Meiobenthos of Cochin backwaters in relation to macrobenthos and environmental parameters

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Front Cover: Study area
Back Cover: Cochin backwater System

CERTIFICATE

This is to certify that the thesis entitled **Meiobenthos of Cochin backwaters in relation to macrobenthos and environmental parameters** is an authentic record of the research work carried out by Ms. Feebarani John, under my supervision and guidance in the Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology, in the partial fulfillment of the requirements for the degree of **Doctor of Philosophy** in Marine Biology of the Cochin University of Science and Technology and no part thereof has been presented for the award of any other degree, diploma or associateship in any University.

Kochi,
07.05. 2009.

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DECLARATION

I hereby declare that the thesis entitled **Meiobenthos of Cochin backwaters in relation to macrobenthos and environmental parameters** is an authentic work carried out by me under the supervision and guidance of Dr. R. Damodaran, Professor (Rtd.), School of Marine Sciences, Cochin University of Science and Technology for the degree of **Doctor of Philosophy** in Marine Biology of the Cochin University of Science and Technology and no part thereof has been presented for the award of any other degree, diploma or associateship in any University.

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CHAPTER 1

INTRODUCTION

1.1. General Introduction

Estuaries are the magical places where river meets the sea. These are the critical transition zones that link land, fresh water and the sea. They are often characterized as having low salinities, shallow depths, high turbidities, excess nutrients and high productivity. They act as filters for terrestrial pollutants and also provide protection from flooding (Turner *et al.*, 2000). The mixing of fresh and salt water creates a unique environment that brims with life of all kinds. Estuaries are exclusive and unique hot spots of biodiversity. It supports a plethora of organisms. They act as critical reproductive and nursery ground for a variety of organisms. The linkage and gateway function of estuaries between marine and fresh water environment is an essential feature in the life cycle of several invertebrates. They serve as migratory routes for the anadromous and catadromous fishes. The intertidal areas of estuary provide feeding grounds for migratory and resident birds. This integrative processes of tying together terrestrial, fresh water and marine biomes, weave a web of complexity far greater than that of their three contributor systems.

Estuaries have always been at the human doorstep and are one of the most heavily utilized zones in our planet. They are cradle of great civilizations. They play an important role in fisheries, aqua culture, recreation, tourism, transport and waste disposal. They are the focal points of rural, urban and industrial development. The amenities they offer render them as the most valuable national treasures, whose health affects the health and the vibrancy of our community and economy.

Benthic environment is the most wide spread habitat on earth and support high biodiversity and key ecosystem services. The benthos refers collectively to all aquatic organisms, which dwell, in, on or near the bottom of water bodies. The benthos encompasses a huge array of life with many phyla. Their distribution spans from the utmost depth of the ocean to the high tide level and from fresh water through estuaries to the hyper saline tropical coastal lagoons. Generally benthic communities are much more diverse in terms of species richness than those of pelagic realm. Traditionally, the fauna of marine sediments is classified into microfauna, meiofauna and macrofauna by the use of defined sieve sizes, whereby organisms retained on a 500 μ mesh sieve are referred to as macrofauna, organisms having a size between 500 μm and 63 μm are meiofauna and organisms smaller than 63 μm are micro fauna. (Mare,1942; McIntyre,1969; Rees,1984; Bachelet,1990). Three functional groups of benthos could also be recognized. They are the infauna, epifauna and hyper-fauna i.e. organisms living within the substratum, on the surface of the substratum, and just above it respectively.

The benthos are the critical component of shallow water estuarine and coastal marine ecosystems. No aquatic system will function long without a healthy benthic community (Paolo, 2003). They regulate the physical, chemical, and biological environment of the estuary and link the sediment to aquatic food web, through their burrowing and feeding activities. Filter feeders in the benthic community pump large amount of water through their bodies. As they filter this water for food, they clean the water by removing sediments and organic matter. Organic matter that is not used within the water-column is deposited on the bottom of the estuary. Deposit feeders then remineralize it into nutrients, which are then given back into the water column. This remineralization of organic matter is an important source of nutrients to the aquatic environment and is critical in maintaining the high primary production rates of estuaries (Giere, 1993; Brown *et al.*, 2000). Many of the benthic organisms have pelagic larvae, a component of planktonic community and influence considerably in the planktonic food web. It is a well engraved fact that there is always a nexus between the benthic standing crop and the production of exploited demersal fishes and crustaceans (Damodaran, 1972; Parulekar *et al.*, 1980).

Man, the integral part of the ecosystem, began to tame nature and modify it for his own requirements right from his emergence on earth. With the onward march of socio-economic revolutions his interference with nature began to increase, often violating the laws of nature. Dumping of enormous quantities of sewage into the estuary, results in enrichment of estuaries with organic and inorganic nutrients leading to eutrophication problems. Likewise acute and chronic oil pollution in estuaries and coastal marine environment poses severe threat to aquatic communities living there. Indian estuaries like the rest of the world are still not adequately protected from human disturbances, (ENVIS, 1997). Consequently, the evolution of biosphere that occurred through biogenesis over millions of years is now proceeds in tune with the willful activities of the mind and brain of man. Estuaries are now under the grave threats of pollution.

