec. 99 to Aug.2001 whereas factor 2 contains Sep.99, Oct.99 and Nov.99. Both factors were having high negative factor loadings implying that benthic distribution in the periods from Dec.99 to Aug.01 were controlled by physico- chemical factors, which were different from that which control benthic population during Sep.99 to Nov.99. The R- mode analysis revealed that factor 2 elements were not so important as that of factor 1 elements, latter being the differential factor group (Table 4. 19).

Table 4. 17. Station 4 R-mode factor analysis

Factor	Months	%	Maxi factor load	Eigen value	Variance value	Variance %
1	Nov.99	2.86	-0.6311	14.22	8.2791	34.49*
	Jan.00	5.03	-0.7169			
	Feb.00	4.5	-0.8360			
	Mar.00	3.86	-0.9499			
	May .00	5.14	-0.9420			
	Aug.00	4.09	-0.8074			
	Oct.00	3.62	-0.5371			
	Dec.00	4.44	-0.7830			
	Jan.01	2.05	-0.8873			
	Feb.01	3.04	-0.6934			
	Mar.01	2.34	-0.6174			
2	Sep.99	2.86	0.6824	2.594	2.9506	12.29*
	Oct.99	4.97	0.9408			
3	Apr.00	7.13	-0.7310	1.409	2.4264	10.11*
	Jul.00	5.38	-0.6666			
	Sep.00	4.21	-0.8466			
4	Apr.01	4.68	0.9369	1.193	2.1322	8.88
	Jun.01	3.68	0.6450			
	Aug.01	2.45	0.6434			
5	May.01	2.51	-0.8809	0.9303	1.8709	7.80
6	Jul.01	2.10	-0.7934	0.8047	1.5711	6.55
7	Dec.99	7.77	0.7368	0.5895	1.4405	6.00
	Nov.00	5.61	-0.6119			
8	Jun.00	2.81	-0.7240	0.5274	0.8076	3.365

* Differential factor groups

Table 4. 18. Station 4 Q-mode factor analysis

Factor	Species	%	Maximum factor load	Eigen value	Variation value	Variation %
1	*Cerithium alveolum*	1.09	-0.6266	10.71	3.8388	8.00*
	Niso heizensis	0.47	-0.9360			
	Syllis cornuta	0.18	-0.8692			
	Tylodipax desigardi	0.29	-0.7645			
	Cymadusa imbroglio	1.11	-0.7152			
2	*Smargdia viridis*	2.57	-0.4517	4.547	4.7393	9.87*
	Tellina palatum	1.4	-0.9397			
	Ceratonereis erythraensis	0.18	-0.8705			
	Pinnotheres pinnotheres	0.64	-0.7561			
	Thalamita crenata	0.35	-0.9322			
	Alpheopsis equalis	0.12	-0.7619			
	Ophiactis savignyi	0.12	-0.7619			
3	*Cerithium rostratum*	4.44	0.7918	3.863	3.9078	8.14*
	Cerithium nesioticum	4.09	0.6421			
	Rhinoclavis sinensis	0.23	0.6341			
	Polinices flemengium	0.12	0.7941			
	Golfingia hespera	0.35	0.7038			
	Glycera sp.	0.29	0.7096			
4	*Cerithium corallium*	3.92	-0.7595	3.567	4.7702	9.94*
	Coralliophila costularis	0.23	-0.7092			
	Smaragdia soverbiana	2.63	-0.6514			
	Cinguloterebra	0.58	-0.6648			
	hedleyana	1.23	-0.5800			
	Notomastes latericeus	0.53	-0.8812			
	Marphysa macintoshi	0.18	-0.7832			
	Eriphis sp.	0.82	-0.4569			
	Macrophthalmus boscii					

Fig. 4. 18. contd...

5	*Gafrarium divarticatum*	26.36	-0.5794	3.229	3.5154	7.32*
	Nereis kauderni	0.18	-0.8617			
	Eupolymna nebulosa	0.53	-0.6543			
	Pilumnus hirtellus	0.29	-0.6122			
	Maera pacifica	1.11	-0.6187			
6	*Niotha stigmaria*	0.53	-0.8518	2.889	2.8853	6.011*
	Modiolus metcalfei	0.12	-0.7145			
	Sipunculus indicus	0.41	-0.7609			
7	*Pyrene vulpecula*	0.47	-0.6805	2.699	3.6089	7.52*
	Hoplonemenrtean sp.	0.35	-0.6558			
	Goniada emerita	0.35	-0.8920			
	Eurythoe complanata	1.87	-0.6961			
8	*Metanachis marquesa*	3.92	0.7971	2.327	4.0982	8.54
	Phascolosoma nigrescence	2.86	0.8270			
	Calappa hepatica	0.35	0.8216			
9	*Cerithium dialeucucm*	0.29	-0.5830	1.965	3.2617	6.8
	Pyrene sp.	12.92	-0.4629			
	Siboglinum fiordicum	2.16	-0.6171			
	Glycera tesselata	3.74	-0.8754			
10	*Cerithium scabridum*	8.24	0.6007	1.814	2.9819	6.21
	Baseodiscus delineatus	3.86	0.8127			
	Siphonosoma australe	0.35	0.5530			

* Differential factor groups

Q-mode: 18 benthic species collected from station 5 for a period of 24 months showed that these 18 species could be classified into 10 factor groups of which only 7 factors were statistically significant- (λ>1) and factors 1 to 5 were differential factor groups and species contained in these factors were indicator species of this station. Factors 1, 3, 4 and 5 have high negative factor loadings where as factor 2 has high positive factor loadings. Benthic species included in each of these factor groups were distinct and unique with respect to their affinity between each other as well as affinity for environmental parameters according as they were controlled or limited in production by these parameters. These species constituted about 66.67% of the benthic community at this station (Table 4. 20).

Station 6

R-mode: A period of 24 months of data when subjected to R-mode factor analysis showed that these 24 months could be classified into 2 significant factor groups.

Q-mode: The 24 months when subjected to factor analysis by R- mode showed that these 24 months could be broadly classified into 2 significant (λ>1) factor groups and only Sept. 99, Oct.99 and Nov. 99 as factor groups 2. All the months included in factor group have factor loadings all negative in the range, -0.993 to –0.729. Factor group, explains about 79.56% of the temporal variability whereas factor 2 explains 4.337 ie, 18.07% of the observed temporal variability in the benthic distribution (Table 4. 21). The 16 species of station 6 was grouped in to 6 factor groups of which the first 5 factor groups were differential factor groups. The number of species included in each factor group decreases from factor 1 down to factor 6. The more number of factors and less number of species in each group was an indication of highly varying environment over the period of two years.

Table 4. 19. Station 5 R-mode factor analysis

Factor	Months	%	Maximum factor load	Eigen value	Variance value	Variance %
1	Dec.99	11.26	-0.8946	21.73	17.54498	73.10*
	Jan.00	3.78	-0.9344			
	Feb.00	3.56	-0.9430			
	Mar.00	1.71	-0.8692			
	Apr.00	2.99	-0.9394			
	May .00	2.64	-0.9572			
	Jun.00	5.20	-0.8975			
	Jul.00	4.13	-0.7837			
	Aug.00	2.85	-0.8168			
	Sep.00	3.99	-0.9521			
	Oct.00	4.70	-0.9095			
	Nov.00	4.13	0.8715			
	Dec.00	5.27	0.9660			
	Jan.01	1.35	-0.7141			
	Feb.01	5.84	-0.9537			
	Mar.01	5.84	-0.9537			
	Apr.01	8.77	-0.9468			
	May.01	2.57	-0.9146			
	Jun.01	3.99	-0.8087			
	Jul.01	3.06	-0.8740			
	Aug.01	2.14	-0.7903			
2	Sep.99	4.42	-0.7484	1.640	5.0283	20.9514*
	Oct.99	1.5	-0.9968			
	Nov.99	4.28	-0.0008			

* Differential factor groups

Table 4. 20. Station 5 Q-mode factor analysis

Factor	Species	%	Maximum factor load	Eigen value	Variation value	Variation %
1	*Smaragdia soverbiana*	0.14	-0.9352	5.100	1.5944	8.86*
	Apseudus sp.	5.92	-0.6130			
2	*Cardiosoma carnifex*	0.07	0.9364	2.555	1.7432	9.68*
	Thalamita crenata	0.14	0.8390			
3	*Cerithium corallium*	10.62	-0.8737	2.016	3.2404	18.00*
	Littorina undulata	59.37	-0.7812			
	Terebralia palustris	18.03	-0.7940			
	Margarites helicinia	0.57	-0.9177			
4	*Uca inversa inversa*	0.07	-0.9635	1.595	1.698	9.43*
	Scylla serrata	0.43	-0.4198			
	Nikoides maldivensis	1.57	-0.7427			
5	*Uca tetragonon*	0.14	-0.9570	1.301	1.2535	6.96*
6	*Tylodipax desigardi*	0.43	0.4152	1.054	1.2365	6.87
	Paratanaeidae sp.	0.50	0.9806			
7	*Pyrene* sp.	0.93	0.9415	1.047	1.1573	6.43
8	*Smaragdia viridis*	0.43	0.8481	0.908	1.1737	6.52
9	*Cerithium rarimaculatum*	0.43	-0.8873	0.632	2.0898	11.61
	Cerithium scabridum	0.50	-0.8406			

* Differential factor groups

Table 4.21. Station 6 Q-Mode factor analysis

Factor	Species	%	Maximum factor load	Eigen value	Variation value	Variation %
1	*Cerithium corallium*	11.61	-0.8538	4.912	3.0566	19.104*
	Littorina undulata	66.52	-0.8023			
	Terebralia palustris	14.99	-0.7434			
	Margarites helicinia	0.70	-0.8512			
2	*Cerithium scabridum*	0.77	0.8256	1.975	1.7490	10.93*
	Smaragdia soverbiana	0.64	0.9082			
3	*Cerithium rarimaculatum*	0.19	-0.9497	1.630	1.334	8.34*
4	*Smaragdia viridis*	0.19	0.8231	1.373	1.6882	10.55*
	Uca inversa inversa	0.13	0.9369			
5	*Illyograpsus paludicola*	0.06	-0.9712	1.271	1.156	7.22*
6	*Paratanaeidae* sp.	0.06	0.9899	1.097	1.097	6.86

* Differential factor groups

Chapter. 5

EFFECT OF ENVIRONMENTAL PARAMETERS ON BOTTOM FAUNA

The abundance or biomass of benthic organisms can be related to the environmental parameters by means of linear regression. But this relation being controlled by only one independent variable, gives only the prediction efficiency of a single factor at a time. In ecological studies a number of factors were jointly responsible for the bioactivities at a point in time or space. Hence it was very essential to consider all the quantifiable parameters simultaneously to have the best predictive model. If benthic abundance was related to only one parameter, it becomes only an artifact on the prediction relation. Hence this was an attempt to include the individual factors and their first order interaction effects of the physico-chemical parameters mentioned earlier, in the step up multiple regression model developed in the following lines.

The step up multiple regression model fitted (Jayalakshmi, 1998) contains the individual factors as well as all possible first order interaction effects. The coefficients with which these independent parameters enter the model were computed using the programme MULTIREG. FOR. The model was repeated with all possible transformations for the dependent and independent variables and among these transformations (Jayalakshmi, 1998) the model which explains the maximum explained variability was selected as the best model for predicting benthic abundance. When there were 9 individual parameters a total of 512 models was fitted for each type of transformation and from these the one, which has maximum prediction efficiency, was selected in this study.

The six stations were grouped into 3 sets based on the results of Trellis diagramme on environmental parameters: Set 1 containing stations 1 and 2, Set 2 containing stations 3 and 4, Set 3 containing stations 5 and 6 according as they were southern seagrass area, northern seagrass area and mangrove area respectively.

(a) St. 1 and 2 Surface water parameters and organic carbon on total abundance

The model for stations 1 and 2 was based on surface parameters such as X_1 = water temperature, X_2 =pH, X_3 = dissolved oxygen, X_4 = surface salinity, X_5 = surface silicate, X_6 = surface phosphate, X_7 = surface nitrite, X_8 = surface nitrate and X_9 = organic carbon. The best regression model fitted was that of standardised values of square root of benthic total abundance (Y) on standardised values of square root value of the parameters such as water temperature (X_1), pH (X_2), DO (X_3), surface salinity (X_4), surface silicates (X_5), surface phosphates (X_6), surface nitrite (X_7), surface nitrate (X_8) and organic carbon (X_9). The regression equation was $Y= -33.1518 - 16.4293 X_1 - 66.8597 X_2 - 31.3436 X_3 + 8.6376 X_4 - 36.2319 X_5 - 29.9182 X_6 + 7.8935 X_7 + 27.9835 X_8 + 0.7872 X_9 - 18.0098 X_1 X_2 + 16.3286 X_1 X_3 - 20.2115 X_1 X_4 -0.4573 X_1X_5 -21.4685 X_1 X_6 + 20.0549 X_1 X_7 + 22.4617 X_1 X_8 - 29.6435 X_1 X_9 + 1.1061 X_2X_3 - 18.0098 X_2X_4 + 18.8303 X_2X_5 - 3.2849 X_2X_6 - 94.3041 X_2X_7 - 50.3930X_2 X_8 + 16.8866 X_2 X_9 + 3.6861 X_3X_4 + 9.5030 X_3X_5\ 15.4513 X_3X_6 -65.8050 X_3 X_7 - 46.4103 X_3 X_8 + 24.7596 X_3 X_9 + 1.5912 X_4X_5 - 40.4953 X_4X_6 - 23.0779 X_4X_7 -13.4452 X_4 X_8 + 33.6688 X_4 X_9 - 3.6662 X_5X_6+ 112.7655 X_5 X_7 - 19.7951 X_5 X_8 + 73.0869 X_5 X_9 + 1.4227 X_6 X_7 - 10.7245 X_6 X_8+ 19.2847 X_6 X_9 + 2.0864 X_7 X_8 - 41.4570 X_7 X_9 + 5.9466 X_8 X_9$.

This model explained about 75.17% of the seasonal variability in benthic production, $F_{(45,2)} = 4.1612$ ($P<0.05$). The relatively most important parameters of the model were $X_5X_7 > X_2X_9 > X_5X_9 > X_2 > X_3X_9 > X_2X_8 > X_3X_8 > X_7X_9 > X_4X_6 > X_5$. Of these X_5X_7, X_2X_9, X_2, X_2X_8, X_3X_8, X_3X_9 were limiting the benthic abundance while the rest of the above were controlling the benthic total abundance.

The values showed that nearly 50% of the model parameters were limiting the benthic abundance and out of these limiting parameters nearly 25% were highly significant whereas nearly 8% of the controlling parameters were statistically significant. For better prediction the interaction effects were to be considered separately and regression model was to be developed based on these highly significant interaction effects.

(b) Stations 1 and 2 Interstitial water parameters and dissolved oxygen on total abundance

The best predictive model was that of standardized values of $\log_{10}(y+1)$ on x where y = total benthic abundance and X's were the environmental parameters namely X_1 = dissolved oxygen, X_2 = interstitial salinity, X_3 = interstitial silicate, X_4 = Interstitial phosphate and X_5 = Intersitial nitrate.

The best regression model was, $\text{Log}_{10}(y+1) = 3.57619 - 1.08779X_3 + 1.08520X_3X_5 + 1.05802X_4X_5 + 1.04243X_5 + 0.92036X_2X_3 - 0.85274X_2 + 0.715076X_1X_5 - 0.69307X_3X_4 + 0.28067X_4 + 0.27949X_1X_2 - 0.21188X_2X_4 - 0.17814X_1X_3 + 0.13348X_2X_5 + 0.12772X_1 - 0.11246X_1X_4.$

This model explained about 17.905% of the variation in total abundance. $F_{(15,32)} = 1.6834$. The regression coefficients were arranged according to their relative importance and hence the last set of 9 parameters were not significantly different from zero $t_{(46,5\%)} >$ calculated t statistic or calculated t<1.96, (P>0.05). Hence the model could be modified by deleting the last set of 9 model parameters.

(c) **St. 3 and 4 Surface water parameters and organic carbon on total abundance**

The best predictive model was that standardized values of original Y on original X 's where Y= total benthic abundance and X 's were the water quality parameters like X_1 = water temperature, X_2 = pH, X_3 = dissolved oxygen, X_4 = surface silicate, X_5 = surface phosphates, X_6 = surface NO_2, X_7 = surface nitrate.

The best model equation was $Y= -8.09443 - 2.46995\ X_3X_6 + 2.01760\ X_6X_7 - 1.37110\ X_3 + 1.00767\ X_1X_7 - 0.99210\ X_3X_7 + 0.97687\ X_7 - 0.79881\ X_5 + 0.78609\ X_2X_6 + 0.68319X_2 - 0.7614X_6 + 0.66204\ X_2X_7 + 0.61299\ X_1X_2 - 0.59006\ X_5X_7 - 0.58691\ X_3X_5 + 0.46859\ X_4X_5 - 0.42232\ X_1X_6 - 0.30975\ X_2X_3 + 0.30798\ X_2X_5 - 0.30303\ X_1X_4 + 0.28905\ X_1X_3 - 0.27710\ X_4 + 0.23712\ X_2X_4 - 0.23584\ X_5X_7 + 0.21957\ X_1 + 0.210832\ X_4X_7 - 0.19494\ X_3X_4 - 0.11904\ X_4X_6 - 0.49911\ X_1X_5$.

This model could explain about 97.04% of the temporal/seasonal variability in the total abundance of benthic organisms, $F_{(28,19)}$= 56.030(P<0.001).

Of the above, the regression coefficients from X_2X_7 onwards could be deleted from the model because it showed that the regression coefficients were not significantly different from zero. (t calculated < 1.96, (P>0.05). Then the model could be modified into a model with the insignificant model parameters being deleted.

(d) **Stations 3 and 4 Interstitial water parameters and dissolved oxygen on total abundance**

The model for stations 3 and 4 based on interstitial parameters using standardized data of$\sqrt{Y}$ on standardized values of log (X+1) where Y=

total benthic abundance, X_1 = water temperature, X_2 = pH, X_3 = dissolved oxygen, X_4 = interstitial salinity, X_5 = interstitial silicate, X_6 = interstitial phosphate, X_7 = interstitial nitrite, X_8 = Interstitial Nitrate and X_9 = organic carbon. A model using only the direct effect was fitted and it could explain only 40% of the seasonal variation in benthic abundance. $F_{(9,38)} = 2.1561$, ($P < 0.05$). Hence a better model using the interaction effects of these parameters also, was considered.

The best model obtained as the one depending on X_1 - water temperature, X_2 - pH, X_3 - dissolved oxygen, X_4 - interstitial salinity, X_5 - interstitial silicate, X_6 - interstitial phosphate, X_7 - interstitial nitrite. The model was the standardized $\sqrt{Y}$ on standardised log (X+1). The model equation was $\sqrt{Y} = 0.4271 + 0.5278\, X_1 - 0.7454\, X_2 - 1.9832\, X_3 + 1.1814\, X_4 + 1.4249\, X_5 + 1.2039\, X_6 - 1.4722\, X_7 + 0.4316\, X_1X_2 + 1.3852\, X_1 X_3 + 1.4456\, X_1 X_4 - 0.7403\, X_1X_5 + 1.5648\, X_1 X_6 - 1.9708\, X_1 X_7 + 1.3633\, X_2X_3 - 0.4769\, X_2X_4 - 0.9450\, X_2X_5 - 1.2657\, X_2X_6 + 1.1254\, X_2X_7 - 0.6444\, X_3X_4 + 2.8418\, X_3X_5 - 0.2868\, X_3X_6 + 1.0528\, X_3 X_7 + 0.3558\, X_4X_5 - 1.0467\, X_4X_6 - 2.3407\, X_4X_7 + 0.3268\, X_5X_6 - 0.8564\, X_5X_7 - 1.4451\, X_6X_7$.