The response of ecosystem to environmental impacts are typically complex and diverse, it has been recognized that chemical and physical measurements are unable to properly assess impacts. The use of faunal diversity as an indicator of health is the most advantageous and cost-effective approach. Biomonitoring refers to the use of biological responses to assess changes in the environment that are often due to anthropogenic activities. The benthic fauna is the most amenable and suitable group to focus on this purpose. These integrate many small negative effects and it is also an indicator of past transient events that may be missed by water quality monitoring programs. Benthic infaunal monitoring is widely accepted as the fundamental step to most recent interdisciplinary studies of contaminant effects on ecosystems. From the monitoring perspective, benthos offer mainly three positive attributes: 1) They are relatively sedentary and long-lived, the infauna cannot avoid exposure to contaminated sediments 2) They occupy an important intermediate trophic position, and 3) Infaunal communities are composed of a diverse array of species which respond differentially to varying environmental conditions, like high mortality of pollution-sensitive species and increasing abundance or frequency of pollution-tolerant species (Weisberg *et al.*,1993). Responses of the infauna are representative of overall ecosystem status, because the infauna generally depends upon and interact with biological process in the water column.

1.2. Significance of the present study

The ecology of macrofauna community structure of Indian coasts has attracted the attention of many ecologists but aspects leading to the meiofauna have not obtained the needed attention so far. The omission of a complete section of the biological spectrum is potentially counter productive. Furthermore their study is important in fishery management. Nematodes usually dominate in all meiofauna samples both in abundance and biomass; and represent the most frequent metazoans. Little is known about the community structure of free-living nematodes inhabiting in Indian estuarine sediments. Very effective effort should be made to study this 'tiny wonders'of the ecosystem.

The accurate and consistent recognition of different zoological taxa is fundamental to all biological investigations whether taxonomic, ecological, physiological or behavioral. Though taxonomy and systematics form the actual basis for all biological sciences, currently taxonomy is on the wane and skilled taxonomists are rapidly decreasing in number, leading to serious questions in the scientific community concerning the preservation of this knowledge. So it is high time to protect this vulnerable branch of science.

Cochin, t*he queen of Arabian Sea*- is the economic and commercial capital of Kerala. Cochin has to unravel a venerable and glorious history before the world. It was one of the finest natural harbors of the east. This in turn paved way for a deluge of sea faring visitors from the Arabs to the Chinese and later from Portuguese, Dutch to British. By the last phase of colonial regime Cochin climbed the heights of fame as a rich commercial center, which utterly nurtured the economy of Kerala.The Cochin consists of cluster of islands. Cochin backwaters, the absolute largesse of nature, were once the only trade ways; dictated 'the queen's history', shaped her presence and promised a future and enabled her to become a precious gem in the necklace of mother India. The palm fringed tranquil backwaters enjoy the rank of one of the biggest backwater system and wintering grounds for migratory waterfowl. The cornucopia of flora and fauna raise this backwater system to a status of esteem and in no way it can be neglected while listing out the most exotic hot spots of India. Presently the backwater is subjected to modern land use planning and management. It is subjected to various threats like reclamation, canalization, siltation and pollution. The health status and the biological diversity of the ecosystem are deteriorating day by day through man-made activities.

The concept of Vallarpadam Container Transshipment Terminal (ICTT) had been hanging fire for the last two decades. Recently India is committed to the development of ICTT at Vallarpadam. The country's first global hub terminal is all set to alter the development map of Kerala, by ushering in huge investment in the coming years. The Vallarpadam ICTT project will be a benchmark in Cochin port development. The Appellate Committee constituted to finalize the rail link from Kochi to the Vallarpadam ICTT site has identified the route through Vaduthala in the suburban area of the city as the most feasible one. As per the above proposal, some portions of the proposed road will create barriers in the Cochin estuary. Land reclamation can have disastrous consequences for the marine and coastal ecosystems. The aim of the study is to determine the present health status of the benthic fauna in the Cochin backwaters, a part of the Ramsar site 'the Vembanadu Lake'. The documentation of the existing conditions within the estuary will provide a quantitative benchmark for tacking any future changes due to disturbances.

Historical data are useful touchstones for the past occurrence of species, which help to trace the biodiversity change that might have occurred over the years. However evolution of benthic community over time has not been thoroughly investigated in Indian screen. Such a comparative study is highly relevant to understand "Is it still the same today"?

These issues are relevant to identify the bottleneck hindering the progress in the estuarine research programs. This study will be useful to assess the past conditions of the estuary; the present changes and plan its future strategy.

1.3. The Objectives of present investigation

In an attempt to address the aforesaid shortcomings, a multi disciplinary investigation was carried out in Cochin backwaters, west coast of India. The specific challenges undertaken to analyse the problem were:

- To characterize the study area in terms of environmental parameters.
- To document, spatial and temporal variation in the functional composition of meiobenthos.
- To characterize the community structure of free-living estuarine nematodes.
- To evaluate the contemporary conditions of macrofauna in the study area.
- To understand the standing stock of meiobenthos and macrobenthos.
- To compare the community structure of macrobenthos of present and past.
- To integrate and evaluate biological information in relation to environmental parameters using statistical tools.

CHAPTER 2

REVIEW OF LITERATURE

Investigations on benthic community have a long history. A literature review was undertaken as an evaluation step for various aspects of benthic research. This review pinpoints an account of past and present benthic research activity from existing scientific informations. Written records of significant biological observations concerning marine organisms began with the early Greek philosophers, most notably Aristotle. Until the renaissance period, very few studies were carried out, since it was the prevailing view that Aristotle had already discovered and described everything. Renewed interest in natural history began to increase by the 16^{th} century and over the next few hundred years, many studies carried out by amateur naturalists. Investigations with respect to benthos advanced well only in the late 18^{th} and early 19^{th} centuries when the use of various dredging devices became popular .

A new era in the benthic study was started during early 1900's. It was connected with the detailed investigations of Petersen (1913, 1915 and 1918) and Petersen and Jensen (1911) along Danish waters. Their works mainly focused on community structure and standing crop of benthic animals. This initiated a number of other investigations on benthic fauna in different parts of the world. But most of these studies were restricted to macrobenthos owing to the relative ease in investigation. The works of Remane (1933), Mare (1942) and Weiser (1953 and 1960) on meiobenthos have been considered as pioneer investigations in the field of meiobenthology. The earlier researchers at some stage struggled to convince the public or those in power, of the values of ecosystems that remain hidden from view.

Jones (1940,1951,1952 and 1956), Blacker (1957), Sanders (1956,1958 and 1968), Wieser (1959 and 1960), McIntyre (1961,1968 and 1969), Bush (1966), Lie (1969), Tietjen (1969), Hulings (1971), Coull (1973), Gray (1978) and Dye (1979) examined the composition and structure of bottom population in relation to environmental parameters. These works were characterized by broad complexity, which raised them to qualitatively higher level.

Peterson (1979), Rhoads and Boyer (1982) and Eckman (1990 and 1996) conducted experiments to test important ecological principles concerned with stability, competition and succession. A number of scientists surveyed intensively on trophic dynamics of benthos; Probert (1984 and 1986), Thomas and Dieter (1998), Marleen (2001), Chindah and Braide (2001), Jan *et al.* (2004) and Jake *et al.* (2005) are worth mentioning.

At present greater access to survey and visualization tools, have given opportunities to study the unique animal assemblages. Studies on population dynamics, reproductive status and size frequency of population, post recruitment survivorship of individuals, community structure and seasonal variation and factors governing the distribution of benthos are innumerable; Bell (1980), Paine and Levin (1981), Gunther (1992), Black (1992), Walsh (1993), Hall (1994), Snelgrove and Butman (1994), Gaines and Lafferty (1995), MC Comb (1995), Levine *et al.* (1996), Eckman (1996), Keough and Black (1996), Richmond and Woodin (1996), Norkko and Bonsdorff (1996), Hagberg and Tunberg(2000), Graham *et al.* (2002),Thomas *et al .(*2002), Alberto and Jaqueline (2002), Rzeznik *et al.* (2003), Jasna Vidakovi´c and Irella Bogut(2004) and Leonardo and Emilio*(*2005) are some of the well documented studies.

In recent times there has been a steady shift in the study of benthic communities from the base line to applied aspects. Considering the vast body of literature available in recent times, only the monumental works has been reviewed here. Published results are available on benthic responses to contamination (Mu *et al.,* 2002; Paolomagni, 2003). Britta Gribsholt and Erik Kristensen (2003) examined benthic metabolism and sulfur cycling. Thomson (1983), Rees and Walker (1983,1984&1988), Norton *et al.* (1984), Carr *et al.* (2000), Schratzberger (2003), Borja *et al.* (2000 and 2004), Mathew *et al.* (2005), Robert *et al.* (2005) and Martin *et al.* (2006) well documented the impact of pollution and pollution monitoring using benthic invertebrates. Melanie (2004) examined the effect of boat generated waves on benthos along Sidney coast. Christian *et al.* (2005) examined the biogeographic provinces of polychaetes along Chile coast. These works are worthy and would be of immense use to the benthic ecologists. Resurvey of historical sampling location to study the long term change in community structure is recently giving curiosity to a handful of scientists. The investigations of Bruce *et al.*(1977), Bradshaw *et al.* (2002), Edgar *et al.* (2004) are worth mentioning. Reports are accessible on evolutionary aspects also; Sorakang *et al.* (2000), Richard *et al.* (2001), Angelika *et al.* (2004), David *et al.* (2005) are of special concern. Currently there is an upsurge of investigations to map the bottom morphology and biocoenoses using advanced techniques. Florian *et al.* (2003) studied the spatial variability of bethic communities by axial tomodensitometry. Matarrese *et al.* (2004) mapped the bottom community using side scan sonar and under water video camera.

Recently univariate and multivariate techniques are being used to trace the community stucture. The reports of Clarke (1993), Maurer *et al.* (1995 and 1998), Warwick and Clarke (1996 and 1998),Somerfield and Clarke (1995 and 1997), Clarke and Warwick (1998), Wilson *et al.* (2001), Maria and Anna (2004) and Emilca *et al.* (2004) Solis *et al.*(2004), Julie and Susan (2006) have been received well in the scientific community.