This model explained about 70.66 % of the seasonal variation in the benthic abundance distribution, $F_{(28,\ 19)} = 5.0425$ ($P<0.05$). The order of importance of the parameters was $X_3 X_5 > X_4 X_7 > X_3 > X_7 > X_1 X_4 > X_6 X_7 > X_5 > X_1 X_3 > X_2 X_3 > X_2 X_6$ were the leading model parameters. Of these $X_3 X_5$, X1 X_4, X5, X1 X_3, X2 X_3 were controlling the benthic abundance whereas the remaining leading parameters were limiting the benthic abundance.

(e) **St. 5 and 6 Surface water parameters and organic carbon on total abundance**

The best regression model was that of standardized values of original values of abundance Y on standardized values of original values of parameters X which were X_1 = water temperature, X_2 =pH, X_3 =dissolved oxygen, X_4 =surface salinity, X_5 = surface phosphates, X_6 = surface nitrate, X_7 =organic carbon. The best model equation was Y = 2.6035 - 10.8824 X_2X_7 + 9.7110 $X_1 X_7$ - 4.5173 X_5X_7 + 4.2481 X_2X_6 - 3.7621 X_1X_6 - 3.6498 X_1X_3 + 2.7101 X_1 - 2.6526 X_4X_7 -2.5225 X_2 + 2.2835 X_2X_5 - 1.9916 X_3X_5 + 1.6486 X_1X_4 - 1.4061 X_3X_7 - 1.3302 X_2X_4 - 1.3193 X_3 + 1.3071 X_4X_6 - 1.2904X_6 - 1.1310 X_3X_6 + 0.95036 X_2X_3 - 0.91178 X_6X_7 + 0.7450 X_1X_2 + 0.46307 X_5X_6 + 0.4606 X_4 + 0.40178 X_4X_5 + 0.36347 X_7 - 0.2439 X_1X_5 + 0.10085 X_3X4.

This model explained about 49.71% of the temporal variability in the abundance distribution, $F_{(28,\ 19)}$= 2.6592 (P, 0.05). The results were given in Table 5.5. In the above table, the 1^{st} 7 parameters including X_2X_5,, X_1X_4, X_2 & X_6X_7 were significantly different from zero and hence these were to be given due importance in the model study. Deleting any of the parameters, other than those mentioned above will not affect the efficiency of the prediction model.

(f) Stations 5 and 6 Interstitial water parameters and dissolved oxygen on total abundance

The best model was that of standardised values of original values of abundance Y (abundance) on original values of water quality parameters namely X_1= water temperature, X_2 =pH, X_3 =dissolved oxygen, X_4 =interstitial salinity, X_5 = interstitial nitrite, X_6 = interstitial nitrate, X_7 =organic carbon. The best model equation was Y= 0.47824 + 3.9199 X_5X_7 + 3.7246 $X_3 X_6$ - 3.7076 X_4X_7 + 3.3241 X_2X_6 – 2.3055 X_1X_6 – 1.9365 X_1X_3 + 1.8901 X_6X_7 - 1.8811 X_1X_5 + 1.6820 X_3 + 1.4954 X_2 + 1.3033 X_5 - 1.1551 X_4X_6 +0.91066 X_6 - 0.87919 X_1X_4 - 0.82327 X_4 + 0.7939 X_2X_4 - 0. 7651 X_4X_5 + 0.7209 X_3X_7 + 0.74733 X_1X_2 + 0.70598 X_2X_7 -

0.4809 X_1X_7 - +0.40745X_7 - 0.3815 X_2X_5 - 0.3571 X_1 + 0.30667 X_2X_3 - 0.28594 X_3X_4 - 0.1948 X_3X_5.

This model explained about 64.72 % of the temporal variability in the benthic total abundance on interstitial parameters, $F_{(28,19)}$= 4.07, ($P<0.05$). The results were given in Table 5.6. This table deleted the parameters from X_6 onwards since these co-efficients were not significantly different from zero ($P<0.05$). By this process the model parameters could be restricted to parameters up to X_6 as the ecologically most important parameters.

The standard error, test statistic for the significance of the above given correlations, along with Lower confidence limit (LCL) and Upper confidence limit (UCL) were given in Table 5. 1 to 5. 6 for further reference.

Table 5. 1. St.1 and 2 surface water parameters and O.C on abundance

Table showing the standard error, t statistic, UCL (Upper confidence limit) and LCL (Lower confidence limit) for the regression coefficients.

Parameters	Std. error	t statistics	LCL	UCL
X_1	8.1398	-2.0184	-51.4547	18.5961
X_2	53.5769	-1.2479	-297.4013	163.682
X_3	12.8508	-2.4390	-86.6406	23.9534
X_4	8.4752	1.0192	-27.8313	45.1065
X_5	24.4113	-1.4842	-141.2737	68.8100
X_6	13.1833	-2.2694	-86.6460	26.8096
X_7	18.8867	0.4179	-73.3760	89.1630
X_8	15.0871	1.8548	-36.9365	92.9035
X_9	0.6171	1.2755	-1.8683	3.4426
X_1X_2	130.7707	-0.1377	-580.7161	544.6965
X_1X_3	11.8827	1.3741	-34.8027	67.4598
X_1X_4	12.4091	-1.6287	-73.6076	33.1853
X_1X_5	11.8955	-0.0384	-51.6435	50.7289
X_1X_6	22.7512	-0.9436	-119.3671	76.4301
X_1X_7	21.9482	0.9137	-74.3884	114.4982
X_1X_8	16.8567	1.3325	-50.0725	94.9959
X_1X_9	6.5159	-4.5494	-57.6815	-1.6055
X_2X_3	2.1351	0.5180	-8.0814	10.2935
X_2X_4	130.7864	-0.1377	-580.7834	544.7639
X_2X_5	5.5264	3.4074	-4.9497	42.6103
X_2X_6	25.0871	-0.1309	-111.2346	104.6647
X_2X_7	110.7094	-0.8518	-570.6867	382.0786
X_2X_8	32.4666	-1.5521	-190.0969	89.3110
X_2X_9	24.7590	0.6820	-89.6515	123.4246

Table 5. 1. contd....

Parameters	Std. error	t statistics	LCL	UCL
X_3X_4	3.2565	1.1319	-10.3264	17.6987
X_3X_5	8.1778	1.1620	-25.6863	44.6923
X_3X_6	14.9647	1.0325	-48.9418	79.8445
X_3X_7	48.1150	-1.3677	-272.8437	141.2336
X_3X_8	25.5750	-1.8147	-156.4577	63.6371
X_3X_9	11.8616	2.0874	-26.2809	75.8001
X_4X_5	2.5264	0.6298	-9.2798	12.4622
X_4X_6	27.3834	-1.4788	-158.3262	77.3357
X_4X_7	10.3831	-2.2226	-67.7563	21.6005
X_4X_8	19.4621	-0.6908	-97.1906	70.3002
X_4X_9	32.5468	1.0345	-106.3800	173.7177
X_5X_6	3.7090	-0.9885	-19.6262	12.2937
X_5X_7	101.0695	-1.1157	-547.6675	322.1364
X_5X_8	8.2247	-2.4068	-55.1858	15.5955
X_5X_9	19.5119	3.7446	-10.8988	157.0726
X_6X_7	0.7473	1.9039	-1.7928	4.6383
X_6X_8	31.9964	-0.3352	-148.4048	126.9559
X_6X_9	21.4746	0.8980	-73.1207	111.6900
X_7X_8	1.9722	1.0579	-6.3998	10.5726
X_7X_9	67.4100	-0.6150	-331.5222	248.6082
X_8X_9	3.0298	0.1963	-12.4428	13.6321

Table 5. 2. St. 1 and 2 interstitial parameters and D.O on abundance

Parameters	Std. error	t statistics	LCL	UCL
X_3	0.4015	-2.7094	-1.8747	-.3009
X_3X_5	0.3769	2.8795	0.3465	1.8239
X_4X_5	0.2921	3.6225	0.4856	1.6305
X_5	0.2736	3.8100	0.5062	1.5787
X_2X_3	0.3460	2.6601	0.2422	1.5985
X_2	0.2432	-3.5066	-1.3294	-0.3761
X_1X_5	0.4464	1.6018	-0.1599	1.5901
X_3X_4	0.3682	-1.8826	-1.4146	0.0285
X_4	0.2107	1.3322	-0.1323	0.6936
X_1X_2	0.2664	1.0493	-0.2426	0.8016
X_2X_4	0.2491	-0.8505	-0.7002	0.2764
X_1X_3	0.3089	-0.5768	-0.7835	0.4272
X_2X_5	0.3371	0.3960	-0.5272	0.7941
X_1	0.2126	0.6007	-0.2890	0.5449
X_1X_4	0.3142	-0.3579	-0.7283	0.5034

Table 5. 3. St. 3 and 4 surface water parameters and O. C on abundance

Parameters	Std. error	t statistics	LCL	UCL
X_3X_6	0.1648	-14.9872	-2.8149	-2.1250
X_6X_7	0.8403	2.4011	0.2589	3.7763
X_3	0.3271	-4.1923	-2.0556	-0.6866
X_1X_7	0.3639	2.7692	0.2461	1.7693
X_3X_7	0.3045	-3.2580	-1.6294	-0.3548
X_7	0.3525	2.7712	0.2391	1.7147
X_5	0.3940	-2.0277	-1.6234	0.0257
X_2X_6	0.9468	0.8302	-1.1956	2.7678
X_2	0.4431	1.5419	-0.2442	1.6106
X_6	0.2621	-2.9055	-1.3099	-0.2129
X_2X_7	0.4131	1.6024	-0.2027	1.5268
X_1X_2	0.4779	1.2826	-0.3873	1.6131
X_5X_7	0.6577	-0.8971	-1.9667	0.7866
X_3X_5	0.3774	-1.5572	-1.3767	0.2029
X_4X_5	0.4951	0.9465	-0.5676	1.5048
X_1X_6	0.2311	-1.8274	-0.9060	0.0614
X_2X_3	0.2361	-1.3119	-0.8039	0.1804
X_2X_5	0.6605	0.4663	-1.0744	1.6903
X_1X_4	0.2411	-1.2570	-0.8076	0.2015
X_1X_3	0.3370	0.8578	-0.4162	0.9943
X_4	0.3295	-0.8410	-0.9667	0.4125
X_2X_4	0.2158	1.0989	-0.2145	0.6887
X_5X_6	0.4066	-0.5806	-1.0861	0.6144
X_1	0.1920	1.1437	-0.1822	0.6214
X_4X_7	0.5166	0.4081	-0.8704	1.2920
X_3X_4	0.7449	-0.2617	-1.7541	1.3642
X_4X_6	0.9035	-0.1318	-2.0101	1.7720
X_1X_5	0.4196	-0.1189	-0.9281	0.8283

Table 5. 4. St. 3 and 4 interstitial parameters and D. O on abundance

Parameters	Std. error	t statistics	LCL	UCL
X_1	0.5869	0.8993	-1.3545	2.4100
X_2	-2.7679	0.2693	-1.3092	-0.1818
X_3	-4.6619	0.4254	-2.8736	-1.0928
X_4	2.3588	0.5008	0.1336	2.2296
X_5	3.2092	0.4440	0.4956	2.3542
X_6	1.4181	0.8490	-0.5730	2.9810
X_7	-1.7963	0.8196	-3.1876	0.2432
X_1X_2	1.0275	0.4201	-0.4476	1.3109
X_1X_3	1.9149	0.7234	-0.1288	2.8992
X_1X_4	1.0161	1.4226	-1.5320	4.4231
X_1X_5	-1.9963	0.3708	-1.5165	0.0358
X_1X_6	0.1862	0.8273	-1.5750	1.8879
X_1X_7	-0.4480	0.4399	-1.1178	0.7236
X_2X_3	3.9072	0.3489	0.6330	2.0936
X_2X_4	-0.8226	0.5798	-1.6905	0.7366
X_2X_5	-0.8063	1.1721	-3.3982	1.5081
X_2X_6	-2.0439	0.6193	-2.5618	0.0304
X_2X_7	2.4886	0.4522	0.1789	2.0719
X_3X_4	-1.0974	0.5822	-1.8135	0.5847
X_3X_5	3.6133	0.7865	1.1957	4.4879
X_3X_6	-0.4397	0.6523	-1.6520	1.0784
X_3X_7	1.3235	0.7954	-0.6121	2.7176
X_4X_5	0.3983	0.8934	-1.5140	2.2256
X_4X_6	-0.8215	1.2742	-3.7137	1.6203
X_4X_7	-2.3479	0.9949	-4.4273	-0.2542
X_5X_6	0.2102	1.5545	-2.9269	3.5804
X_5X_7	-0.5211	1.6434	-4.2960	2.5833
X_6X_7	-50.2683	0.0089	-1.4457	-1.4444

Table 5. 5. St. 5 and 6 surface parameters and O. C on total abundance

Parameters	Std. error	t statistics	LCL	UCL
X_2X_7	2.9681	-3.6664	-17.0947	-4.6701
X_1X_7	2.8019	3.4658	3.8466	15.5754
X_5X_7	1.1509	-3.9251	-6.9261	-2.1085
X_2X_6	1.7351	2.4483	0.6165	7.8796
X_1X_6	1.6380	-2.2967	-7.1905	-0.3337
X_1X_3	1.2494	-2.9212	-6.2649	-1.0347
X_1	1.0481	2.5857	0.5164	4.9039
X_4X_7	1.3276	-1.9980	-5.4313	0.1261
X_3	0.8343	-1.5814	-3.0654	0.4268
X_2X_5	0.7947	2.9992	0.7201	4.0469
X_3X_5	1.4292	-1.3935	-4.9830	0.9998
X_1X_4	0.7760	2.1244	0.0243	3.2729
X_3X_7	1.0571	-1.3301	-3.6187	0.8065
X_2X_4	1.2600	-1.0557	-3.9674	1.3070
X_2	1.0517	-2.3985	-4.7237	-0.3213
X_4X_6	0.7379	1.7714	-0.2373	2.8515
X_6	0.6612	-1.9516	-2.6742	0.0935
X_5	0.8603	-1.3682	-2.9776	0.6235
$X_3 X_6$	0.8221	-1.3757	-2.8516	0.5897
X_2X_3	0.5818	1.6333	-0.2674	2.1682
X_6X_7	0.4328	-2.1066	-1.8177	-0.0059
$X_1 X_2$	0.8457	0.8809	-1.0251	2.5151
X_5X_6	0.4006	1.1560	-0.3753	1.3015
X_4	0.9009	0.5113	-1.4249	2.3461
X_4X_5	0.5466	0.7351	-0.7422	1.5457
X_7	0.5530	0.6573	-0.7939	1.5208
X_1X_5	0.8047	-0.3031	-1.9281	1.4403
X_3X_4	0.4723	0.2135	-0.8876	1.0893

Table 5. 6. St.5 and 6 interstitial parameters and D.O on benthic abundance

Parameters	Std. error	t statistics	LCL	UCL
X_5X_7	0.7853	4.9920	2.2764	5.5635
X_3X_6	1.4733	2.5281	0.6411	6.8081
X_4X_7	1.0466	-3.5426	-5.8981	-1.5171
X_2X_6	1.2339	2.6940	0.7416	5.9066
X_1X_6	1.2349	-1.8670	-4.8901	0.2791
X_1X_3	1.6258	-1.1911	-5.3393	1.4663
X_6X_7	0.3928	4.8123	1.0680	2.7122
X_1X_5	1.7096	-1.1003	-5.4594	1.6971
X_3	0.6303	2.6688	0.3629	3.0012
X_2	0.4407	3.3934	0.5730	2.4177
X_5	1.4699	0.8867	-1.7731	4.3798
X_4X_6	1.4043	-0.1326	-3.1254	2.7530
X_6	0.3607	2.5244	0.1556	1.6657
X_1X_4	0.5616	-1.5654	-2.0547	0.2963
X_4	0.8138	-1.0117	-2.5265	0.8799
X_2X_4	0.6046	1.3130	-0.4716	2.0594
X_4X_5	0.4324	-0.1769	-0.9816	0.8286
X_3X_7	0.4734	1.5228	-0.2699	1.7118
X_1X_2	0.2728	2.7396	0.1764	1.3183
X_2X_7	0.8622	0.0008	-1.8038	1.8052
X_1X_7	0.7038	-0.0683	-1.5212	1.4250
X_7	0.4166	0.9781	-0.4645	1.2793
X_2X_5	0.6998	-0.5451	-1.8460	1.0831
X_1	0.4873	-0.7328	-1.3771	0.6629
X_2X_3	0.4165	0.7363	-0.5651	1.1784
X_3X_4	0.5307	-0.5388	-1.3967	0.8248
X_3X_5	1.0180	-0.1913	-2.3255	1.9359

Chapter. 6

BENTHIC PRODUCTION AND TROPHIC RELATIONSHIPS

Broom (1982) suggested that although different phyla dominate in different latitudes, the various trophic types (deposit feeders, scavengers, suspension feeders, algal grazers, predators) are well represented worldwide, with different but similar genera filling identical niches.

A major role of benthic communities is to receive organic detritus and convert it to invertebrate biomass, which serves as food for demersal fish and other predators. The conversion process is relatively inefficient and the by-products include CO_2 and inorganic nitrogen, phosphorous, silicon etc. which are regenerated in the water column and used again in secondary production (Mann, 1988). Between the primary production and the fish production, the role of benthic organisms first as a feeder of detritus and plant material and in turn forming food of some predators like crabs and fishes is already proved.

At Minicoy Island, the surveyed seagrass beds and mangroves showed the presence of many reef fishes, perches, barracudas etc. The juveniles belonging to family Acanthuridae, Apogonidae, Ballistidae, Carangidae, Chaetodontidae, Diodontidae, Platacidae, Exocoetidae, Fistulariidae, Haemulidae, Hemiramphidae, Holocentridae, Kuhlidae, Labridae, Lethrinidae, Lutjanidae, Mugilidae, Mullidae, Muraenidae, Pemphridae, Pomacanthidae, Pomacentridae, Scaridae, Scorpanidae, Serranidae, Siganidae, Sphyraenidae and Tetraodontidae were reported from the seagrass beds of Kavaratti Atoll, Lakshadweep by Vijay Anand and Pillai (2005). Some of them like Acanthuridae, Apogonidae, Chaetodontidae, Fistulariidae, Holocentridae, Lutjanidae, Mullidae, Scaridae were found in all seasons from the seagrass beds. The study evolved a positive relation of juvenile abundance with salinity. In the present study Pomacentrids and

Sphyraenidae adults as well as juveniles were abundantly found at the mangrove as well as seagrass ecosystems of Minicoy.

The fishes considered for gut content analysis from the seagrass as well as mangrove sites include adults and juveniles of *Abudefduf* spp., *Sphyraena* spp., Perches, Carangids etc. owing to their frequent grazing at seagrass and mangrove regions. The gut content of *Sphyraena*, Carangids and Perches showed presence of crustaceans, polychaetes, soft molluscan shell remnants, detritus material etc. *Abudefduf* spp. showed mostly algal remnants in their gut. The qualitative gut content analysis revealed that most of these fishes are benthic feeders and there is a strong trophic link between benthos and demersal fishes of that region.

Eventhough there appears to be a great potential for many species of fish like pomacentrids, apogonids, carangids and perches among the seagrass areas of Minicoy, less attention is paid for the exploitation and therefore estimation of the fish stock at these locations since the fishermen of Minicoy are averse to capture fishes other than tunas. Therefore data on estimated potential of demersal lagoon fishes are not yet available from Minicoy Island.

The maximum production in terms of carbon and biomass production was noticed at the southern seagrass site followed by the mangrove site. At the southern seagrass site the mean biomass wet weight was 173.52 g/m^2. At the northern seagrass site and mangroves, the mean biomass wet weight values were 67.58 g/m^2 and 109.13 g/m^2 respectively. The dry weight values, worked out using Parulekar's conversion factors for each group, at each area were 10.88 g/m^2, 4.36 g/m^2 and 7.01 g/m^2 respectively. The annual carbon productions at these three sites were 7.51 $gC/m^2/y$, 3.1 $gC/m^2/y$ and 4.84 $gC/m^2/y$ respectively. The annual biomass production in $g/m^2/y$ was estimated as 347.05, 135.16 and 219.43 respectively (based on Sander's suggestion of a production of about twice the standing crop for the benthic animals). Considering all these values and taking the potential benthic yield as 10% of the benthic standing crop, the potential yield was estimated as 34705 Kg/km^2, 13516 Kg/km^2 and 21943 Kg/km^2 respectively from the southern seagrass, northern seagrass and mangrove sites (Table 6. 1).

Table 6. 1. Benthic biomass, annual production and potential yield from Southern seagrass, Northern seagrass and Mangrove area.

Areas	**Mean biomass wet wt. (g/m^2)**	**Mean biomass dry wt. (g/m^2)**	**Carbon content (gC/ m^2)**	**Annual carbon prodn. (gC/m^2/y)**	**Annual biomass prodn. (g/m^2/y)**	**Potential yield (Kg/km^2)**
Southern seagrass	173.52	10.88	3.75	7.5	347.05	34705
Northern seagrass	67.58	4.36	1.5	3.0	135.16	13516
Mangroves	109.13	7.01	2.41	4.84	219.43	21943

Chapter. 7

DISCUSSION

It is well known that the marine population fluctuates from time to time. The widest inter-annual variations in faunal densities and species richness occur in the tropics, coinciding with the great variety of habitats and environmental conditions. Nearly 40% of the total open ocean area and 30% of the total area of the world's continental shelves lie within the tropics. In the tropics changes in benthic communities is related to monsoonal rains, comparatively higher water temperature/salinity conditions, carbonate sedimentation, dissolved oxygen and nutrient concentrations. Variations in composition and abundance of macrobenthos have been mainly related to the changing environmental conditions (Eagle, 1981; Nichols, 1985; Frouin and Hutchings, 2001), interspecific competition for space (Woodin and Jackson, 1981; Mc Auliffe, 1984), food resources (Kemp, 1988) and substrate composition (Bursarawich *et al.,* 1984; Campbell *et al.,* 1986; Cano and Garcia, 1982; Colella and Geronino, 1987; Eckman, 1983 and Ferenz, 1974). The apparent success of distribution and abundance of crustaceans and bivalves in the tropics can be attributed to their motility and ability to escape or avoid high temperatures and salinity or desiccation. Garrity *et al.* (1986) found that the shell crushing predation of inter tidal gastropods is greater in the tropics. Moore (1972) found that tropical inter tidal communities are on an average subjected to greater environmental stress. Benthic organisms normally attempt to avoid stress by a variety of physiological and behavioural mechanisms, including horizontal and vertical migration, aestivation, hibernation and habitat modification.

Seagrass meadows are known for their high productivity (Orth, 1986). Seagrasses become unique owing to their ability to live in a saline medium, to function normally when fully submerged, having a well developed anchoring system, ability to complete the generative cycle when fully submerged and ability to compete with other organisms under more or less stable conditions of the marine environment (Hartog, 1979; Doering and Chamberlain, 2000). Considerable information is available on the animal communities of seagrass beds of temperate environments (Kikuchi, 1980). However, the fauna of tropical coral reef seagrass beds have received less attention. The lagoons of Minicoy have luxuriant seagrasses and coralline algae dominated by species of *Thalassia hemprichii, Cymodaceae, Halodule, Syringodium and Halimeda.* (Jag tap, 1987). Lagoon sediments, consisting of fragments of corals, gastropod shells, foraminiferans and coarse to medium sand have varied amounts of seagrass coverage (Ansari *et al.*, 1991). Macrofaunal densities from seagrass beds were different in different studies from the same *Thalassia testudinum* beds.

Typical mangrove plants like *Avicinnia marina* and *Cereops tagal* demarcated certain zones in southern area of Minicoy Island as mangroves. Mangrove plants produce huge quantity of litter (mainly leaves, twigs, bark, fruit and flowers). Some of this is eaten by crabs, but the major portion must be broken down before the nutrients become available to other animals. That is where the bacteria and fungi come in. Dividing sometimes every few minutes, they feast on the litter, increasing its food value by reducing unusable carbohydrates and increasing the amount of protein — up to four times on a leaf which has been in seawater for a few months (Nassar *et al.*, 1999). Partly decomposed leaf particles, loaded with colonies of protein-rich microorganisms, are then eaten by fish and prawns (Chong *et al.,* 1996). They in turn produce waste, which, along with the smallest mangrove debris, is taken up by molluscs and small crustaceans. Even dissolved substances are used by plankton or, if they land on the mud surface, are browsed by animals such as crabs and mud whelks. Mud whelks belonging to the species *Terebralia palustris* occupies a key position in this region along with crabs and crustaceans.

Although these study areas (seagrass as well as mangrove zones) were close to the coast and sampling depths varied between stations, no clear distinction into zones was feasible on the basis of species composition. This review addresses the structural and functional aspects of tropical soft-bottom benthos, emphasizing differences between the mangrove and seagrass ecosystems of Minicoy atoll.

7. 1. Bottom fauna

Composition

In the present study very high species diversity was noticed in southern seagrass stations (137 species for the entire study period both at station 1 and 2) and northern seagrass stations (74 and 62 species at stations 3 and 4 respectively). But in the mangrove stations comparatively very low species diversity of 18 and 16 were observed at stations 5 and 6 respectively. Dugan (1990) noticed that the low diversity in mangroves is caused by the severe climatic and environmental conditions with limitations in the range of suitable habitats and niches. The seagrass beds, on the other hand, with their dense vegetation and thick and branched rhizomes increases the available substrate surface for epiphytic algae and associated fauna (Stoner, 1980; Stoner and Lewis, 1985). These in turn attract other fauna (gastropods, polychaetes and crustaceans), which form the basis of food chains within the seagrass ecosystem and add to the high species diversity. The predator-prey relationship appear to play a major role in maintaining the reported high densities of macrofauna in seagrass beds (Orth *et al.*, 1984; Prieto *et al.*, 2000; Paula *et al.*, 2001), although other factors (physical/physiological factors) could also be important. Marine benthic diversity varies greatly within the tropics, as other studies have found very high species diversity in seagrass (Young and Young 1982; Campbell and Mc Kenzie, 2004). Johnson (1974) postulated that the shallow water infaunal species diversity is influenced by food- resource diversity. Seagrass meadows are essentially detritus rich environments and the dominance of suspension feeders and detritivores like polychaetes, amphipods and isopods is not surprising. However it is believed that such detritus is often not easily digestible by invertebrates and leads to slow growth of the animals (Tenore, 1977).

Sediment stability as well as habitat complexity are important for the occurrence of infaunal groups. Dense beds of *Thalassia hemprichii* reduces the wave action near the bottom, thus trapping and preventing removal of finer sediment particles (Orth, 1973). An increased surface area and increased habitat complexity in seagrass systems plus an abundance of food from decaying seagrass and organic sedimentary material support these large and diverse populations of benthic invertebrates in such ecosystems (Connel, 1975). Martin *et al.* (2000) suggested that within a seagrass bed the size and composition of the associated macroinvertebrate community are not determined by the structural complexity of the plants, but by the amount of plant available. This is in tune with the present findings of less macrofauna abundance at northern less sparse *Cymodaceae* bed. The study showed a high species diversity at *Thalassia* beds (which have more leaf blade surface area, thickened growth and highly entangled thick rhizomes), while comparatively lesser diversity was noticed at the *Syringodium* station where leaf blade surface area less and rhizomes are not thick and entangled. This is in tune with the findings of Brook (1978) and Bostrom and Bondorff (2000).

Kikuchi and Peres (1977) observed a much richer fauna in scattered seagrass bed with mixed *Thalassia, Cymodocea,* and *Halodule* than a seagrass bed of *Syringodium,* which shows an impoverished fauna.

Eight major groups identified in the present study were gastropods consisting of 58 species, bivalves of 12 species, polychaetes of 27 species, other worms (including all worms except polychaetes) of 7 species, crabs of 24 species, other crustaceans (including prawns, amphipods, isopods, stomatopods, tanaeids, etc.) of 19 species, echinoderms of 11 species and sponges of only 2 species leading to a grand total of 160 species from the entire study area. So far the studies on macrobenthos from the seagrass intertidal areas of Minicoy were limited to group composition (Ansari, 1984). He observed that polychaetes were numerically the most abundant group comprising 60-92% of total macrofauna numbers and were dominated by suspension and deposit feeding forms. In the present investigation the ostracods and anthozoan groups found in earlier study were absent and instead echinoderms, sponges, tanaeids, etc. were present. Anthozoans were limited to seagrass leaves as attached phytofauna. Raut *et al.* (2005) observed that there were marked changes in benthic community structure relative to an earlier investigation from the same study area (Kakinada Bay) over years. Wide variations in diversity occur more commonly within the same habitat over time (Vincent, 1986; Vargas, 1988; Luczak, 2001). Pinkster and Goris (1984) suggested that in the monthly samples not more than 25-40% of those species that occur throughout the year can be found. They recommended that the 2 sampling periods (April-June and Sept.-Oct) would give the best representation (up to 60% of the species that occur throughout the year). In the present study, based on sampling done for 24 consecutive months, it can be assumed that all the species were sampled.

According to Sanders (1968) the underlying cause of high diversity was the persistence of stable environmental conditions over a long period of time. Based on his stability-time hypothesis the communities in stable condition become biologically accommodated and the biological stress between species such as intense competition or non-equilibrium in predator-prey relationships become progressively reduced over a long period of time. Evolutionary history of the geographical region and interspecies competition between individual species and their relationships to the physical environment are the two factors responsible for the presence or absence of groups/species in a given area/station. Diversity indicates the degree of complexity of a community structure. It is a function of two elements namely number of benthic species and their abundance or equitability, which is richness and evenness with which the individuals are distributed among the benthic species. Diversity is a concise expression of how individuals in a community are distributed within subsets of groups/species.

The measurement of temporal variation of diversity provides useful information on the succession of the community structure. Several diversity indices have been proposed by Simpson (1949), Shannon Weaver (1963), Pielou (1966 a & b), Margalef (1968) and Heip (1974). These indices measure the species richness as a rough measure of diversity, species concentration as a measure of dispersion of abundance about the mean abundance, species diversity a theoretical measure of diversity, species dominance to study the dominating nature of one or more species in a particular month/location and finally equitability or uniformity in the distribution of total abundance among the various species present during a particular season at a particular station respectively. These five factors together define the structure of the community. High richness, high concentration, high diversity, low dominance and high evenness refer to a healthy community with stable structure provided the coefficient of variation for each of these indices is very low for each station over all months or for each month over all stations.

From the analysis of indices it becomes clear that stable structure of community was seen at station 1 because this station showed the highest richness, highest concentration, highest diversity, comparatively higher evenness and lower dominance index. Coefficient of variation was also comparatively lower at station 1. Station 3 and 4 showed almost same stability just like station 1. Station 2 has also shown high stability by showing comparatively low dominance and high richness. Station 5 and 6 showed not much difference between themselves but were different from other stations thus showing low stability of ecosystem owing to the low richness, low concentration, very low diversity, high dominance and low evenness. Diversity index showed a value greater than 3 at the seagrass areas and lesser than 3 at the mangroves indicating the unstable nature of the mangrove ecosystem.

Standing stock

Biomass. though exhibited seasonal fluctuations, did not vary much corresponding to the population count. High biomass values did not show a direct relationship with the numerical abundance. Harkantra and Parulekar (1981) suggested that biomass depended on the size of the animal and not on the numerical abundance. The biomass is not necessarily related to the quantity of organic matter in a deposit, but seems rather more related to the suitability of the deposit as a habitat for particular species. Based on benthic abundance/biomass of groups (3-way ANOVA studies), it further clarified that the three areas namely southern seagrass, northern seagrass and mangroves were significantly different from each other.

In the present study, the highest biomass wet weight ($173 g/m^2$) was observed at southern seagrasses followed by mangroves ($110 g/m^2$) and least at northern seagrasses ($67 g/m^2$). The biomass observed at the mangrove stations was mainly due to the large sized gastropod flesh of *Terebralia* *palustris.* This was the major contributor of biomass at mangrove stations. The main biomass contributor at the northern seagrass area were *Gafrarium divarticatum* as well as that of *Tellina palatum.*

Great variations may occur in the density of species where soils of varying grade occur within the same area. The food of most species during pelagic larval life and of suspension feeders in the adult population is the plankton, and since fluctuation in phyto and zooplankton are closely linked with the supply of nutrients, it follows that the density of benthic species is related to changes in the nutrient level. An increase in fertility do not necessarily affect all species in the same way. The pelagic larval stage of many macrobenthic organisms (Thorson, 1957) is important in determining the distribution of species. According to Willems *et al.* (1984) the explanation for variable abundances of benthic invertebrates include 1) differentially successful and sequential recruitment by larvae of various species. 2) predation and 3) habitat complexity. Predation has been found to be a major factor affecting benthic population (Sikora and Sikora, 1985). Post and Cusin (1984) hypothesized that fishes remove large numbers of small crustaceans such as cumaceans and amphipods from benthic assemblages.

In the present study gastropods were the numerically most abundant group followed by bivalves. Polychaetes came in the third position. The extreme range of macrofaunal density could be the result of differing food supply and the sediment characteristics. Beach exposure also plays an important role in the distribution of intertidal fauna. This is in agreement with the findings of Mclachlan (1977) who reported the dominance of bivalves in the intertidal macrofauna of South African beaches and Thomassin *et al.* (1975) who reported the dominance of molluscs in the coral sediments of Polynesian atolls. Sheppard *et al.* (1992) found that in the Arabian marine environment, approximately 50% of the seagrass inhabitants are molluscs.

The southern seagrass stations showed the highest abundance followed by the northern seagrass stations and least abundance was seen at the mangrove stations. But when compared to the very low species diversity at the mangrove site, the contribution of each species to the numerical abundance was comparatively high. The uniqueness of the mangrove lies with low species diversity, but richness of individual species. It is the concentration of individual species rather than their diversity, which characterises the mangrove (Dugan, 1990).

The total abundance observed at southern seagrass area, northern seagrass area and mangroves were 670/0.25m^2, 295/0.25m^2 and 247/0.25m^2 respectively. This is in tune with the observations of Ansari (1984) in the *Thalassia* beds of Minicoy. Stoner (1980) also observed similar values at *T.testudinum* beds. Many faunal groups like bivalves, echinoderms, polychaetes, 'other worms' etc. were absent or negligibly present at the mangrove sites, due to the unfavourable environmental conditions and the prevailing nature of sediments, except some mud whelks, crabs and detritus feeding crustaceans. 'Other worms' showed a preference for the northern seagrass site (numerical abundance-29.5/ 0.25m^2). The highly entangled rhizomes with the hard sediment at the southern seagrass region may restrict the movement of these organisms during certain periods of the year and that may be the reason for less number of 'other worms' there. The density of benthic infauna is affected by vegetative growth, particularly of eelgrass (*Zostera* spp.), which increases sediment stability and interrupts the movement of burrowing animals (Orth, 1973). The detritivorous and carnivorous polychaetes showed a faunal preference for the southern seagrass area (owing to the abundance of their prey) often showing camoflague with the *Thalassia/Cymodaceae* rhizomes and their numerical abundance was comparatively lesser in northern stations due to the more sandy nature of the sediment, less chances of food and the prevailing tidal waves. Eventhough some mud crabs and mangrove crabs (*Uca* spp.) were present in the mangrove area, their abundance was comparatively lesser when compared with the seagrass area. The seagrass flora, at the same time provides food and shelter to these organisms. In the case of crustaceans, seasonal variations were maximum for numerical abundance because of the seasonal mass appearance/disappearance of amphipods. They were found most abundant at southern seagrass area. The crustaceans at the mangrove area were represented by the shrimp *Nikoides maldivensis*, *Apseudus* sp. and Paratanaeideans. They prefer the detritus rich environment and can withstand the prevailing tough conditions.

7. 2. Ecological relationships:

7. 2. 1. Hydrography and Bottom fauna

Since benthos is dependent on the environment in which they inhabit directly and indirectly (Sanders 1958, 1960 and 1968), different environments induce different species or community structures. Benthos vary greatly in their responses to changes in water quality. Some taxa are relatively tolerant to organic enrichment and low dissolved oxygen levels while others are quickly eliminated under low dissolved oxygen conditions (Boesch *et al.*, 1976; Simboura *et al.*, 1995). Increased nutrient inputs can strongly affect abundances of some species, through indirect and direct influences on food availability and sediment conditions, while not affecting others. In general, sediment type, organic content, dissolved oxygen, salinity and temperature are considered most important in determining abundance and types of animals in bottom communities. This intimate relationship between the benthos and the physical and chemical environment in which they live provides us with an extraordinary tool for evaluating marine intertidal systems and changes in these systems. By examining shifts in the benthic community over time (years), one can gain an understanding of the major environmental processes affecting the local biota (Hyland *et al.*, 1996).

Over the tropical seas, climatic variations are smaller, but rainfall pattern differ greatly. The western boundaries of the oceans are warmer, wetter and more stable climatically than the eastern boundaries. These differences are of great ecological significance because the distribution of tropical shallow water habitats, especially mangroves and coral reefs and their associated vegetation is a reflection of these climatological variations. The water mass structure in the reefs and lagoons are determined by factors such as seasonality, regional precipitation and net radiation resulting in surface heating and cooling (Andrews and Pickard, 1990). Benthic fauna are subjected to natural environmental changes like salinity fluctuations and rainfall during SW monsoon, which constantly modify the ecological conditions and affect the settlement and accommodation of new species. For the accurate estimation of the organic material cycle in the benthic domain and for the application of benthic community as an indicator of the environmental conditions, structural characteristics of benthic communities must be clarified in time and space, and then some real relationships between their characteristics and environmental factors must be examined. Jones (1950) stated that temperature, salinity and bottom deposits were the major factors influencing the distribution of bottom fauna. Gage (1974) suggested that the fluctuating temperature and salinity values at the surface operate as a stress condition with the result that only a limited number of larvae of benthic species survive. In the present study even though wide fluctuations in surface temperature and salinity were not observed spatially, fluctuations were observed seasonally and this could have lead to the mortality of many larval forms.