Though extensive literature is available on the benthos of temperate zones, information along Indian waters is insufficient. Our knowledge of benthic realm lacks behind that of terrestrial environment. Among the limited studies, preponderance of work concentrated on shallow costal waters, intertidal zones and mangrove ecosystems, giving limited attention to estuarine bottom fauna. Investigations of Annandale (1907) in brackish water ponds of Port canning and Bengal turned over a new leaf in the history of Indian benthic explorations. Annandale and Kemp (1915) examined the ecology of benthic fauna of Chilka Lake. Pannikkar and Aiyar (1937) studied the brackish water fauna of Madras.Although studies on bottom living animals have been made on early epoch of 20th century, the qualitative and quantitative work using suitable sampling equipments is comparatively recent.

The knowledge on benthos along east coast of India has increased considerably during recent decades. Ganapathy and Rao (1959) surveyed the benthic fauna in north east coast of India. Harkantra *et al.* (1982) surveyed macrobenthos of the shelf off North-eastern Bay of Bengal. Ingole (2003) investigated the distribution of macrobenthos of central Indian Ocean. Altaff *et al.* (*2005*) studied the impact of tsunami on meiofauna along Chennai beach. AjmalKhan *et al.* (2004) discussed the utility of graphical tools and diversity indices in pollution monitoring studies.AjmalKhan and Murugesan (2005) rewied the polychaete diversity in Indian waters. Ajmal Khan (2006) concentrated studies on environmental impact assessment using benthos. Ingole (2007) examined polychaete diversity of Paradip.

There are a few studies carried out on the bottom communities of the estuaries of the east coast of India.Jayalakshmy *et al.* (2004) conducted a detailed investigation on community structure of foraminifera of Chilka Lake. Ecology of nematodes inhabiting littoral sands of Hoogly estuary was investigated by Sinha and Choudhury (1987). Bandyopadhyay and Datta (1988) studied the population dynamics of benthos of Hoogly estuary. With respect to Godavari- Vasista- Gautami estuarine system, Sarma and Rao (1982) concentrated on the distribution of the *Dendronereis arborifera*. Srinivasa Rao and Sarma (1983) conducted investigations on the distribution of polychaetes in relation to various environmental parameters. Kondala Rao (1984) published a paper on the diversity of harpacticoid copepods in the same area. Murthy and Rao (1987) documented composition and ecological aspects of meiofauna of Gautami-Godavari estuary. Kondala and Murty (1988) conducted a study on meiofaunal diversity in the Gautami- Godavari estuarine system. It is worth mentioning the most outstanding investigations of Anzari *et al.* (1982) during the 94th cruise of R.V.Gaveshi. They collected the bottom samples from the mouth of four estuaries (Godavari, Krishna, Mahanadi and Hoogly) and published papers on comparative studies on macrofauna and meiofauna biocoenoses of these estuaries. Rao (2002) highlighted the impoverished production of meiobenthos of Vasishta-Godavari estuary.

Coming to Gosthani estuary, Annapurana and Ramasarma (1986) foccused on the distribution of ostracods in Binili backwaters of Gosthani estuary. Sunitha (1990) investigated Meiofaunal distribution in relation to hydrography. Meiofaunal density of Gosthni estuary was highlighted by Rao and Sarma (1990). Rao (1994) monitored meiofaunal abundance in relation to environmental constraints in the estuary.

Reddy and Reddy (1994) gave a comprehensive picture of foraminiferal assemblage in Araniar estuary. Distribution of benthic Ostracoda in Adyar estuary was investigated by Hussain and Mohan (2001).

Regarding Vellar estuary, Balasubrahmanyan (1964) and Ajmalkhan *et al.* (1975) are the pioneer researchers in this field. Distribution and seasonal variation of macrobenthos was investigated by Chandran *et al.* (1982). Fernando *et al.* (1984), Chandran (1987) and Srikrishnadas *et al.* (1987) focused on qualitative and quantitative survey of macrofauna.

When we consider Coleroon estuary, Prabha Devi (1986) and Prabhadevi and Ayyakkannu (1989) surveyed macrobenthos of the Buckingham Canal backwaters of Coleroon Estuary. Later Raveenthiranaath Nehru(1990) , Jegadeesan and Ayyakkannu (1992) and Paterson Eward and Ayyakkannu(1992)carried out extensive survey of benthos of this region.

Coming to west coast of India, Kurian (1953) conducted detailed investigations along Travancore coast. Desai and Kutty (1967) conducted a preliminary survey of meiofauna and macrofauna of near shore region of the Cochin. Later Kurian (1967 and 1971) carried out extensive investigations on bottom fauna along southwest coast of India. Damodaran (1972) investigated the meiobenthos of mudbank of Kerala coast. Seshappa (1953) gave an account of bottom fauna of Malabar Coast. Joydas (2002) analyzed the faunal composition of macrobenthos from the shelf regions off the west coast of India. Raghunathan *et al.* (2003) surveyed the impact of turbidity on macrobenthos along selected regions of west coast. Joice and MadhusudanaKurup (2006) investigated the impact of bottom trawling on benthos along the in shore waters off Kerala. Sajan and Damodaran (2007) analyzed the faunal composition of meiobenthos from the shelf regions off the west coast of India.Nanajkar and Ingole (2007) studied the potential of using nematode as indicator organism along central west coast of India. The regulation of sediment granulometry on the community composition of macrobenthos along the continental shelf of south west coast of India was documented by Jayaraj *et al.* (2007).