Temperature is considered as a factor of prime importance in the physical environment of organisms. Studies on temporal variation in Vellar estuary by Chandran and Ramamoorthy (1984) revealed variations in water temperature from 24°C to 33.5°C mostly influenced by the fluctuating atmospheric temperature of 23.5°C to 36.5°C than tidal influence. Many authors reported high water temperature during pre-monsoon. In the present study all the three identified areas showed their highest water temperatures during pre-monsoon months in both years coinciding with the high atmospheric temperature prevailing in the region showing significant temporal variations and effect of monsoon. The study area being shallow, the changes were relatively fast. The least temperature values were observed in post-monsoon (1st year) and monsoon (2nd year) seasons. The temporal variations were above 4°C at all three areas and the maximum variation was observed at area 1. The range in surface water temperature noticed at area 1, area 2 and area 3 was 26.55°C (August 2001) to 31.5°C (May 2001), 26.5°C (October 1999) to 31.05°C (May 2001) and 26.5°C (December 1999) to 30.5°C (April 2000) respectively.

Temperature did not show any marked spatial variations (<1.5°C) since the stations are close by. In most of the months, northern seagrass area showed comparatively lesser temperature values. The variations of temperature singly did not impart any significant variation in the fauna. Water temperature seldom exerts significant influence on the ecology of organisms, as the annual variation of temperature normally does not exceed 5-7°C (Chandran, 1987). But by the combined effect with other environmental parameters, it showed a positive correlation with abundance of fauna at the mangrove area.

Kinne (1966) suggested that salinity is the ecological master factor controlling the life of benthic animals. Desai and Krishnankutty (1969), Patnaik (1971), Kurian (1973), Parulekar (1984), Parulekar and Dwivedi (1974), Ansari *et al.* (1977 a & b) and Varshney (1985) reported that salinity fluctuations had a strong bearing on the distribution of the benthic fauna.

According to Patnaik (1971) and Murugan *et al.* (1980) salinity does not directly affect biomass. In the present study both surface as well as interstitial water salinities were analysed and found that interstitial salinity had significant spatial variations when compared to surface salinity. Area 3, the mangrove zone showed significantly different values from the other two areas. During the two-year study period almost all the months (except monsoon months) showed comparatively low salinity value at mangrove ecosystem than the other areas (confirmed by the Trellis diagram results for comparing between stations). The temporal variations were exhibited for both surface as well as interstitial salinity. The range in interstitial salinity noticed at area 1, area 2 and area 3 were 27.3ppt to 35.69ppt, 25.6ppt to 35.7ppt and 26.17ppt to 32.58ppt respectively. Surface salinity temporal variations ranged from 6.84ppt to 8.015ppt and interstitial variations ranged from 5.25ppt to 9.35ppt for the entire study area. Temporal variations were lowest at area 3. The multiple regression analysis have proved that a negative correlation existed between the monthly numerical abundance and interstitial salinity at the seagrass stations. Quasim *et al.* (1969) showed an inversely proportional correlation between population count and salinity.

Low values of dissolved oxygen indicate a poor oxygenated condition. Eventhough, in general, dissolved oxygen was not found to be a factor limiting benthic abundance and distribution, a dissolved oxygen value less than 2ml/l may result in diminishing occurrence of some benthic groups other than molluscs. Ability of molluscs to withstand anaerobic conditions has been studied by Moore (1931), Dales (1958) and Karandeeva (1959). In the present study, both at northern as well as southern seagrass zones, more than 2ml/l of dissolved oxygen was observed during every season, having a range of 2.33 to 6.45 ml/l. Dissolved oxygen values were slightly more at northern seagrass zone where constant flushing of seawater occurred due to tidal influence. At mangrove zone (where the DO value differs significantly from that of other stations) where dissolved oxygen values were less than 2ml/l in some of the months, many faunal groups were found absent and gastropods like mud whelks were found in abundance in the absence of their competitors. The present observations also revealed that this did not result in a decrease in total biomass at the mangrove zone. Damodaran (1973) observed that a decrease in total biomass could not be attributed to poorly oxygenated conditions. But a positive correlation was observed between this parameter and the numerical abundance at the mangrove site as well as northern seagrass site.

At a given temperature, pH is controlled by the dissolved chemical compounds and the biological processes in the solution (Chapman, 1996). Ellis (1937) pointed out that fish and common aquatic life prefer pH values between 6.7 and 8.4 and pH values below 5 or above 8.6 are definitely detrimental or even lethal to aquatic life. In the present study pH varied from 7.4 to 8.5 for the entire study period. The slight alkalinity may be due to the calcium and carbonate deposits particular to the coral reef ecosystems. Temporal variations in pH were found insignificant for all zones. Spatially, only the mangrove zone showed slightly higher pH value ranging from 7.9 to 8.5 and thus differed from the seagrass stations. The pH values recorded were in good conformity with the observations of Ramachandran and Ajaykumar Varma (1997) for Minicoy Island.

The benthic organisms are dependent upon the fertility of the overlying water for their food supply and factors, which control the planktonic production in any area, are likely to have an indirect influence upon the abundance of the benthic fauna (Damodaran, 1973). Concentrations of the principal dissolved inorganic nutrients (NO_2, NO_3, SiO_3, PO_4) are normally lower in tropical interstitial waters and their concentrations are within the µm range only (Hart-wig 1976; Ullman and Sandstrone, 1987; Williams *et al.*, 1985).

Silicon dynamics of coral reefs have received less attention than nitrogen and phosphorous, primarily because, coral reef organisms are calcareous and not siliceous and silicon is not an essential element for most reef flora and fauna (Haneefa, 2000). In the present study the surface silicate values showed a wide range of variation in all three sites. The highest variation was observed at southern seagrass site followed by northern seagrass site. At southern seagrass area, the surface silicates varied from 1 μg at /l to 9.5 μg at /l. At the northern seagrass area, the value ranged from 1 μg at /l to 5.67 μg at /l. Minimum surface Silicates recorded at the mangrove area was 1.11 μg at /l and the maximum was 6 μg at /l. For Interstitial silicates, slightly higher seasonal variations were observed at mangrove site. The interstitial silicate values ranged from 1.56 μg at /l to 6.4 μg at /l (area 1), 1.45 μg at /l to 6.7 μg at /l (area 2) and 2.67 μg at /l to 7.88 μg at /l (area 3). Haneefa's study (2000) showed a similar range of values 1.5 to 5.8 μg at /l at Minioy lagoon. In the present study the pre-monsoon months showed comparatively very high surface silicate values in all three sites. For interstitial silicates distinct spatial differences were showed by seagrass and mangrove ecosystems (confirmed by the Trellis diagram for comparing stations). The seasonal differences of silicates (surface as well as interstitial) showed a positive correlation with abundance of benthos at both seagrass sites.

Phosphate is an important constituent of seawater and vital in the biological process of the sea. There are reasons for assuming that changes in phosphate concentrations may influence the quantity of fish present in a given area (Cooper, 1948). However Raymont employed experimental methods in a partially enclosed sea loch and the results showed that phosphate concentration did not affect the benthos (Raymont, 1950). The surface phosphate values varied from 0.75 to 4.4 μgm.at./l (for the entire study period) at seagrass sites and 0.75 to 2.7μg at /l at the mangrove site. For interstitial phosphate values, wide variations were observed spatially as well as seasonally. The monthly values at different sites ranged from 3 to 24.8µg at /l at site 1, 3.15 to 19µg at /l at site 2 and 2.57 to 35µg at /l at site 3. During post-monsoon months slightly lesser values were observed. The mangroves showed the highest value among the three sites. A positive correlation was observed between abundance of fauna and phosphate concentration (interstitial) at the southern seagrasses while it was negative at the northern seagrasses.

One characteristic of tropics is the frequent presence of nitrite (NO_2) in the pore waters, which is an intermediate product of nitrification and generally an indicator of moderate anaerobic conditions. Nitrite is found most common in the moderately anaerobic calcareous sediments in shallow waters of the tropics (Alongi, 1987). In the present study during most of the months, value of surface nitrites ranged from 0.17 to 2.5 µg at /l. At site 1, during the first year of the study period, the avg. was only 0.35 µg at /l and during the second year it showed an increase with a peak of 2.5 µg at /l in March 2001. Again from June onwards it started descending. At station 2 also same was the situation reaching a high of 2.5 µg at /l in February 2001. Spatial difference was negligible in most of the months. At station 3 the values ranged from 0.13 to 3.75 µg at /l. In the case of interstitial nitrites also the second year showed comparatively higher values. But these values were much higher than surface values coming up to 6.67 µg at /l at site 1, 8.65 µg at /l at site 2 and 7.5 µg at /l at site 3. No spatial variations occurred and hence it was proved that the nitrite concentrations have no effect on the spatial difference of fauna at stations. The correlation studies indicated that a negative correlation existed between abundance of fauna and nitrite concentrations at the northern seagrasses.

Spatial and temporal distribution of surface nitrate content in the study area indicated irregular patterns and comparatively higher values. A positive correlation was observed between abundance of fauna and nitrate concentration (surface and interstitial) at the southern seagrasses while it was negative at the northern seagrasses.

7. 2. 2. Substratum and bottom fauna

The sediment formed an important source of both organic and macronutrients along seacoasts and is an important abiotic factor deciding the quantitative and qualitative distribution of benthic fauna. The significance of sediments in the distribution of infaunal invertebrates has been recognized by several investigators (Thorson 1957, 1958; Sanders, 1959; Herman *et al.*, 2001). Distribution of bottom fauna has direct relationship with the type of bottom and physical nature and extraneous inputs may drastically alter the number and type of species (Sanders, 1959). The nature and extent of fluctuation in the composition of sediments can indicate the extent of stress on shallow aquatic environments. The sediments in the habitat indicate the balance between the erosional and depositional forces of the ecosystem. The type of sediment in an area is determined by the complex interaction of many environmental factors (Swedrup *et al.,* 1942).

The sediment texture and the content of dead organic matter in the substratum are undoubtedly the most important factors as far as the benthic biota are concerned. According to Damodaran (1973), the character of the sediment at any particular region is determined by;

1) Factors determining the source of supply of sedimentary material
2) Factors determining the transportation and
3) Factors determining the deposition

This clearly indicates the importance of the study of sediments in understanding the complex of ecological factors significant to benthic organisms. The global distribution of sedimentary organic carbon and nitrogen is not related to latitudes, but dependent upon water depth, grain size, terrestrial runoff and hydrography (Romankevich, 1984).

In the study areas, it was already proved that seawater temperature and salinity seldom affected the spatial distribution of bottom fauna and therefore sediment texture has due importance. In environments characterized by almost identical temperature and salinity regimes the sediment characteristics might play an important role in the distribution of benthic organisms (Sanders, 1958; Kurian 1973; Damodaran, 1973; Pillai 1978; Chandran, 1987).

According to Ansari (1984) the median particle diameter at intertidal zones of Minicoy ranged from 0.27 to 0.55mm indicating the dominance of median coralline sand particles. Narayanan and Sivadas (1986) reported median particle size of 0.38 to 0.43mm at Kavaratti atoll. In the present study, the sediment texture of all the stations can be termed as sandy since sand content is more than 80%. The clay content varied from 1-17%. The highest clay content was observed at the mangrove site (avg. 15 %). In the other two sites it comes around 5.8% (southern seagrass site) and 4% (northern seagrass site). There is no significant variation in silt percentage at all three sites ranging from 2-3 %. Taylor (1968) proved that littoral fringes of intertidal ecosystems are often inhabited by calcareous algae (eg. *Halimeda* spp.) and sparse seagrass beds and the sediments of these areas are usually a mixture of carbonate and terrigenous sand.

In ecosystems like seagrass and mangrove, an understanding of organic carbon is a prerequisite for assessing and determining the extent of nutrient input into the surrounding water. Eventhough distribution of organic carbon in sediment is temporally similar, spatial differences are prominent. In dry tropical areas, organic matter concentrations do not appear to vary seasonally (Alongi, 1989). Lowest organic nutrient concentration recorded in the tropics are found mainly in carbonate sediments where percentage of organic C ranges from 0.32-0.6, 0.22-0.66 etc. and in muddy sand it ranges from 0.1 to 1.8, 1.1 to 9.1, 0.07 – 0.85 (Alongi, 1990). Low values of organic carbon were also reported (Thomassin and Vitiello, 1976) in the coralline sediment of Tulear reef Madagaskar. Present study revealed that organic carbon in the northern seagrass area was very less (avg.0.46%) compared to the southern seagrass area (avg.1.5%). This may be due to the fact that in these oceanic lagoons, the sources of organic input are limited. The main contributors of organic carbon were dead and decaying seagrasses and seaweeds. Organic carbon was higher at mangrove site (clayey sand) during all seasons (avg.3%). The maximum organic carbon can be expected in clayey sediment and there is a direct correlation between organic carbon content and clay % in the sediment. Bader (1954), Rao (1960), Murty and Veerayya (1972), reported higher organic carbon content in finer sediments. Earlier studies found that there is higher retention of organic matter on fine-grained material. Organic carbon is predominantly trapped by clay and to a lesser degree by fine silt, coarse silt and sand (Russel, 1973). This may be the reason for the very less organic content observed at the seagrass stations, which are coralline sandy in nature.

The extreme range of macrofaunal density could be the result of differing food supply and the sediment characteristics. Dominance of bivalves among intertidal macrofauna of South African beaches (Mclachlan, 1977) and dominance of molluscs in the coral sediments of Polynesian atolls (Thomassin *et al.*, 1975) confirm the statement. The sediment of seagrass intertidal zones of Minicoy was dominated by fine calcareous sand and consisted of a more diverse fauna dominated by gastropods, bivalves, polychaetes etc. But the fauna of seagrasses included mud living specimens like *Pinna muricata* due to the fine nature of bottom sand trapped by the seagrass rhizomes.

Benthic communities in different sites of Minicoy seagrass/mangrove areas can be correlated with sediment particle composition and organic carbon content. This relationship is biologically interpreted based on the feeding type of benthos. The organic carbon content in the sediment is of considerable importance as a potential food for the benthic fauna, by keeping the fertility of soil and thereby increasing the biological productivity. A positive correlation of organic carbon with faunal abundance was made by Bader (1954), Sanders (1956) and Damodaran (1973). The filter feeders or animals that obtain food from suspended matter make up the majority of the fauna in the sandy sediments, while the deposit feeders living on organic matter in or on the bottom dominate the fauna in the fine sediments. The particulate organic matter as food of benthic organisms may be deposited on the sediment surface on the muddy bottom which has a weak bottom current, but may be suspended near the sediment surface on the sandy bottom which has a relatively strong bottom current. Muddy bottom communities are therefore predominated by deposit feeders and sand bottom communities by suspension feeders (Sanders, 1958). Deposit feeders (polychaetes) occur in the bottom, which has high organic content in the sediment, but suspension feeders (bivalves) occur on the bottom, which has low organic content. Bader (1954) observed a decrease of pelecypod population related to high values of organic carbon in the mud. In the present study it was observed that the pelecypods were found flourished in the northern seagrass area, where the organic carbon was found minimum. From the multiple regression analysis, it was proved that a negative correlation existed between abundance of fauna of northern area with organic carbon content of soil. The organic carbon content was not acting as a limiting factor on the fauna of southern seagrass area, dominated by detritus feeders and carnivores. In the case of mangrove area, with the highest organic carbon content, this factor was acting as a limiting factor. Very low and high values of organic carbon content show poor fauna and medium values show rich fauna (Harkantra *et al.*, 1980). Most sand and mud inhabiting animals are detritus feeders. Clams, cockles and some worms are filter feeders feeding on the detritus suspended in the water. Other animals are deposit feeders that engulf the sediment and process it in their gut to extract organic matter. Small crustaceans, crabs and some worm species are scavengers preying on any available plant or animal material. In the present study, the seagrass areas having very low organic matter supported less number of deposit feeding forms like sedentary polychaetes and more number of detritus/suspension feeding forms like gastropods, bivalves, amphipods, crustaceans and some members of the errant polychaetes. The mangrove areas were supporting only very few hardy species of molluscs like mud whelks and typical mangrove crustaceans like tanaeids, due to the prevailing unfavorable environmental conditions. Sometimes the high-suspended sediment loads result in the clogging of filtering apparatus thus preventing survival of filter feeders in this area (Harkantra, 1982). Lower diversity in mangroves may also be attributed to negative effects of polyphenolic acids derived from mangrove roots, bark and detrital matter, low water content and generally low concentrations of interstitial oxygen and surface micro algae (Schrijvers, 1998). The presence of crustaceans at mangrove site revealed that benthic crustaceans being detritiphagus their distribution is dependent on the availability of detritus than on the nature of sediment (Savich,1972). Higher density of crustaceans in organically enriched sediments has been reported by Chandran (1987). Preetha (1994) stated that bivalves prefer sandy substratum and on the other hand gastropods prefer clayey sand. Abundance of bivalves was observed at the most sandy site in the present study also. This work is in perfect agreement with the result of Preetha (1994) that area with highest percentage of organic carbon inhabited large number of tanaeids and the gastropod *Littorina* spp.

7. 2. 3. Seasonal variations of bottom fauna

The seasons greatly influence the benthic standing stock of an area due to fluctuating environmental conditions. All species undergo at least 2 main periods of recruitment, one during the pre-monsoon months and the other in the monsoon, during which time total community diversity and species richness decline markedly (Harkantra and Parulekar, 1985). Increase in number and biomass in post-monsoon period may indicate presence of newly settled young ones or further growth of the early settlers. In the present study gastropods, the most dominant groups showed their maximum abundance and biomass in the post-monsoon season. Thus it was obvious that during the monsoon and the post-monsoon periods, the animals in the intertidal regions grew in size contributing to the large biomass. Crabs and echinoderms were found abundant during monsoon (such hardy species which can easily tide over monsoonal effects took the competitive advantage in the absence of many other major groups). The worms (polychaetes as well as 'other worms') and 'other crustaceans showed their highest abundance in pre-monsoon season because of the recolonisation in late post-monsoon. The most stable physico-chemical conditions on the SW Indian beaches were attained in the pre-monsoon months, when species richness reached at its peak (Ansell *et al.*,1972 a). The benthic organisms, which got depleted during monsoon, recolonised during post-monsoon and a rich bottom fauna was observed during post and next pre-monsoon periods (Preetha, 1994). The increasing number of benthic organisms like other crustaceans and worms during pre-monsoon is thus an indication of recolonization.

In the wet tropics, most benthic communities suffer increased mortality or migrate during monsoons to escape sediment erosion and low salinities. The detrimental effects of the monsoons in India on macroinfauna are well documented (Ansell *et al.*, 1972 a, b; Dwivedi *et al.*, 1973; Achuthankutty, 1976; Nandi and Choudhury, 1983). During the present study, the northern seagrass as well as mangrove area, showed their minimum total numerical abundance during monsoon due to this effect. Epibenthic and infaunal macrobenthic communities respond negatively to the onset of monsoonal rains and the fauna are subjected to natural environmental changes like salinity fluctuations and rainfall during SW monsoon, which constantly modify the ecological conditions and affect the settlement and accommodation of new species. Beach erosion takes place during the monsoon and only species capable of migrating persist. Thus echinoderms and crabs flourished in the monsoon season and groups like polychaetes, other worms, crustaceans other than crabs etc. suffered a terrible decline.

Post-monsoon season showed the maximum total numerical abundance of organisms at all the three areas. This may be due to the increase in the number of some dominant species of gastropods (*Cerithium corallium, C. scabridum, C. nesioticum, Pyrene* sp., *Terebralia palustris, Margarites helicinia*), bivalve (*Gafrarium divarticatum*), worms and polychaetes (*Baseodiscus delineatus, Eurythoe mathaei, Glycera lancadivae*), amphipod (*Cymadusa imbroglio*) etc. Some of the molluscs (*Cerithium* spp., *Metanachis marquesa, Tellina palatum*), polychaetes (*Notomastus latericeus, Marphysa macintoshi, Nephtys* spp.) and crabs (*Calappa hepatica, Pinnotheres* spp.) showed their maximum abundance in monsoon season indicating some adaptive mechanisms. Amphipods including *Maera pacifica, Stenothoe kaia* and *Malaccota insignis* showed their heavy abundance and occurrence at pre-monsoon season after the recolonization in late post-monsoon. About 25 species were found totally absent in the monsoon season and the least number of species's absence was noticed in post-monsoon season indicating the lowest species diversity in monsoon and highest species diversity in the post-monsoon season and these results are in tune with the findings of Preetha (1994).

Based on the results of similarity index of months (cluster diagram) worked out at each station, it was found that less number of high similarity month clusters were noticed in the southern seagrass station and more number of high similarity clusters were noticed in mangrove region and in the northern seagrass region. These month clusters denote specific seasons, which in turn is related to species, which specifically occurred in different seasons, thus proving the seasonal influence on species.

The two **southern seagrass stations** showed similar faunal preferences during different seasons. During the pre-monsoon period, both stations showed the presence of certain benthic species like *Siboglinum fiordium* (worm), *Maera pacifica* (amphipod), *Mallacoota insignis* (amphipod), *Glycera tesselata* (polychaete) etc. But by the onset of monsoon, amphipods showed only stray occurrence and by the end of monsoon they completely vanished from the habitat proving that these species are vulnerable to monsoonal rains and land runoff. Species, which successfully thrived and took competitive advantage in the monsoon season, included mainly crabs (*Calappa hepatica*, *Pachygrapsus* sp.,), Molluscs (*Tellina palatum, Pinna muricata, Cerithium* spp.,) and a few polychaete worms like *Nephtys* spp., and *Arabella* sp. By the return of post-monsoon season many of the polychaete species like *Eurythoe*, *Eupolymna nebulosa* and *Goniada emerita* reappeared in the habitat and by the end of post-monsoon, amphipods returned to the habitat. The species, which can tolerate both hot and cold climatic conditions, include some worms (*Phascolosoma nigrescens, Baseodiscus delineatus, Hoplonemertean* sp.), gastropod species (*Cerithium*, *Smaragdia*, *Cyprea*, *Conus*, *Niotha stigmaria),* crab (*Calappa hepatica*) and many members of echinodermata. Some species, which showed tolerance to wider range of environmental conditions, include *Baseodiscus delineatus* (other worms), *Syllis* spp.(polychaete), *Niotha stigmaria* (gastropod), *Ctena delicatula* (bivalve) and *Ophiactis savignyi* (echinoderm).

At **northern stations**, there were slight differences in the occurrence of species with seasons when compared to the southern stations. The individuals dominated in pre-monsoon included polychaete species like *Eurythoe, Eupolymna nebulosa, Glycera* etc. During monsoon all the major *Cerithium* sp., were found flourishing along with some other gastropods like

Smaragdia sp., *Cyprea* sp., *Polinices flemengium* etc. Crustaceans and polychaetes were found minimum during this season (may be washed off and perished since the rhizomes were not so branched and rigid like *Thalassia* rhizomes which preserves the fauna during land runoff). By the beginning of post-monsoon season some polychaete species and amphipods which reappeared in sufficient numbers, after the monsoonal decline, included some members of worms and polychaetes (*Nereis* spp., *Arabella* sp., *Glycera* spp., *Goniada emerita*, *Eurythoe* spp., *Eupolymna nebulosa, Phascolosoma nigrescens*) and amphipods like *Maera pacifica, Cymadusa imbroglio* etc. Some species of crabs (*Calappa hepatica*), molluscs (*Smaragdia* spp., *Cerithium scabridum, C. nesioticum, Cyprea* spp., *Modiolus metcalfei*), worms and polychaetes (*Syllis* spp., *Eurythoe* spp., *Baseodiscus delineatus, Hoplonemertan* sp.) and echinoderm (*Ophicornella sexadia*) occurred both in extreme hot and cold months.

At the **mangrove sites**, the crustacean species like *Nikoides maldivensis* and paratanaeidae were found extensively in pre-monsoon and post-monsoon months but found missing in monsoonal months. The species which flourished during monsoon included members of *Cerithium* sp. The major mangrove gastropod species *Terebralia palustris* and *Littorina undulata* showed their occurrence in all seasons indicating non-preferability for seasons.

When similarity analysis based on PRIMER 5 was conducted at different stations based on occurrence of species, it was found that specific species clusters were obtained from each station, denoting the co-existence of species in different months owing to the seasonal changes occurring in each month. Certain species showed more or less identical clusters at both southern seagrass stations. These included gastropods such as *Cerithium scabridum, Cerithium coralliun, Smaragdia soverbiana, Pyrene* sp., *and Smaragdia viridis*, all of which together showed 60% of co-existence at station 1 and 45

% at station 2. Likewise the gastropod pairs *Smaragdia viridis* and *Smaragdia soverbiana* showed 75% co-existence at both stations. The bivalves, *Pinna muricata* and *Gafrarium divarticatum* showed 75% at station 1 and 45 % at station 2. All other clustures were found different at the two southern seagrass stations. While compiling the northern seagrass stations, it was found that *Smaragdia soverbiana* and *Smaragdia viridis* showed 70-72% co-existence at both station 3 and 4. *Cerithium nesioticum, Pyrene* sp. and *Gafrarium divarticatum* showed 75% co-existence at both stations. These two small clustures together showed 68% at station 2 and 40% at station 3. At both mangrove stations gastropods such as *Terebralia palustris, Cerithium corallium* and *Littorina undulata* showed 80-82% co-existence. *Apseudus* sp. showed 60-70% co-existence with the above cluster. No other pairs of similarity were common among station 5 and 6. High percentage of co-existence observed at the mangrove sites may be primarily due to the high frequency of occurrence of the above-mentioned species (23/24months) there. These findings were clarified using R- mode and Q-mode factor analysis, based on the factor scores obtained.

7. 2. 4. Annual variations of bottom fauna

In the present study slight annual variations were observed for numerical abundance at all stations. Earlier studies showed changes in the bottom fauna over number of years. While seasonal changes do occur, particularly in shallow water, these are far out weighed by the year-to-year changes (Peterson, 1918).

In the case of biomass, significant annual variations (comparatively very high biomass during the 2nd year) were observed at the southern seagrass area owing to the increased abundance of *Cerithium corallium* during the 2nd year. Eventhough *C. corallium* flourished in the southern seagrass area, its abundance was very less at the other two areas irrespective of season.

Therefore a marked annual variation in biomass was not observed at the other two areas. Eventhough the abundance of this gastropod increased during the 2nd year, the total abundance was not changed markedly owing to the decrease in abundance of amphipods of almost same magnitude during the year. The biomass of *C. corallium* is many more times higher than that of amphipod and hence the very high increase in biomass. The annual variations in the occurrence of benthic fauna may be due to the variations observed in the intensity of rain fall, organic carbon content, nitrite and nitrate concentrations etc.

7. 3. Trophic relationships

The importance of benthos in the diets of most tropical demersal organisms, has generally been well documented (Longhurst, 1957; Pauly, 1975; Wallace, 1975; Brook, 1977; Chong and Sasekumar, 1981; Stoner 1986; Wassenburg and Hill, 1987; Buchanan and Stoner, 1988; Jackson, 2001). Longhurst (1957) first investigated the relationship between demersal fish and soft bottom benthos and found that macro-invertebrates are the main diet for fish. Eventhough the demersal fishes were non-specific in their feeding habits, they normally avoid benthic adult molluscs due to their hard shells. Juvenile molluscs, crustaceans and polychaetes were found in the stomachs of many fishes. The predominance of demersal fishes and crabs in tropical lagoons and estuaries suggest, a strong trophic link between the benthos and species of demersal fishes. Trophically, nearly a quarter of tropical demersal fishes are benthic feeders with a slightly higher proportion (about 38%) of mixed benthic and fish feeders (Pauly, 1979). As a key to protecting essential fish habitats, benthos of nearby areas play a vital role (Peterson, 2000). The primary production studies of Lakshadweep seagrass beds were limited to findings of Qasim and Bhattathiri (1971) and Kaladharan and David Raj (1989).

The shallow coastal areas containing mangrove and seagrass beds are considered important nurseries for reef fish. Pelagic fish larvae settle into these habitats, and grow from juveniles to sub adults or adults that leave these habitats by means of post- settlement migrations (Blaber, 2000 and Dorenbosch *et al.*, 2004). It has been shown on various islands that a reduced density of several of these nursery species on the coral reef is related to the absence of seagrass beds and mangroves (Nagelkerken *et al.*, 2002). The importance of mangroves as shelter for fishes after recruitment has been emphasized by Shulman (1985). Large predators normally keep away from shallow waters. The two advantages that seagrass offeres new recruits are shelter and food during their early life history stages when individuals are susceptible to predation (Bell and Pollard, 1989).

In the present study seasonal availability of juvenile fishes was noticed in the mangroves and seagrasses of Minicoy. Juvenile fishes were observed less frequently during the monsoon season. Seasonal abundances of juvenile and adult fishes in reefs and seagrass beds were discussed earlier (Williams *et al.*, 1984; Leis and Goldman, 1987; Vijayanand and Pillai, 2003; 2005). Apart from providing shelter and food for juveniles, sea grass zones formed feeding grounds for adult fishes. Some fishes fed on seagrass leaves, others on attached fauna etc. The gut content analysis conducted during the present study revealed that most of the juvenile/ adult demersal fishes, which forage among seagrasses and in mangrove, are benthic feeders (gut content showed presence of crustaceans like amphipods, decapod larvae, polychaetes, molluscan remnants etc.).

The food for the benthos in shallow waters are algae and organic detritus. In most areas, plankton form the chief source of nutrition of macrobenthos. Productivity of benthos is presumably related to the primary productivity of the overlying water column (Lie, 1968). The benthos forms the second stage in the ecological pyramid of aquatic environment, which in turn form the food for the higher carnivores including demersal fishes, which are tertiary producers. Thus benthos form a very important link in the food chain.

Chapter. 8

SUMMARY AND CONCLUSION

The lack of sufficient information on benthic fauna of an Island territory in India paved the way for the present study. This is an attempt to study the macrobenthos at the intertidal zones of seagrass and mangrove ecosystems of Minicoy Island of Lakshadweep. The objectives of the study include the identification of benthic fauna, their distribution and composition, standing stock, qualitative and quantitative nature in relation to hydrography, seasons and sediment texture, community structure analysis and trophic relationships. For this purpose a monthly plan of sample collection and analysis were carried out at six stations in the Minicoy seagrass/mangrove area from September 1999 to August 2001.

The first chapter gives an introduction covering the importance of benthos, inter tidal zones, seagrass beds and mangroves. Review of literature, scope and purpose of study are also included in this chapter. The second chapter 'Materials and Methods' describes the study area, period of study and frequency of sampling. The methods adopted for the study of environmental parameters, macrofauna and benthic abundance, statistical techniques etc. are explained in this chapter. The third, fourth, fifth and sixth chapters contain the results of the studies on environmental parameters, bottom fauna, regression analysis for correlation and benthic production respectively. The seventh chapter is the discussion based on the results and the eighth is the summary and conclusion.

The study of the environmental parameters and ANOVA showed that there was only less variations exhibited between stations 1 & 2, stations 3 & 4 and stations 5 & 6 and hence treated as area 1, area 2 and area 3 respectively for further analysis. The parameters analysed were atmospheric temperature, surface water temperature, surface salinity, interstitial salinity, dissolved oxygen, pH, surface and interstitial nutrients (silicate, phosphates, nitrites and nitrates), sand/silt/clay fraction, organic carbon content of soil and rain fall. Area 3, the mangrove zone showed significantly different environmental values from the seagrass areas. At the mangrove area comparatively lower salinity and dissolved oxygen, higher pH, interstitial silicate, surface/interstitial phosphate, clay fraction, organic carbon content etc. were noticed than in the seagrass areas.

The surface water temperature patterns of the study area showed marked seasonal variations (the highest value in the pre-monsoon). But these variations of temperature singly did not impart any significant change in the fauna. During the two-year study period almost all the months (except monsoon months) showed comparatively low salinity value at mangrove ecosystem (ranging from 26.16 to 32.58ppt.). In the case of dissolved oxygen, the two seagrass areas showed more than 2ml/l of dissolved oxygen in all season, having a range of 2.33 to 6.45 ml/l. Dissolved oxygen values were slightly more at northern seagrass zone where constant flushing of seawater occurred due to tidal influence. At mangrove zone, during certain months, the dissolved oxygen was less than 2ml/l. The pH variations at the study area were not significant to induce any change in fauna.

At the seagrass areas, the surface silicates varied from 1 μg at /l to 9.5 μg at /l. and at the mangrove area it was 1.11 μg at /l to 6 μg at /l. The interstitial silicate values ranged from 1.45 μg at /l to 6.7 μg at /l at the seagrass areas and 2.67 μg at /l to 7.88 μg at /l at mangroves. In general the silicate concentrations showed seasonal and spatial variations during the present study. When compared to the surface phosphates, interstitial phosphate values showed wide seasonal variations ranging from 3 to 24.8μg at /l at seagrasses and 2.57 to 35μg at /l at the mangroves. The nitrites showed slight seasonal variations while the spatial and temporal distribution of surface nitrate content in the study area indicated irregular patterns and comparatively higher values.

The results of the study of sediment texture revealed that in all study areas, the substratum was predominated by sand followed by clay and silt in comparatively smaller proportions. The sediment texture at all areas except the mangroves can be termed as sandy since the percentage of sand exceeds 80 irrespective of seasonal influence. At the mangrove areas, the texture of sediment can be termed as sandy clay since the percentage of sand was below 80 at certain seasons and that of clay was comparatively higher ranging from 13 to 17. The organic carbon content of the sediment was found to be highest at mangrove site (3%) and lowest at northern seagrass area (0.46%).

In the present study very high species diversity was noticed in southern seagrass stations (137 species each for the entire study period at station 1 and 2) and northern seagrass stations (74 and 62 species at stations 3 and 4 respectively). But in the mangrove stations comparatively very low species diversity of 18 and 16 were observed at stations 5 and 6 respectively. Eight major groups identified in the present study were gastropods of 58 species under 27 genera, bivalves of 12 species under 7 genera, polychaetes of 27 species under 14 genera, other worms (including all worms except polychaetes) of 7 species under 6 genera, crabs of 24 species under 11 genera, other crustaceans of 19 species under 13 genera, echinoderms of 11 species under 7 genera and sponges of 2 species under 2 genera.

Cerithium was the most common genus at all stations except mangroves. The highly congregative nature of *Terebralia palustris* and *Littorina undulata* in the mangrove zones was noticeable. From the analysis of indices it become cleared that stable structure of community was seen at southern seagrass area followed by northern seagrass area. The mangroves showed an unstable ecosystem, having a diversity index less than 3, resulting in less species diversity.

Biomass wet weight at different areas were 173g/m^2, 67g/m^2 and 110g/m^2 for southern seagrass, northern seagrass and mangroves respectively. In the present study a high biomass was observed for the mangrove stations when compared with their less numerical abundance, due to the large sized gastropod flesh of *Terebralia palustris.* Highest biomass values were observed at post-monsoon season for gastropods, crabs and echinoderms. The total abundance observed at southern seagrass area, northern seagrass area and mangroves were 670/0.25m^2, 295/0.25m^2 and 247/0.25m^2 respectively. The seagrass flora, provides food and shelter to the benthic organisms to a very great extent. Highest seasonal variations were observed for crustaceans, because of the seasonal mass appearance and disappearance of amphipods. They were found most abundant at southern seagrass area. Based on benthic abundance/biomass of groups (3-way ANOVA studies), it was further revealed that the three areas namely southern seagrass, northern seagrass and mangroves were significantly different from each other.

At southern seagrass area, the gastropods contributed 62-81%, bivalves 6-11%, other worms 1-2%, polychaetes 3-8%, crabs 2-5%, other crustaceans 6-10% and echinoderms1-2%. Just like *Cerithium* genera which contributed the major share of gastropods (>40%), *Gafrarium divarticatum* contributed major share of bivalves (90%). The faunal composition of the benthos at northern seagrass area comprised of gastropods (48-53%), bivalves (21-28%), other worms (7-10%), polychaetes (9%), crabs (3%) and other crustaceans (2-7%). The bivalve *Tellina palatum* contributed its share considerably at this region. Worms other than polychaetes were found comparatively more at this station. *Phascolosoma nigrescens*, *Siboglinum fiordicum* and *Baseodiscus delineatus* were present in good numbers. At the mangrove area, 91-96% were contributed by gastropods, 1% crabs and 3-8% other crustaceans. Major share of the gastropods was contributed by *Littorina undulata* (59% of total abundance), *Terebralia palustris* (18%) and *Cerithium corallium* (10%). All other major groups were absent at this station. But the frequency of occurrence of *Apseudus* sp. and *Paratanaeidae* sp. was high.

Cluster analysis based on Bray Curtis Similarity index (PRIMER 5) was made to study similarity between months and species. It was noticed that the similarity between species occurred in certain specific seasons at all stations. Factor analysis was conducted to segregate species/months based on the factor score obtained. The results revealed indicator species/months, to be given due importance and which in turn determines and contributes to the total information on benthic community of each area and species/months which are insignificant to be avoided from further studies. According to this analysis, the species clustures which showed maximum co-existence at southern seagrass area were *Cerithium scabridum, Cerithium corallium, Smaragdia soverbiana, Pyrene* sp., *and Smaragdia viridis.* Likewise, the pairs *Smaragdia viridis* and *Smaragdis soverbiana* showed 75% co-existence and *Pinna muricata* and *Gafrarium divarticatum* showed 45-75% at this area. In the northern seagrass stations, it was found that *Smaragdia soverbiana* and *Smaragdia viridis* showed 70-72% co-existence, *Cerithium nesioticum, Pyrene* sp. and *Gafrarium divarticatum* showed 75%. At the mangrove area, clustures were observed between *Cerithium corallium, Littorina undulata* and *Terebralium palustris*. These findings were clarified using R- mode and Q-mode factor analysis, based on the factor scores obtained.