A number of investigations have been carried out in the estuaries of west coast also. In Kayamkulam estuary effect of hydrogen sulphide on benthic fauna was documented by Gopakumar and Kuttyamma (1999). Nair *et al.* (1984) studied the ecology and distribution of benthic macrofauna in the Ashtamudi estuary. Abdul Azis and Nair (1983) surveyed the meiofauna of the Edava-Nadayara Paravur backwater system and highlighted the effect of coconut retting on meiofauna.

Coming to Vembanad Lake, Devassy and Gopinathan (1970) gave a brief account of the macrofauna and meiofauna, and discussed their relationship with salinity. Jayasree (1971) put an initial step in the meiofaunal investigation at Cochin backwaters. Kurian (1970) and Ansari (1977) studied the bottom community in relation to physical and chemical parameters. Pillai (1977) described the seasonal abundance of macro benthos in relation to sediment properties. Antony (1979) analysed the foraminiferal distribution. Remani *et al.*, (1983) investigated the indicator organisms of pollution. Batcha (1984) investigated the bottom fauna of north Vembanad Lake.The Influence of decaying macrophytes on composition and seasonal abundance of macrobenthos in the Vembanad Lake was investigated by Gopalan *et al* (1987). Sarala Devi and Venugopal (1989) focused on the effect of pollution on macrofuna. Rao and Balasubramanian (1996) gave a detailed attention on forminiferal distribution in Cochin backwaters. Sheeba (2000) investigated the macrofauna of selected mangrove region around Cochin backwaters.

Saraladevi *et al.* (1994) examined benthic production of Korapuza estuary and Beypore estuary. Coming to Netravathi and Gurupur estuary, population dynamics of Meiofauna was investigated by Venkatswamy and Hariharan (1985). Bhat and Gupta (1986) conducted a survey on abundance and dominance of benthos. In Mulki Estuary effect of sediment characteristics on macrobenthos was documented by Ramachandra *et al.* (1984). When we consider Kali estuary, Harkantra (1975) and Bhat and Neelakandan (1984) investigated extensively on macrofaunal composition and salient features in their distribution. Bhat and Neelakandan (1991) carried out some important work on distribution of meiobenthos in relation to environmental parameters.

Parulekar's investigations in Mandovi-Zuari canal system are milestones in the history of benthic exploration. Parulekar *et al.*1973, 1975, 1980 and 1986 and Parulekar and Dwivedi (1975) paid attention on macrofaunal distribution, production, trophic relations and regularities of faunal distribution. He highlighted the need to conserve the fragile ecosystem. Ansari *et al.* (1982 and 1994) examined the feeding habits of macro benthos and meio benthos in Mandovi estuary. Ansari and Parulaker (1993) focused on the distribution and abundance of subtidal meiofauna in the estuary. Ansari *et al.* (2001) concentrated on population dynamics and vertical distribution of meiofauna in Mandovi and Zuari estuarine system.

Varshney *et al.* (1984) examined meiobenthos of polluted and unpolluted environments of Versova, Bombay. Estimation of biological characteristics of the Vashishti Estuary, Maharashtra was carried out by Nair *et al.* (1998). Govindan *et al.* (1983) gave useful information on benthic studies along Gujarat estuaries.

The pursuit of literature make it abundantly clear that enumeration, identification and correlation with some physicochemical factors have historically been the forte of Indian researchers and even these efforts did not make much headway. In other countries, studies advanced by leaps and bounce to an enviable level of achievement. We have also an intervening period of inaction. The present study is an endeavor to bridge this gap.

CHAPTER 3

MATERIALS AND METHODS

3.1. DESCRIPTION OF THE STUDY AREA

Cochin Estuary (Lat. 09^0 30'-$10^0$10' N and Lon. 76^0 15'-$76^0$25' E) is a bar-built estuary constituting a network of shallow canals situated on the southwest coast of India. Although the estuary has two openings at Cochin and Azhikode, the former inlet is wider (450 m) and forms the main entrance to the Arabian Sea. Six rivers and several tributaries discharging 20,000 Mm^3 of freshwater annually in to this estuary, makes it the largest wetlands along west coast of India. Of these, River Periyar draining into the northern region of the estuary has a major influence on the salinity distribution of the estuary (Madhupratap, 1987). Salinity remains near zero over a large part of the estuary during monsoon period; but soon after as river discharge gradually diminishes, salinity gains momentum to play an important role in the ecology of the system (Madhupratap, 1987; Menon *et al.,* 2000).

The sampling was conducted from the following six stations in the Cochin backwaters (Fig: 1).

Stn No.	Name	Latitude	Longitude
1	Thevara	Lat 9^0 55' 35 N	76^0 17' 53 E
2	Mattancherry	Lat 9^0 56' 47 N	76^0 15' 52 E
3	Barmouth	Lat 9^0 58' 26 N	76^0 14' 39 E
4	Marine Science Jetty	Lat 9^0 57' 39 N	76^0 16' 40 E
5	Bolghatty	Lat 9^0 58' 52 N	76^0 15' 50 E
6	Varapuza	Lat 10^0 4' 30 N	76^0 16' 48 E

3.2. PERIOD OF INVESTIGATION

The Research Vessel 'King fisher' was used as conveyance for the sample collection. The survey period consisted of two phases. During the first phase (July 2002-June 2003) monthly collection of samples was done. In the second phase (July 2003-May 2004) seasonal sampling was carried out. Altogether 15 collections were done.