Correlation between the environmental parameters and abundance of bottom fauna was tested by predictive step up multiple regression model. The results brought to light specific parameters which decide the abundance and occurrence of fauna at seagrass and mangrove stations. The southern sea grass stations were mostly controlled by the single or combined effects of environmental parameters like surface silicate, surface nitrate, interstitial silicate, interstitial nitrate and interstitial phosphate. Interstitial salinity was acting as a limiting factor at the southern sea grass station. In the northern seagrass stations, the major factors significantly controlling the numerical abundance were dissolved oxygen, interstitial silicates and surface nutrients. The limiting factors were interstitial salinity, interstitial phosphates, interstitial nitrites and nitrates etc. At the mangrove sites, the controlling factors included dissolved oxygen, pH and water temperature.

Animal sediment relationship proved that, organic carbon acted as a limiting factor for the sandy bottom preferring suspension feeders of northern sea grasses. But in the southern sea grass, there was no controlling or limiting effect of organic carbon for the faunal abundance, since the fauna at this location prefers detritus food.

Studies on the seasonal variation of macrobenthic components revealed that the northern seagrass as well as mangrove area have their minimum total numerical abundance at monsoon. The post-monsoon season showed the maximum total numerical abundance at all three areas. The gastropods, the most dominant group showed their maximum abundance and biomass at post-monsoon season. Increase in number and biomass in post-monsoon period may denote presence of newly settled young ones or further growth of the early settlers. Thus it was obvious that during the monsoon and post-monsoon period, the animals in the intertidal regions grew in size contributing to the large biomass. The *Cerithium corallium* invariably showed high growth and biomass during this season. Crabs and echinoderms were abundant during monsoon (hardy species which can easily tide over monsoonal effects and took the competitive advantage in the absence of many other major groups) followed by worms (polychaetes as well as 'other worms') while 'other crustaceans showed their highest abundance in pre-monsoon season because of the recolonisation in late post-monsoon.

In the southern seagrass area, the groups which undergone monsoonal decline and high abundance in next pre-monsoon were other crustaceans, polychaetes, sponges and other worms. Groups which showed high abundance in monsoon were crabs, bivalves and echinoderms and groups which showed high abundance in post-monsoon were gastropods. In the northern seagrass area, other crustaceans, polychaetes, bivalves and other worms showed monsoonal decline, crabs and gastropods showed high abundance in monsoon and post-monsoon respectively. In the mangrove area, a prominent seasonal pattern or monsoonal decline was not observed, but other crustaceans showed a slight increase in abundance during pre-monsoon just as in the case of other areas.

The annual observations revealed that in the case of biomass, significant annual variations (comparatively very high biomass during the 2nd year) were observed at the southern seagrass area owing to the increased abundance of *Cerithium corallium* during the 2nd year. Eventhough *C. corallium* flourished in the southern seagrass area, its abundance was very less at the other two areas irrespective of season. Therefore a marked annual variation in biomass was not observed at the other two areas. Eventhough the abundance of this gastropod increased during the 2nd year, the total abundance was not changed markedly owing to the decrease in abundance of amphipods of almost same magnitude during the year. The biomass of *C. corallium* was far more higher than that of amphipod and hence the very high increase. The annual variations in abundance of fauna may be due to the variations observed for rain fall, organic carbon content, nitrite and nitrate concentrations.

Shallow coastal areas containing mangroves and seagrass beds are considered important nurseries for juvenile reef fish, mainly by providing them with shelter and food. In the food web of these regions, the benthic fauna like crustaceans, polychaetes, small molluscs etc. feed on meiofauna, detritus or organic matter and in turn become prey to bottom feeding adult and juvenile fishes. The gut content analysis of fishes from this area showed that most of them are mainly benthic feeders. The maximum production in terms of carbon and biomass was noticed at the southern seagrass site followed by the mangrove site. The annual biomass production in $g/m^2/y$ from southern seagrass, northern seagrass and mangroves was estimated as 347.05, 135.16 and 219.43 respectively and these figures suggests that the macrobenthos from these regions may be important as the food of bottom feeding adult and juvenile fishes of lagoon and adjacent reefs.

Thus from the present study it become cleared that the species diversity of different areas are governed by prey-predator relationships and food resource availability. In the seagrass beds, grazing as well as detritus food chains and food web existed, the diversity is higher when compared to the mangroves, where only detritus food chains are present. It become also revealed that sediment stability and habitat complexity play a role in the diversity of fauna and due to this reason only less diversity was observed at northern sea grass beds when compared to the southern thickly populated seagrass. The extreme environmental conditions, existing in certain areas, like tidal influxes (the northern seagrass area), very less dissolved oxygen during certain months (mangrove area), more sandy nature of substratum with less organic carbon (northern seagrass area) also determine the diversity of fauna.

The observed nutrient level of water was high in the pre-monsoon season and this in turn leads to the high production of phytoplankton as well as zooplankton for the successful feeding of benthic macrofaunal adults and larvae. This may be the reason for the high abundance of many suspension feeding faunal groups during this particular season.

The annual variations in the abundance/biomass of fauna noticed in the present study revealed that significant shifts occur in the benthic community over the years. The faunal distribution at the northern area proved that the bivalves prefers more sandy and less organic carbon soil. The species like *Terebralia palustris* and *Littorina* showed its presence in all seasons irrespective of seasonal changes and can be considered as keystone species.

From the indices analysis, it was proved that the mangrove area at Minicoy is not a stable one and hence further stress due to pollution or destruction of trees on the ecosystem may result in the destruction of the whole ecosystem and hence to be avoided. Mangroves support the lagoon and coral reef fishery of Minicoy and hence the destruction of mangroves may in turn result in depleting or disappearance of certain specific fishery resources of the lagoon and nearby reef areas.

This base line study at Minicoy, thus establishes that the benthos of seagrass and mangrove ecosystems (nursery grounds) determines the richness and diversity of demersal fish fauna at the nearby lagoon and reef areas to a great extent. Any serious stress on these ecosystems may lead to disappearance of certain fish species in the nearby future.

REFERENCES

Achuthankutty, C.T. 1976. Ecology of sandy beach at Sancoale. Goa: Part I - Physical factors influencing production of macrofauna. *Indian J. Mar. Sci.,* **5**: 91-97.

Alongi, D. M. 1987. Intertidal zonation and seasonality of meiobenthos of tropical mangrove estuaries. *Mar. Biol.*, **95**: 447-458.

Alongi, D. M. 1989. The role of soft bottom benthic communities in tropical mangrove and coral reef ecosystems. *Rev. Aquat. Sci.*, **1**: 234 -280.

Alongi, D. M. 1990. The ecology of tropical soft bottom benthic ecosystems. Margaret Barnes, Ed. Aberdeen University Press. *Oceanogr. Mar. Biol. Annu. Rev.*, **28**: 381-496.

Andrews, J. C. and G. L. Pickard. 1990. The physical oceanography of coral-reef systems. *In*: Z. Dubinski (Ed.) *Coral Reefs*, Elsevier., Amsterdam. pp. 11-48.

Annandale, N. and S. Kemp. 1915. Introduction to the fauna of Chilka Lake. *Mem. Ind. Mus.*, **5**: 1-20.

Ansari, Z. A. 1984. Benthic macro and meio fauna of seagrass (*Thalassia hemprichii*) bed at Minicoy, Lakshadweep. *Indian J. Mar. Sci.,* **13** (3): 126-127.

Ansari, Z. A., A. H. Parulekar, S. N. Harkantra and S. A. Nair 1977a. Shallow water macrobenthos of the central west coast of India. *Mahasagar-Bull. Natnl. Inst. Oceanogr.,* **10** (3 & 4): 123-127.

Ansari, Z. A., S.N. Harkantra, S.A. Nair and A.H. Parulekar. 1977b. Benthos of the Bay of Bengal: A preliminary account. *Mahasagar-Bull. Natnl. Inst. Oceanogr.*, **10** (1 & 2): 55-60.

Ansari, Z. A., B. S. Ingole and A. H. Parulekar. 1984. Macrofauna and Meiofauna of two sandy beaches at Mombasa, Kenya. *Indian J. Mar. Sci.,* **13**: 187-189.

Ansari, Z. A., P. Ramani, C. V. Rivonker and A.H. Parulekar. 1990. Macro and meio faunal abundance in six sandy beaches of Lakshadweep Islands. *Indian J. Mar. Sci.,* **19**: 159 –164.

Ansari, Z. A., C. V. Rivonker, P. Ramani and A. H. Parulekar. 1991. Seagrass habitat complexity and macroinvertebrate abundance in Lakshadweep coral reef lagoons, Arabian Sea. *Coral Reefs,* **10** (3): 127-131.

Ansell, A.D., P. Sivadas, B. Narayanan, V. N. Sankaranarayanan and A. Trevallion. 1972 (a). The ecology of two sandy beaches in South West India. I. Seasonal changes in physical and chemical factors in the macrofauna. *Mar. Biol.,* **17**: 38- 62.

Ansell, A.D., P. Sivadas, B. Narayanan and A. Trevallion. 1972 (b). The ecology of two sandy beaches in South West India. II. Observations on the populations of *Donax incamatus* and *Donax spiculum. Mar. Biol.,* **17**: 318-322.

Ayyangar, S. R. 1922. Notes on the fauna and fishing industries of the Laccadives. *Madras Fish. Bull.,* **15**: 45-69.

Bader, R. G. 1954. The role of organic matter in determining the distribution of pelecypods in marine sediments. *J. Mar. Res.,* **13**: 32.

Bakus, T. G. 1990. *Quantitative ecology and marine biology.* Oxford and IBH publishing Co. New Delhi. 157pp.

Bakus, G. J. 1994. *Coral reef ecosystems.* Oxford and IBH publishing Co. New Delhi. 232pp.

Balasubramanian, K. 1961. Studies on the ecology of Vellar estuary. 1. A preliminary survey of the estuarine bottom. *J. Zool. Soc. India,* **12**: 209-215.

Balasubramaniam, T. and S. Ajmal Khan (Eds.). 2001. *Lagoons of India- State of the art report* - Environmental Information system center (for Estuaries, Mangroves, Coral reefs and Lagoons). 100pp.

Bell, J. D. and D. A. Pollard. 1989. Ecology of fish assemblages and fisheries associated with sea grasses. *In*: Biology of sea grasses – A treatise on the biology of sea grasses with special reference to the Australian region (Eds. Larkum, A. W. D., Mc Comb, A. J. and S. A. Shepherd) Elsevier, Amsterdam, pp: 565-609

Birkett, L. and A. D. Mc Intyre. 1971. Methods for the study of marine benthos. *In*: *IBP handbook No. 16*: Treatment and sorting of samples, Blackwell Sci. Publ., Oxford and Edinburg. 157pp.

Blaber, S. J. M. 2000. Tropical estuarine fishes. Ecology, exploitation and conservation. *In*: *Fisheries and Aquatic Resources.* Sereis **7**, Blackwell science, Oxford. 372pp.

Boesch, D.F., R. J. Diaz and R.W. Virnstein. 1976. Effects of tropical storm Agnes on soft-bottom macrobenthic communities of the James and York River estuaries and the lower Chesapeake Bay. *Ches. Sci.*, **17**: 246-259.

Bordovsky, O. K. 1964. Accumulation of organic matter in bottom sediments. *Mar. Geol.*, **3** (1&2): 34-79.

Borradaile, L. A. (1903) a. Marine crustaceans II Portunidae *In*: J. S. Gardiner (Ed). *The fauna and geography of the Maldive and laccadive archipelago* Cambridge Univ. Press. Cambridge, **1**: 199-208.

Bostrom Christopher and E. Bondorff. 2000. Zoobenthic community establishment and habitat complexity- the importance of seagrass shoot-density, morphology and physical disturbances for faunal recruitment. *Mar. Ecol. Prog. Ser.,* **205**: 123-138

Bostwick, H Ketchum. 1983. Ecosystems of the world. *In*: Bostwick H Ketchum (Ed.) *Estuaries and enclosed seas.* Elseveir Scientific Publishing company- New York. 500pp.

Brook, I. M. 1977. Trophic relationships in a seagrass community (*Thalassia testudinum* in card sound, Florida. Fish diets in relation to macrobenthic and cryptic faunal abundance. *Trans. Am. Fish. Soc.*, **106** (3): 219-229.

Brook, I. M. 1978. Comparative macrofunal abundances in turtlegrass (*Thalassia testudinum*) communities in south Florida characterized by high blade density. *Bull. Mar. Sci.,* **28**: 212-217

Broom, M. J. 1982. Structure and seasonality in a Malaysia mudflat community. *Estuarine Coastal Shelf Sci.*, **15**: 135-150.

Buchanan, B. A. and A. W. Stoner. 1988. Distributional patterns of blue crabs (*Calinectes* sp.) in a tropical estuarine lagoon. *Estuaries*, **11**: 231-239.

Bursarawich, S., A. Nateewathana and J. Hyllenberg. 1984. Distributor of marine benthic amphipods off Phuket Island, with emphasis outing mining and a model of species individual relationships. *Res. Bull. Phuket Mar. Biol. Cent.*, **32.**

Campell, D., R. Kwiatkowski and R.C. Crea. 1986. Benthic communities in 5 major rivers of the Hudion Bay lowlands, Canada. *Water Pollu. Res. J. Can.*, **21** (2): 235-250.

Campbell, S.J. and L.J. McKenzie. 2004. Flood related loss and recovery of intertidal seagrass meadows in southern Queensland, Australia. *Estuarine, Coastal and Shelf Sci.*, **60**: 477-490.

Cano, J. and M.T. Garcia. 1982. Preliminary results of the study of the benthos of Malaya. *Bat. Oceol. Aquati.*, **6** : 107-117.

Chandra Mohan, P., R. G. Rao and F. Dehairs. 1997. Role of Godavari mangroves (India) in the production and survival of prawn larvae. *Hydrobiologia*, **358**: 317-320.

Chandran, R. 1987. Hydrobiological studies in the gradient zone of the Vellar estuary IV- Benthic fauna. *Mahasagar-Bull. Natnl. Inst. Oceanogr.*, **20** (1): 1-13

Chandran, R and K. Ramamoorthy. 1984. Hydrobiological studies in the gradient zone of the Vellar estuary. 1. Physico-chemical parameters. *Mahasagar-Bull. Natnl. Inst. Oceanogr.*, **17**(2): 69-77.

Chapman, D. 1996. *Water Quality Assessments. A guide to the use of biota, sediments and water in environmental monitoring.* (2nd Ed.), E & FN Spon, London, UK.

Chong, V. C. and A. Sasekumar. 1981. Food and feeding habits of the white prawn *Penaeus merguiensis*. *Mar. Ecol. Prog. Ser.*, **5**: 185-191.

Chong, V.C., A. Sasekumar, and E. Wolanski. 1996. The role of mangroves in retaining penaeid prawn larvae in Klang Strait, Malaysia. *Mangroves and Salt Marshes*, **1**: 11-22.

Colella, A. and I.D. Geronimo. 1987. Surface sediments and macrofauna of the Crati submarine from Ionian sea, Italy, *Sedi. Geol.*, **51** (3-4): 257-277.

Connel, J. H. 1975. *Ecology and evolution of communities*, M. Cody and J Diamond (Eds), Harward Universtiy Press, Cambridge, 460pp.

Cooper, L.H.N. 1948. Phosphate and fisheries. *J. Mar. Biol. Ass.*, **27**: 326.

Coutiere, H. 1906. Les Alpheidae. *In*: J. S. Gardiner (Ed). *The fauna and geography of the Maldive and laccadive archipelago* Cambridge Univ. Press. Cambridge, **2**: 852-921.

Crisp, D. J. 1979. Methods for the study of marine benthos. *In*: N. A. Holme and A. D. McIntyre (Eds.) *IBP Handbook*, Blackwell, Oxford, 197pp.

Dales, R. P. 1958. Survival of anaerobic periods by two intertidal polychaets, *Arenicola marina* (2) and *Owenia fusiformis* della Chiaje. *J. mar. biol. Ass. U.K.*, **37**: 521-529.

Damodaran, R. 1973. Studies on the benthos of the mud banks of the Kerala coast. *Bull. Dept. Mar. Sci. Univ. Cochin*, **6**: 1-126.

Desai, B.N and M. Krishnankutty. 1967. Studies on the benthic fauna of Cochin backwaters. *Proc. Ind. Acad. Sci.*, **66**: 123-142.

Desai, B.N. and M. Krishnankutty. 1969. A comparison of the marine and estuarine benthic fauna of the near shore regions of Arabian Sea. *Bull. Nat. Inst. Sci. India*, **30** (16): 671-686.

Dhargalkar, V. K. and N. Shaikh. 2000. Primary productivity of marine macrophytes in the coral reef lagoon of the Kadmat Island, Lakshadweep. *Curr. Sci.*, **79** (8): 1101-1104.

Doering, H. Peter and R. H. Chamberlain. 2000. Experimental studies on the salinity tolerance of turtle grass, *Thalassia testudinum*. *In*: Stephen. A. Bortone (Ed.) *Seagrasses- monitoring, ecology, physiology and management*, CRC Press. Boca Raton, Florida, 318 pp.

Dorenbosch, M., M. C. van Riel, I. Nagelkerken and G. van der Velde. 2004. The relationship of reef fish densities to the proximity of mangrove and seagrass nurseries. *Estuarine, Coastal and Shelf Sci.*, **60** (1): 37-49.

Dugan, P.J. (Ed.). 1990. *Wetlands Conservation: A Review of Current Issues and Required Action*. IUCN-The World Conservation Union, Gland (Switzerland). 95 pp.

Dwivedi, S. N., S. A. Nair and A. Rahim. 1973. Ecology and production of intertidal macrofauna during monsoon in a sandy beach at Calangatu, Goa. *J. Mar. Biol. Ass. India.*, **15**: 274-284.

Eagle, R. R. A. 1981. Natural fluctuations in a shift bottom community. *J. Mar. biol. Ass. U.K.*, **55**: 865-878.

Eckman, J. E. 1983. Hydrodynamic processes affecting benthic recruitment. *Limnol Oceanogr.*, **28** (2): 241-257.

El-Wakeel, S. K. and J. P. Riley. 1957. The determination of organic carbon in marine muds. *J. Cons. Perm. Int. Explor. Mer.*, **22**: 180-183.

Eleftheriou, A. and N.A. Holme. 1984. Macrofauna techniques. *In:* N.A. Holme and A.D. McIntyre (Eds.), *Methods for the Study of Marine Benthos, IBP Handbook 16*, Blackwell Scientific Publications, Oxford, UK, pp: 140-216.

Eliot, C. 1906. Nudibranchiata, with some remarks on the families and genera and description of a new genus Doridimorpha. *In*: J. S. Gardiner (Ed). *The fauna and geography of the Maldive and laccadive archipelago* Cambridge Univ. Press. Cambridge, **2**: 540-573.

Ellis, R. H. 1924. *A short account of the Laccadive Islands and Minicoy.* Govt. Press, Madras: iv + 122pp.

Ellis, M. M. 1937. Detection and measurement of stream pollution. *Bull. Zz. U. S. Bur. Fish.*, **58**: 365-437.