For the sake of interpretation, the data collected were pooled together based on the seasons and subjected to further analyses. A calendar year was divided into 3 distinct seasons viz.,

i. Monsoon (June- September)

ii. Post-monsoon (October -January)

iii. Pre-monsoon (February -May)

3.3. ANALYSIS OF PHYSICOCHEMICAL PARAMETERS

Water samples for hydrographic data were collected at three intervals (surface, subsurface (0.5m depth) and bottom) along the water column. An ordinary clean plastic bucket was used to collect surface water. Subsurface and bottom samples were collected using Niskins Water Sampler. The analysis of following parameters was done in standardized way.

3.3.1. Depth (m)

The depth of the water column was measured by dead reckoning method using a lead weight connected to a graduated rope marked in centimeters.

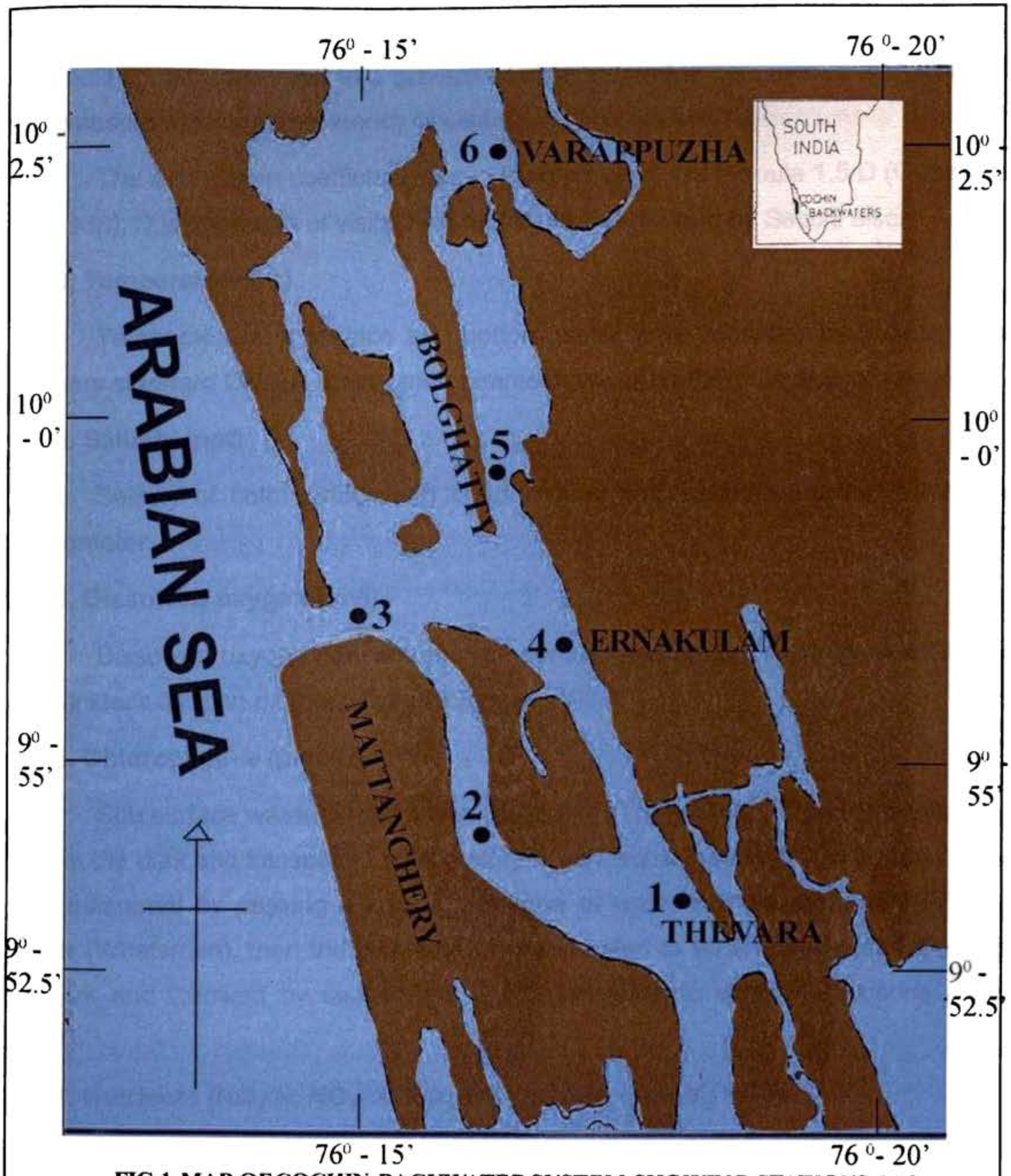


FIG. 1 MAP OF COCHIN BACKWATER SYSTEM SHOWING STATIONS 1 - 6

3.3.2. Water transparency

A secchi disc of 30 cm diameter painted black and white in alternate sectors with ballast and connected to a graduated rope marked in centimeters was used for the measurement of transparency of water.