English, S., C. Wilkinson and V. Baker. 1997. *Survey Manual for Tropical Marine Resources.* (2nd Ed.). Australian Institute of Marine Science, Townsville, 402pp.

Ferenez, M. 1974. Data on the horizontal and vertical distribution of the zoobenthos of the Tiza. *Tisca*, **9**: 65-67.

Frouin, P and Hutchings. 2001. Report: Macrobenthic communities in a tropical lagoon (Tahiti, French Polynesia, central Pacific) *Coral Reefs* (Heidelberg), **19** (3): 277-28.

Furukawa, K., E. Wolanski and H. Muller. 1997. Currents and sediment transport in mangrove forests. *Estuarine, Coastal and Shelf Sci.*, **44**: 301-310.

Gage, M.J. 1974. The food of the shrimp *M. monoceros* (Fabricus) caught from the backwaters. *Indian J. Fish.*, **21**: 495-500.

Gardiner, J.S. 1900. The Atoll of Minicoy. *Proc. Camp. Phill. Soc. Biol. Sci.*, **11** (1): 22-26.

Gardiner, J. S. (Ed.). 1903. *The fauna and Geography of the Maldive and Laccadive Archipelagoes* 1. Cambridge Univ. Press, Cambridge, pp: 1-11

Gardiner, J. S. (Ed.). 1906 a. *The fauna and geography of the Maldive and Laccadive archipelagoes* 2. Cambridge Univ. Press. Cambridge, pp: 933-957.

Gardiner, J. S. 1906 b. Notes on the distribution of the land and marine animals with a list of the coral reefs. Cambridge Univ. Press. Cambridge, 1046-1057.

Garrity, S. D., S. C. Levings and H. M. Caffey. 1986. Spatial and temporal variation in shell crushing by fishes on rocky shores of Pacific Panama. *J. Exp. Mar. Biol. Ecol.,* **103**: 131-142.

Gopinathan, C. P. and M. S. Rajagopalan. 1983. Mangrove resources. *Bull. Cent. Mar. Fish. Res. Inst.,* **34**: 1-10

Gosliner, T. M., D. W. Behrens and G.C. Williams. 1996. *Coral reef animals of the Indo-pacific.* 314pp.

Geological Survey of India. 1995. Proceedings of Workshop on "*Status of Scientific Database on Lakshadweep Islands*", No. **56**, Trivandrum.

Guerreiro, J., S. Freitas, P. Pereira, J. Paula, and A. Macia. 1996. Sediment macrobenthos of mangrove flats in Inhaca Island, Mozambique. *Cahiers de Biologie marine,* **37**: 309- 327.

Haneefa Koya, C. N. 2000. Studies on ecology, chemical constituents and culture of marine macroalgae of Minicoy Island, Lakshadweep. *Ph. D. Thesis,* CIFE, Mumbai. 184pp.

Harkantra, S.N. 1982. Studies on sub-littoral macrobenthic faunal of the Inner Swansea Bay. *Indian J. Mar. Sci.,* **11**: 75-78.

Harkantra, S. N and A. H. Parulekar. 1981. Ecology of benthic producion in the coastal zone of Goa. *Mahasagar-Bull. Natnl. Inst. Oceanogr.,* **14** (2): 135-139.

Harkantra, S. N. and A. H., Parulekar. 1985. Community structure of sand-dwelling macrofauna of an estuarine beach in Goa, India. *Mar. Ecol. Prog. Ser.,* **30**: 291-294.

Harkantra, S. N and A. H. Parulekar. 1994. Soft sediment dwelling macro-invertebrates of Rajapur Bay, central west coast of India. *Indian J. Mar. Sci.,* **23**: 31-34.

Harkantra, S N, S. A Nair, Z. A. Ansari and A.H. Parulekar. 1980. Benthos of shelf region along the west coast of India. *Indian J. Mar. Sci.,* **9**: 106-110.

Hartwig, E. O. 1976. The impact of nitrogen and phosphorus release from a siliceous sediment on the overlying water. *In*: M. Wiley (Ed.) *Estuarine processes*, Academic press, New York, Volume **I**: 103-117.

Hartog, C. Den. 1977. Structure, function and classification in seagrass communities. *In:* C. Peter Mc Roy and Carla Helfeerich (Eds.) *Sea grass ecosystems*. 89-119pp.

Heip, C. 1974. A new index measuring evenness. *J. Mar. Biol. Ass. UK.,* **54**: 555-557.

Herman, P. M. J., J. J. Middleburg and C. H. R. Heip. 2001. Benthic community structure and sediment processes on an intertidal flat: results from the ECOFLAT project. *Continental Shelf Res.*, **21** (18-19): 2055-2071.

Hiscock, K. 1987. Subtidal rock and shallow sediments using diving. *In*: Baker, J.M. and Wolf W.J. (Eds.), *Biological surveys of estuaries and coast.* Cambridge University Press, Cambridge. 198-237pp.

Hiscock, K. and R. Mitchell. 1989. Practical methods of field assessment and conservation evaluation of nearshore/estuarine areas. *In*: McManus, J. and Elliot, M. (Eds.) *Development in estuarine and coastal study techniques*. Olsen and Olsen, Int. Symposium Ser., Fredensborg, Denmark. 53-55pp.

Holme, N. A and A.D. Mc Intyre. 1984. Methods for the study of marine benthos. *IBP Hand book No. 16.* (2^{nd} Ed.). Blackwell scientific publications. 387pp.

Hornell, J. 1910. Report on the results of the fishery cruise along the Malabar coast and the Laccadive Islands in 1908. *Madras. Fish. Bull.*, **4**: 71-126.

Hyland, J. L., T.J. Herlinger, T.R. Snouts, A.H. Ringwood, R.F. Van Dolah, C.T. Hackney, G.A. Nelson, J.S. Rosen and S.A. Kokkinakis. 1996. Environmental quality of estuaries of the Carolinian Province: Annual statistical summary for the 1994 EMAP - Estuaries Demonstration Project in the Carolinian Province. NOAA Technical Memorandum NOS ORCA 97. NOAA/NOS, Office of Ocean Resources Conservation and Assessment, Silver Spring, MD. 102pp.

Jackson, E. L., Rowden, A. A., Attrill, M. J., Bossey, S. J., Jones and M. B. 2001. The importance of seagrass beds as a habitat for fishery species. (Eds.) H Barnes, RN Gibson, M Barnes and RJA, Atkinson, *Oceanography and Marine Biology Annual Review (Winchester),* **39**: 269-303

Jagtap, T. G. 1987. Distribution of algae, seagrasses and coral communities from Lakshadweep, Eastern Arabian Sea. *Indian J. Mar. Sci.,* **16**(4): 256-260.

Jagtap, T.G. 1998. Structure of major seagrass beds from three coral reef atolls of Lakshadweep, Arabian Sea, India. *Aquat. Bot.,* **60**(4): 397-408.

Jagtap, T. G and A. G. Untawale. 1984. Chemical composition of marine macrophytes and their surrounding water and sediments, from Minicoy, Lakshadweep. *Indian J. Mar. Sci.,* **13** (3): 123-125

Jagtap, T. G., A. G. Untawale and S. N. Inamdar. 1994. Study of mangrove environment of Maharashtra coast using remote sensing data. *Indian J. Mar. Sci.,* **23**: 90.

Jagtap, T. G., K. S. Deepali., C. L. Rodrigues and S. Rouchelle. 2003. Status of a seagrass ecosystem: An ecologically sensitive wetland habitat from India. Wet lands, **23** (1): 161-170.

James, P. S. B. R., C. S. Gopinadha Pillai, P. P. Pillai, P. Livingston and Madan Mohan. 1986. Marine fisheries research in Lakshadweep- A historical resume. *Mar. Fish. Infor. Serv. T & E Ser.,* **68**: 7-9.

Jayalakshmi, K. V. 1998. Biometric studies on trophic level relations in the Indian Ocean. *Ph. D Thesis* of Cochin University of Science and Technology.

Jayaraman, R., C. P. Ramamirtham, K. V. Sundara Raman and C. P. Aravindakshan Nair. 1966. Hydrography of the Laccadive offshore waters. *J. Mar. Biol. Ass. India,* **2** (1): 24-34.

Johnson, R.G. 1974. Particulate matter at the sediment water interface on coastal environments. *J. Mar. Res.*, **113**: 313-330.

Jones, N. S. 1950. Marine bottom communities. *Biol. Rev.*, **25**: 283-313.

Jones, S. 1959. Research vessel Kalava and co-operative oceanographic investigations in Indian waters. *J. Mar. Biol. Ass. India,* **1** (1): 1-6

Jones, S. 1986. Lakshadweep- general features and some considerations. *Mar. Fish. Infor. Serv. T & E Ser.*, **68**: 3-6.

Joy Das, T.V. 2002. Macrobenthos of the shelf waters of the west coast of India. Dept. Marine Biology, *Ph. D. Thesis* of Cochin University of Science and Technology. 151pp.

Kaladharan, P and I. David Raj. 1989. Primary production of seagrass *Cymodocea serrulata* and its contribution to the productivity of Amini atoll of Lakshadweep islands. *Indian J. Mar. Sci.,* **18**: 215-216.

Karandeeva, O.G. 1959. Metabolised Modila and Mytilus in anaerobic and port anaerobic conditions. *Trudy Sevastopol biol. St.*, **11**: 238-253.

Kemp, P. F. 1988. Bacteriovory by benthic ciliates: significance as a carbon source and impact on sediment bacteria. *Mar. Ecol. Prog. Ser.*, **49**: 163-169.

Kikuchi, T. 1980. Faunal relationship in temperate seagrass beds. *In*: Philips RC, Mc Roy CP (Eds.) *Handbook of seagrass biology: an ecosystem perspective*. Garland, STPR, New York, 153-172.

Kikuchi, T and J. M. Peres. 1977. Consumer ecology of seagrass beds, *In*: C. Peter Mc Roy and Carla Helfferich (Eds.) *Seagrass ecosystems* 147-185pp.

Kinne, O. 1966. Physiological aspects of animal life in estuaries with special reference to salinity. *Neth. J. Sea. Res.,* **3**: 222-244.

Kirkman, H. 1985. Community structure in seagrasses in southern Western Australia. *Aquat. Bot.*, **21**: 363–375.

Kirkman, H. 1995. Baseline and monitoring methods for seagrass meadows. *J. Environ. Management*, **47**: 191–201.

Krumbein and F.J. Petti John. 1938. *Manual of Sedimentary Petrography.* Appleton Century Crafts, New York. 549pp.

Kurian, C. V. 1953. A preliminary survey of the bottom fauna and bottom deposit of Travancore coast within the 15 fathom line. *Proc. Nat. Inst. Sci. India,* **19**: 746-775.

Kurian, C. V. 1967. Studies on the benthos of the southwest coast of India. *Bull. Nat. Inst. Sci. India*, **38**: 649-656

Kurian, C. V. 1972. Ecology of benthos in a tropical estuary. *Proc. Indian. Natn. Sci. Acad.*, **38**:156-163

Kurian, C.V. 1973. Ecology of benthos in a tropical estuary. *Proc. Natn. Inst. Sci India*, **38** B: 156-163.

Lie, U. 1968. A quantitative study of benthic infauna in Puget Sound, Washington, U.S.A., 1963-64. *In*: Fisk Skritter Sereis Hauderskelser, **14**: 229-556.

Leis, J. M. and B. Goldman. 1987. Composition and distribution of larval fish assemblages in the Great Barrier Reef Lagoon, near Lizard Island, Australia. *Aust. J. Mar. Freshw. Res.*, **38**: 211-223

Longhurst, A. R. 1957. The food of the demersal fish of a West African Estuary. *J. Anim. Ecol.*, **26**: 369-387.

Lovegrove, T. 1966. The determination of the dry weight of plankton and the effect of various factors on the values obtained. *In*: Harold Barnes (Ed.) *Some contemporary studies in marine science*, 429-467pp.

Luczak, C. 2001. Long-term changes in specific diversity within the subtidal macrobenthic series: how to interpret? *Oceanis* (Paris), **25**(3): 377-393.

Mallik, T. K. 1976. Grain size variation in the Kavaratti lagoon sediments, Lakshadweep, Arabian Sea. *Mar. Geology*, **20** (1): 57-75.

Manikandavelu, D and V. Ramdhas. 1994. Bioproduction dynamics of a mangal bordered brackishwater in Tuticorin coast. *Indian J. Mar. Sci.,* **23**: 108-109.

Mann, K.H. 1988. Production and use of detritus in various freshwater, estuarine, and coastal marine ecosystems. *Limnol. Oceanogr.*, **33**: 910–930.

Mare, M. F. 1942. A study of a marine benthic community with special reference to the microorganisms. *J. Mar. Biol. Ass. UK.,* **25**: 517-554

Margalef, R. 1968. *In*: Perspectives in ecological theory. Univ.Chicahp Press, 111 pp.

Martin, J. Attrill, A. James, A. Strong and A. Ashley and Rowden. 2000. Are macro invertebrate communities influenced by seagrass structural complexity? *Ecography*, **23** (1): pp 114.

Mc Auliffe, J. R. 1984. Competition for space, disturbance and the structure of a benthic stream community. *Ecology*, **65** (4): 894-908.

McKee, L. Karen. 2003. Mangrove Ecosystems: Definitions, Distribution, Zonation, Forest Structure, Trophic Structure, and Ecological Significance. *In*: Ilka. C. Feller (Ed.) *Mangrove ecology: A Manual for a Field Course A Field Manual Focused on the Biocomplexity on Mangrove Ecosystems*, Smithsonian Environmental Research Center, Smithsonian Institution. 1-7pp.

Mc Roy, C. Peter and Calvin Mc Millan. 1977. Production ecology and physiology of seagrasses. *In:* C. Peter Mc Roy and Carla Helfeerich (Eds.) *Sea grass Ecosystems.* 53-81pp.

McLachlan, A. 1977. Composition, distribution, abundance and biomass of the macrofauna and meiofauna of four sandy beaches. *Zool. Afr.*, **12**: 279 -306.

Moore, H. B. 1931. The muds of the Clyde Sea Area III. Chemical and physical condition, the rate and nature of sedimentation and fauna. *J. Mar. Biol. Ass. U. K.*, **17**: 325-398.

Moore. H. B. 1972. Aspects of stress in the tropical marine environment. *Adv. Mar. biol.,* **10**: 217-269.

Morrison, D.F. 1978. *Multivariate Statistical Methods*, (2^{nd} Ed). McGraw-Hill Book Company- Singapore.

Mullin, J. B and J. P. Riley. 1955. The spectrophotometric determination of nitrate in natural water with particular reference to Sea water. *Anal. Chim. Acta.*, **12**: 464-480.

Murphy, J and J. P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta.*, **27**: 31-36.

Murthy, P.S.N. and M. Veerayya. 1972. Studies on the sediments of Vembanad Lake, Kerala state. Part 1, Distribution of organic matter. *Indian J. Mar. Sci.*, **1**(1): 45-51.

Murugan, T., O. Divakaran, N. Balakrishnan Nair and K. G. Padmanabhan. 1980. Distribution and seasonal variation of benthic fauna of the Veli lake, South west coast of India. *Indian J. Mar. Sci.,* **9** (3): 184-188.

Nagabhushanam, A. K and G. C. Rao. 1972. An ecological survey of the marine fauna of Minicoy atoll, Laccadive archipelago, Arabian sea. *Mitt. Zool. Mus.* Berlin, **48** (2): 265-324.

Nagelkerken, I., Kleijnen, S., Klop. T., R.A.C.J, Van den Brand, E. Coheret de la Moriniere and P.H. Nienhuis. 2002. How important are mangroves and seagrass beds for coral reef fish? The nursery hypothesis tested on an island scale. *Marine Ecology progress Series.,* **245**: 191-204.0

Nair, N. B and P. K. Abdul Aziz. 1987. Ecology of the Ashtamudi Estuary, Southwest coast of India. *J. Mar. Biol. Ass. India,* **29**(1 & 2): 177-194.

Nair, N. B and D.M. Thampy. 1980. *A textbook of Marine Ecology*. The Macmillan Co. India Ltd., New Delhi. 352pp.

Nair, P. V. R., G. Subbaraju, K. J. Mathew, V. K. Pillai and V. K. Balachandran. 1986. Productivity of the seas around Lakshadweep. *Mar. Fish. Infor. Ser., T& E. Ser.,* **68**: 13-15

Namboodiri, P. N. and P. Sivadas. 1979. Zonation of molluscan assemblage at Kavaratti atoll (Laccadives). *Mahasagar-Bull. Natnl. Inst. Oceanogr.,* **12**: 239-246.

Nandi, S. and A. Chowdhary. 1983. Quantitative studies on the benthic macrofauna of Sagan Island, Intertidal zones, Sunderbans, India. *Mahasagar-Bull. Natnl. Inst. Oceanogr.,* **16**: 409-414.

Narayanan, B and P. Sivadas. 1986. Studies on the intertidal macrofauna of the sandy beach at Kavaratti atoll. *Mahasagar-Bull. Natnl. Inst. Oceanogr.,* **19**(1): 11-22

Nassar, A. K. V., V. A. Kunhikoya and P. M. Aboobaker. 1999. Mangrove ecosystem of Minicoy Island, Lakshadweep. *Mar. Fish. Infor. Ser., T& E. Ser.,* **159**: 8-10

Nichols, F.H. 1985. Abundance fluctuations among benthic invertebrates in two Pacific estuaries. *Estuaries*, **8** (2): 136-144.

Orth, R. J. 1973. Benthic infauna of eelgrass, *Zostera marina*, beds. *Chesapeake Sci.*, **14**: 258.

Orth, R. J. 1986. Potential values of seagrass meadows as critical nursery areas in the Indian Ocean, an evaluation method for associated faunal communities. *In*: Thompston MF, S. R. Nagabhushanam R (Eds.) Indian ocean- biology of benthic marine organisms. Oxford IBH Publishing Company, New Delhi. 167-176pp.

Orth, R.J., K. L. Heck Jr. and J. V. van Mont francis. 1984. Faunal communities in seagrass beds: A review of the influence of plant structure and prey characteristics on predator-prey relationships. *Estuaries*, **7**: 339-350.

Panikkar, N. K. and R. G. Aiyar. 1937. The brackish water fauna of Madras. *Proc. Ind. Acad. Sci.*, **6**: 284-337

Parulekar, A. H. 1984. Studies on growth and age of bivalves from temperate and tropical estuarine ecosystems. *Indian J. Mar. Sci.,* **13**: 193-195.

Parulekar, A. H. and S. N. Dwivedi. 1974. Benthic studies in Goa estuaries. Part 1- standing crop and faunal composition in relation to bottom salinity distribution and substratum characteristics in the estuary of Mandovi River. *Indian J. Mar. Sci.,* **3**: 41-45.

Parulekar, A.H., V. K. Dhargalkar and S. Y. S. Singbal. 1980. Benthic studies in Goa estuaries: Part III – Annual cycle of macrofaunal distribution, production and trophic relations. *Indian J. Mar. Sci.,* **9**: 189-200.

Parulekar, A. H., S.N. Harkantra and Z. A. Anzari. 1982 Benthic production and assessment of demersal fishery resources of the Indian seas. *Indian J. Mar. Sci.,* **11**: 107-114.