The attenuation coefficient was calculated using the formula 1.5/D (Quasim *et al.,* 1968); D is the depth of visibility in meters as determined by Secchi disc.

3.3.3. Temperature (^{0}c)

Temperatures of surface and bottom water were recorded by means of an ordinary standard Celsius thermometer immediately after the collection of samples.

3.3.4. Salinity (ppt)

Salinity of both surface and bottom water was estimated using E-2 model salinometer.

3.3.5. Dissolved oxygen (ml/l)

Dissolved oxygen concentration of surface and bottom water was estimated by Winkler's titration method (Grasshoff *et al.,* 1983)

3.3.6. Chlorophyll- *a* (µmol/l)

Sub surface water samples were collected in black colored plastic containers, kept in the dark and transported to laboratory in an icebox.Chlorophyll -*a* concentration was estimated by passing a known volume of water sample through GF/F filter paper (Whatsman), then the pigments were extracted in 90% acetone at 4^{0}C for 24 hr dark and followed by subsequent spectrophotometric analysis (Parsons *et al.,* 1984).

3.3.7. Nutrients (NO_2-N, NO_3- N, PO_4-P & SiO_3-Si) (µmol/l)

The surface and bottom samples were collected in clean plastic bottles and transported to the laboratory in an icebox and analysis of Nitrite-Nitrogen (NO_2-N), Nitrate - Nitrogen (NO_3-N), Phosphate -phosphorus (PO_4-P) and Silicate-Silicon (SiO_3-Si) were done in standardized methods (Grasshoff *et al.,*1983).

3.4. ANALYSIS OF SEDIMENT CHARACTERISTICS

After the collection of water samples, Sediment samples (quadruplicate) were collected with a 0.05m^2 van Veen Grab. To estimate the interstitial water content, soil texture and total organic carbon about 100gms of well-mixed sediment samples were sub sampled from each station from respective grab haul. The samples were transferred into cleaned labeled polythene bags and transported to laboratory in an icebox.

3.4.1. Sediment temperature (^{0}c)

Temperature of the sediment was recorded by means of a standard Celsius thermometer, immediately after the collection of sediment samples.

3.4.2. Interstitial water content

Interstitial water content was measured by first taking wet weight of a known quantity of sediment, and then dried it to a constant weight at 110^{0}c and reweighed. Wet weight minus dry weight was interpreted as a rough estimate of the weight of the interstitial water content, from which the percentage of interstitial water was calculated.

3.4.3. Texture analysis

The sediment samples were subjected to Pipette Analysis by standard method (Krumbein and Pettijohn, 1938). The percentage composition of each grade (Sand, Silt and Clay) was calculated and plotted on triangular graphs based on the nomenclature suggested by Shepard (1954).

3.4.4. Organic carbon and Organic matter

The organic carbon content in sediment samples was analyzed using the standard method (Walkley and Black, 1934). The amount of organic matter in the sediment is obtained by multiplying the organic carbon values by a factor of 1.724(Trask, 1939).

3.5. ANALYSIS OF BIOLOGICAL SAMPLES

3.5.1. MEIOFAUNA

3.5.1.1. Collection, extraction, enumeration and identification of meiofauna

15 cm long graduated glass corer with an inner diameter of 2.5cm was used to sub sample meiofauna from 0.05m^2 van Veen Grab grab hauls. Duplicate core samples were taken at each station from separate grab hauls. The corer was inserted into the undisturbed sediment, to a depth of 8cm. All sediment cores were vertically subdivided at site into the following depth horizons: 0-2, 2-4, 4-6 and 6-8. Each slice was transferred into separately labeled plastic containers containing 4% neutral formalin and transported to the laboratory.

The sediment containing the meiofauna was stained with Rose Bengal biological stain (0.1g in 100 ml of distilled water). Later the sediment were seived through a set of two sieves, the top one with a mesh size of 0.500mm and the bottom one with 0.063mm mesh size. The filtrate retained by the fine screen was transferred into pertridishes containing water. The organisms were separated and enumerated using a binocular microscope and preserved in 4 % neutral formalin. The numerical abundance of organisms was extrapolated in to no/10cm^2. The nematodes were identified upto genus level; however a few were attempted up to species level. The rest of the organisms were examined upto major taxa. The organisms appearing in small numbers were pooled and categorized as 'others'.

3.5.1.2. Biomass estimation of meiofauna

The wet weight of 50-100 representative of each group of organisms was estimated using high sensitive Sartorius electronic balance. From this the average wet weight of single organism and the biomass of entire community can be calculated. The biomass was expressed in mg/10 cm^2.

3.5.1.3. Permanent slide preparation and Identification of nematodes

From each station hundred nematodes were randomly selected for identification during each collection. In the case of samples with low densities all specimen were taken.

Nematodes were transferred into a cavity block containing Seinhorst solution 1 (95% ethanol, glycerin and distilled water in the ratio 20:1:79) and kept the vial in a desiccator and left overnight in an incubator at 35-40^0C. This will allow all the water in suspension with the nematodes replaced with ethanol. In the next day the vial was refilled with seinhorst II solution (95% ethanol and glycerin in the ratio 95:5). By the next day the organisms were impregnated in pure glycerin and ready for mounting in slides.