Patil, M. R and C. P. Ramamritham. 1963. Hydrography of Laccadive offshore waters. A study of the winter conditions. *J. Mar. Biol. Ass. India,* **5** (2): 159-169.

Patnaik, S. 1971. Seasonal abundance and distribution of bottom fauna of the Chilka lake. *J. Mar. Biol. Ass. India,* **13**: 106-125.

Paula, J., P. Fidalgo E Costa., A. Martins. and D. Gove. 2001. Patterns of abundance of seagrasses and associated infaunal communities at Inhaca Island, Mozambique. *Estuarine Coastal Shelf Sci.*, (London), **53** (3): 307-318.

Pauly, D. 1975. On the ecology of a small west African lagoon. *Ber. Dtsch. Wiss. Komm,* Meeresforsch, **24**: 46-62.

Pauly, D. 1979. Theory and management of tropical multispecies stocks: A review, with emphasis on the Southeast Asian demersal fisheries. *ICLARM Stud. Rev.*, **1**: 1-35.

Peterson, C. G. J. 1913. The animal communities of the sea bottom and their importance for marine zoogeography. *Rept. Dan. Biol. Stat.*, **21**: 1-44.

Peterson, C. G. J. 1918. The sea bottom and its production of fish food. *Rept. Dan. Biol. Stat.*, No. **25**: 1-62.

Peterson, C.H. 1991. Intertidal Zonation of Marine Invertebrates in Sand and Mud. *American Scientist,* **79** (3): 236-49.

Peterson, C. H., H.C. Summerson, E. Thomson, H. S. Lenihan, J. Grabowski, L. Manning, F. Micheli and G. Johnson. (2000). Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. *Bull. Mar. Sci. (Miami*), **66** (3): 759-774.

Pielou, E. C. 1966a. Species diversity and pattern diversity in the study of ecological succession. *J. Theor. Biol.*, **10**: 372-383

Pielou, E. C. 1966b. The measurement of diversity in different types of biological collections. *J. Theor. Biol.*, **13**: 131-144.

Pillai, N. G. K. 1978. Macrobenthos of a tropical estuary. *Ph. D Thesis* of Cochin University of Science and Technology. 133pp.

Pillai, C.S.G. 1986. Status of coral reefs in Lakshadweep. *Mar. Fish. Infor. Ser. T& E Ser.*, **68**: 38-41

Pillai, C.S.G. 1997. A Brief Resume of Research and Understanding of the Reef Corals and Coral Reefs around India. *In*: Hoon, Vinita. (Ed). Proceedings of the SAARC Regional Workshop on the Conservation Sustainable Management of Coral Reefs. MSSRF, Chennai. 26pp.

Pillai, C. S. G and Madan Mohan. 1986. Ecological stress in Minicoy lagoon and its impact on tuna baits. *Mar. Fish. Infor. Serv. T & E Ser.*, **68**: 33-37

Pinkster, S. and M. Goris. 1984. Sampling frequency and seasonal influence in macrofauna research. *Proc. Int. Assoc. Theor. Appl. Limnol.*, **22** (4): 37-45.

Post, J. R. and D. Cusin. 1984. Changes in the benthic community of a small pre Cambrian lake following the introduction of yellow perch. *Can J. Fish. Aquat. Sci.*, **41**(10): 1496-1501.

Prabha Devi, L., P. Natarajan, G. Saraswathy Ammal and P. K. Abdul Aziz. 1996. Water quality and benthic fauna of the Kayamkulam backwaters and Arattupuzha coast along southwest coast of India. *Indian J. Mar. Sci.*, **27**: 264-267.

Preetha, K. 1994. Benthic ecology of selected prawn culture fields and ponds near Cochin. *Ph. D Thesis* of Cochin University of Science and Technology. 135pp.

Prieto, M. J., I. Linero Arana, J. Blanco Rambla and J. Fermin. 2000. Benthic macrofauna associated to *Thalassia testudinum* in Bahia de Mochima, Sucre, Venezuela. Source: *Revista de Biologia Tropical (San Jose).*, **48** (supp. 1): 233-242.

Qasim, S. Z. and P.M.A. Bhattathiri. 1971. Primary production of a seagrass bed on Kavaratti atoll (Laccadives). *Hydrobiologia,* **38** (1): 29-38

Qasim, S. Z., S. Wellershaws, P. M. A. Bhattathiri and S. A. H. Abidi. 1969. Organic production in a tropical estuary. *Proc. Indian Acad. Sci.*, B **69**: 51-94.

Rajan, S. 1964. Environmental studies of the Chilka lake: (2) Benthic animal communities. *Ind. J. Fish.*, **12**: 492-499.

Ramachandran, K. K. and A.Varma. 1997. Review of the Contribution of Centre for Earth Science Studies (CESS) Towards Understanding the totality of Environment of Lakshadweep, India. *In*: Hoon, Vinita. (Ed). Proceedings of the SAARC Regional Workshop on the Conservation Sustainable Management of Coral Reefs. MSSRF, Chennai. 26pp.

Raman, A.V. and P.N. Ganapati. 1983. Pollution effects on ecobiology of benthic polychaetes in Visakhapatnam Harbour (Bay of Bengal). *Mar. Poll. Bull.*, **14**: 46-52.

Rao, M.S. 1960. Organic matter in marine sediments off east coast of India. *Bull. An Assoc. Petroleum Geologists*, **44**: 1705-1712.

Rao, L. V. Gangadhara and R. Jayaraman. 1966. Upwelling in the Minicoy region of the Arabian Sea. *Curr. Sci.*, **35** (15): 378-380.

Raut, D, T. Ganesh, N. V. S. S. Murty and A. V. Raman. 2005. Macrobenthos of Kakinada bay in the Godavari delta, East coast of India; comparing decadal changes. *Estuarine Coastal Shelf Sci.*, **62** (4): 609-620.

Raymont, 1950. A fish cultivation experiment in an arm of a sea-loch. IV. The bottom fauna of Kyle Scotnish. *Proc. Roy. Soc. Edinb.*, B **64:** 65-108.

Richmond, M.D. (Ed). 1997. *A guide to the seashores of Eastern Africa and the western Indian ocean Islands*. Published by Sida/ Department for Research Cooperation, SAREC. 448pp.

Rivonker, C. U. and U. M. X. Sangodkar. 1997. Macrofaunal density along the intertidal region of three atolls of Lakshadweep, Arabian Sea. *Ind. J. Fish.*, **44**(4): 345-352.

Rodrigues, C.L. 1996. Taxonomic and Ecological survey of the Lakshadweep for Perumal Par Marine Park - *Project Completion Report*, Goa University.

Rodrigues, C. L. 1997. An analysis of the carrying capacity of Lakshadweep Coral Reefs. *In*: Hoon, Vinita. (Ed). Proceedings of the SAARC Regional Workshop on the Conservation Sustainable Management of Coral Reefs. MSSRF, Chennai. 26pp.

Romankevich, E. A. 1984. *Geochemistry of organic matter in the ocean*. Springer-Verlag, Berlin, 334 pp.

Russel, E.W. 1973. *Soil conditions and plant growth*. Longman, Green & Co. New York, 849pp.

Sajan Sebastian. 2003. Meiobenthos of the shelf waters of the west coast of India with special reference to free-living marine Nematodes. Dept. Marine Biology, *Ph. D. Thesis* of Cochin University of Science and Technology.

Sanders, H. L. 1956. Oceanography of Long Island Sound 1952-1954, Biology of marine bottom communities. *Bull. Bingham Oceanogr. Coll.,* **15**: 345-414.

Sanders, H. L. 1958 Benthic studies in Buzzards Bay I-Animal sediment relationships. *Limnol. oceanogr.*, **3**: 245-258.

Sanders, H. L. 1959. Sediments and the structure of bottom communities. *In*: International oceanographic congress, reprints (Ed.) Mary Sears (Americal Association for the advancement of Science, Washington DC). 583-584pp.

Sanders, H. L. 1960. Benthic studies in Buzzards Bay III-The structure of the soft bottom community. *Limnol. oceanogr.*, **5**: 138-153

Sanders, H. L. 1968. Marine benthic diversity: A comparative study. *Am. Nat.,* **102**: (925) 243-282.

Saraladevi, K. 1986. Effect of Industrial pollution on the benthic communities of a tropical estuary. *Ph. D. Thesis* of Cochin University of Science and Technology. 380pp.

Sarda, N. and G.A. Burton. 1995. Ammonia variation in sediments: spatial, temporal and method-related effects. *Environ. Toxicol. Chem.,* **14**: 1499–1506.

Savich, M.S. 1972. Qualitative distribution of food value of benthos from the west Pakistan shelf. *Oceanology*, **12**: 113.

Schrijvers, J., M.G. Camargo., R. Pratiwi and M. Vincx. 1998. The infaunal macrobenthos under East African *Ceriops tagal* mangroves impacted by epibenthos. (IZWO) Institute for marine scientific research: *Collected reprints*, **28**: 245-263.

Schwarz Anne-Maree, Fleur Matheson and Trevor Mathieson. 2004. The role of sediment in keeping seagrass beds healthy. *Water and Atmosphere,* **12** (4): 18-19

Schulman, M. J. 1985. Recruitment of coral reef fishes: Effects of distribution of predators and shelter. *Ecology*, **66**: 1056-1066

Seshappa, G. 1953. Observations on the physical and biological features of the inshore seabottom along Malabar coast. *Proc. Nat. Inst. Sci. India,* **19**: 257-279

Shannon, C. E. and W. Weaver. 1963. The mathematical theory of communication. University of Illinois Press, Urbana, Illinois. 117pp.

Sheeba, P. 2000. Distribution of benthic infauna in the Cochin backwaters in relation to environmental parameters, *Ph. D. Thesis* of Cochin University of Science and Technology. 241pp.

Sheppard, C., Andrew Price and Callum Roberts. 1992. *Marine ecology of the Arabian region. Patterns and processes in extreme tropical environments.* London, Academic press.

Shipley, A. E. 1903a. Echiuroidea *In*: J. S. Gardiner (Ed). *The fauna and geography of the Maldive and laccadive archipelago* Cambridge Univ. Press. Cambridge, **1**: 127-130.

Shipley, A. E. 1903b. Sipunculoidea with an account of a new genus Lithacrosiphon. *In*: J. S. Gardiner (Ed). *The fauna and geography of the Maldive and laccadive archipelago* Cambridge Univ. Press. Cambridge, **1**: 131-140.

Sikora and Sikora, 1985. Benthic infauna of anoxic J.P. W.B. Sediments in estuarine habitats. 8th Biennial International estuarine research conference. July 28 – August 2, 1985. Durham, New Hamsphire.

Silas, E. G. 1969. Exploratory fishing by R. V. *Varuna. Bull. Cent. Mar. Fish. Res. Inst.*, **12**: 1-86

Simboura, N., A. Zenetus, P. Panayotides and A. Makra. 1995. Changes in benthic community structure along an environmental pollution gradient. *Mar. Poll. Bull.*, **30**: 470-474.

Simpson, E. H. 1949. Measurement of Diversity. *Nature*,**163**: 688.

Snedecor, G. W and W. G. Cochran, 1967. Statistical Methods, 6th Edn. Oxford and IBH publishing company, New Delhi. 535pp.

Stoner, A.W. 1980. The role of seagrass biomas in the organizations of benthic macrofaunal assemblages. *Bull. Mar. sci.,* **30** (3): 537-551.

Stoner, A.W. 1983. Distribution of fishes in seagrass meadows: Role of macrophyte biomass and species composition. *Fish. Bull. U.S.*, **81**: 837-846.

Stoner, A. W. 1986. Community structure of the demersal fish species of Laguna Joyuda, Puerto Rico, *Estuaries*, **9**: 142-152.

Stoner, A. W. and F. G. Lewis III. 1985. The influence of quantitative and qualitative aspects of habitat complexity in tropical sea-grass meadows. *J. Exp. Mar. Biol. Ecol.,* **94**: 19-40.

Strickland, J. D. H. and T. R. Parsons. 1968. A practical handbook of Seawater analysis. *Fish. Res. Bd. Can. Bull., Ottawa*, **167**: 311.

Strickland, J. D. H and T. R. Parsons. 1972. A practical handbook of Seawater analysis. (2^{nd} Ed.). *Fish. Res. Bd. Can. Bull. Ottawa*, **167**: 419.

Sunil Kumar, R. 2001. Biodiversity and affinity of polychaetous annelids within the mangrove ecosystem of Indo-pacific region. *J. Mar. Biol. Ass. India*, **43** (1&2): 206-213.

Sunil Kumar, R. 2002. Comparison of the macrofaunal benthic assemblages of an estuarine mangrove habitat and adjacent area in Cochin backwaters, Kerala. In: J.K. Patterson Edward, A. Murugan and Jamila Patterson (Eds.), *Proceedings of the National Seminar on Marine and Coastal Ecosystems*: Coral and Mangrove–Problems and Management Strategies. *SDMRI Res. Pub.*, **2**: 37-41.

Suseelan, C. (Ed). 1989. Marine Living resources of the union Territory of Lakshadweep. *Bull. Cent. Mar. Fish. Res. Inst.*, **43**: 1-256

Swedrup, H. U., N. W. Johnson and R. H. Fleming. 1942. The oceans, their physics, chemistry and general biology. Prentice Hall, New York: 1087 pp.

Taylor, J. D. 1968. Coral reefs and associated invertebrate communities (mainly molluscs) around Mahe, Seychelles. *Phil. Trans. R. Soc., London, Ser.*, B **254**: 129-206.

Taylor Michelle, Corinna Ravilious and Edmund P. Green. 2003. Mangroves of East Africa. *UNEP-WCMC Biodiversity Series,* **13**: 24

Tenore, K.R. 1977. Growth of *Capitella capitata* cultured on various levels of detritus derived from different sources. *Limnol. Oceanogr.*, **22**: 936 - 941.

Thomas, P.A. 1979. Demospongiae of Minicoy Island (Indian Ocean) Part I Order Keratosida and Haplosclerida. *J. Mar. Biol. Ass. India,* **21** (1&2): 10-16.

Thomassin, B. A and M.V. Vitiello. 1976. *J. Exp. Mar. Biol. Ecol.,* **22**: 31.

Thomassin, B. A, C. Jouin, J. R. Mornant, G. Pichard and Salvat. 1975. Macrofauna and meiofauna in the coral sediments of the Tiahura reef complex Moorea island (French Polynesia). 13th Pacific Science Cong. B. 392pp.

Thorson, G. 1957. Bottom communities (sublittoral or shallow shelf) *Geol. Soc. Am. Mem.*, **67** (1): 461-534.

Thorson, G. 1958. Parallel level bottom communities, their temperature adaptation and their "balance" between predators and food animal. *In*: A. A. Buzzati-Traverso (Ed.) *Perspective in Marine Biology,* Univ. Calif. Press, Berkeley, California. 67-86pp.

Tuckey, J. W. 1949. One degree of freedom for non additivity. *Biometrics*, **5**: 232-242.

Ullman, W. J and M.W. Sandstrom. 1987. Dissolved nutrient fluxes from the nearshore sediments of Bowling Green Bay, Central Great Barrier Reef Lagoon (Australia). *Estuarine Coastal Shelf Sci.*, **24**: 289-303.

Untawale, A.G., S. Wafar and T.G. Jagtap. 1992. Status of mangroves along the countries bordering the Arabian Sea. *In*: Desai, B.N. (Ed.) *Oceanography of the Indian Ocean*, A.A. Balkema, Rotterdam, The Netherlands. 239-245pp.

Vadivelu, S., A. Muralidharan and A. K. Bandopadhyay. 1993. Soils of Lakshadweep Islands. Central Agricultural Research Institute, Port Blair, *Research Bulletin.*

Vargas, J. A. 1988. Community structure of macrobenthos and the results of a macro predator exclusion on a tropical intertidal mud flat. *Revista de Biologia Tropical* (San Jose), **36**(2A): 287-308.

Varshney, P.K. 1985. Meiobenthic study of Mahim (Bombay) in relation to prevailing organic pollution. *Mahasagar- Bull. Natnl. Inst. Oceanogr.*, **18** (1): 27-35.

Vijay Anand, P.E. 1994. Studies on some aspects of biology and ecology of coral reef fishes of Lakshadweep with observations on other coral reef ecosystem, the seas around India. *Ph. D. Thesis* of Cochin University of Science and Technology. 454pp.

Vijay Anand, P. E. and N. G. K. Pillai. 2003. Habitat distribution and species diversity of coral reef fishes in the reef slope of the Kavaratti atoll, Lakshadweep, India. *J. Mar. Biol. Ass. India*, **45** (1): 88-98.

Vijay Anand, P. E. and N. G. K. Pillai. 2005. Occurrence of juvenile fishes on the seagrass beds of Kavaratti atoll, Lakshadweep, India. *Manuscript.*

Vincent, B. 1986. Monthly variation – the community structure of littoral benthos from fresh water in a cold climate. *Hydrobiologia*, **133** (3): 259-270.

Wafar, M. 1997 Carrying Capacity of Coral Reefs . *In*: Hoon, Vinita. (Ed). Proceedings of the SAARC Regional Workshop on the Conservation Sustainable Management of Coral Reefs. MSSRF, Chennai. 26pp.

Walker, D. I. 1988, Methods for monitoring seagrass habitat, Working Paper no. 18, Victorian Institute of Marine Science, Melbourne, Australia, 26 pp.

Wallace, J. H. 1975. The estuarine fishes of the east coast of South Africa. IV. Occurrence of juveniles in estuarines. *S. Afr. Assoc. Mar. Biol. Res. Ocean. Res. Inst. Invest. Rep.*, **42**: 3-18.

Wassenberg, T. J. and B.J. Hill. 1987. Natural diet of the tiger prawns *Penaeus esculentus* and *P. semisulcatus*. *Aust. J. Mar. Freshwater Res.*, **38**: 169-182.

Willems, K.A., Y. Sharma, C. Heip and A. J. J. Sandee. 1984. Long-term evolution of the meiofauna at a sandy station in lake Grevelingen, the Netherlands. *Neth. J. Sea Res.*, 18: 113-117

Williams, D. Mc B., E. Wolanski and J. C. Andrews. 1984. Transport mechanisms and the potential movement of planktonic larvae in the central region of the Great Barrier Reef. *Coral Reefs*, **3**: 229-236.

Williams, S. L., I. P. Gill and S.M. Yarish. 1985. Nitrogen cycling in back reef sediments (St. Croix, U. S. Virgin Islands). *Proc. Fifth Int. Coral Reef Congr.*, **3**: 389-394.

Wolanski, E. and J. Sarsenski. 1997. Larvae dispersion in coral reefs and mangroves. *American Scientist*, **85**: 236-243.

Woodin, S. A. and J. B. Jackson. 1981. Interphyletic competition among marine benthos. *Amer. Zool.,* **19**: 1029 -1043.

Young, D. K. and M.W. Young. 1982. Macrobenthic invertebrates in bare and seagrass (*Thalassia testudinum*) at Carrie Bow Cay, Belize. *In:* Rutzler K., McIntyre IG (Eds) The Atlantic barrier reef ecosystem at Carrie Bow Cay, Belize. 1. Structure and communities. *Mar. Sci.,* **12**: 115-126.