Bee's wax was melted at about 60^0C. A 10 cm long cross cut metal tube with smooth, thin ring and slightly smaller diameter than the cover slips was heated at one end. Then the heated end was pushed down vertically into the melted bees wax so that it get covered by melting wax, and then pressed the end down vertically on the middle of the glass slide. A small drop of pure glycerin should be added to the center of this wax ring. The specimens were transferred to the glycerin drop. Five to ten nematodes were mounted per slide. Glass rods of an appropriate diameter were kept at four corners of the glycerin drop, under a stereo microscope then the specimen were pushed into the bottom of the glycerin drop with fine needle, made sure none overlapped with one another. Dropped another cover slip over the wax ring and the glycerin drop and put the slide above a small flame, allowed the wax to melt around the glycerin drop. Once the wax was set, it acted both as seal and a separating layer between the cover slips. It was then used for the preparation of Cobb's aluminum slide, which consists of an aluminum carrier supporting two cover slips between which the specimens were sandwiched and sealed; so that they can be turned over and observed from both sides at high power. The detailed examination of the prepared slides was done using a high power microscope, equipped with a 100X oil immersion lens.

The nematodes were mostly identified upto genus level with very few upto species level. Taxonomic fixing of the free-living nematodes were carried out by using Lunds Chile expedition reports (Wieser, 1953, 1954 and 1956) and synopsis of free living marine nematodes 1,11 and 111 (Platt and Warwick, 1983, 1988 and 1998). The illustrated keys by different authors and CDs (Darwin nematode identification project-electronic nematode identification key) were also used. The identifications were confirmed by expertise at University of Gent, Belgium.

3.5.2. MACROFAUNA

3.5.2.1. Collection, extraction, enumeration and identification of macrofauna

Concurrent macrofauna samples were also collected. Four grab hauls were taken from each station. The collected samples were emptied into a plastic tray and well mixed with water. The larger organisms were picked out immediately from the sediment. Macrobenthos was extracted by washing the samples through a 0.5 mm mesh sieve until all fine sediment was washed away; and the material retained in the sieve was stored in a labeled plastic container and fixed with 5 % neutral formalin.

In the laboratory the sediment was stained with Rose Bengal biological stain (0.1g in 100 ml of distilled water) and re-sieved using 0.5mm sieve to remove the residual sediment and formalin. The residue in the sieve was then transferred into

Petri dishes. The organisms were extracted and preserved in 5% neutral formalin for further analysis.

Specimens were identified to the lowest possible taxonomic level.The number of each organism was enumerated. The numerical abundance was expressed in no/0.1m^2.Only organism that were determined to be alive at the time of collection were counted. Many of the bivalves and gastropods had to be opened to confirm staining of biological tissue. Numerous taxonomic references were used for identification.The most often used were Fauvel (1953), Day (1967) and Boggemann (2005).

3.5.2.2. Biomass estimation of macrofauna

Wet weight of each sample was determined using a monopan electronic balance. Biomass values were based on blotted wet weight, excluding hard parts. Biomass of polychaetes, mollusc and crustaceans were taken separately and that of minor groups were pooled and represented as 'others'. The biomass was expressed in gm/m^2. The individual organisms having wet weight more than 0.5g/0.05m^2 were not extrapolated into 1.00 m^2 instead, taken as such in order to avoid a biased picture. Wet weights of major taxonomic groups were converted into dry weight with the conversion factors developed by Parulekar *et al.* (1980). For polychaetes, crustaceans, molluscs and miscellaneous faunal groups the conversion factors were 0.119, 0.141, 0.062 and 0.09 respectively.

3.6. STATISTICAL ANALYSIS

The computer programme PRIMER v.5 (Plymouth Routines in Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory (Clarke and Warwick, 1994; Clarke and Gorley, 2001) was used for statistical analysis. Statistical methods for analyzing the benthic community fall under the following three techniques namely, univariate analyses, distributional techniques and multivariate analyses.

3.6.1. Univariate Methods

This analysis collapse the full set of species counts for a sample in to a single coefficient. The following diversity indices were computed for the estimation of community structure of nematodes and macro fauna.

3.6.1.1. Margalef's index (d) is the measure of total number of species present in a given number of individuals.

$$d = (S-1) / \log N$$

Where N= total number of individuals. S= total number of species

3.6.1.2. Shannon – Wiener index (H') is a measure of species diversity

$$H' = -\Sigma_i P_i \log (P_i)$$

P_i = proportion of the individuals belonging to the ith species.

3.6.1.3. Pielou's evenness index (J') is the relative abundance or proportion of individuals among the species.

$$J' = H'/\text{Log}(S)$$

Where H' = Shannon – Wiener diversity S = total number of species

3.6.1.4. Simpson's index (l-λ') is a measure of Species dominance

$$1-\lambda'=1-\{\Sigma_i Ni (Ni-1)\}/ \{N (N-1)\}$$

Where, Ni is the number of individuals of species $_i$

3.6.2. Multivariate techniques

Multivariate methods of classification and ordination compare communities on the basis of the identity of the component species as well as their relative importance in terms of abundance or biomass. For multivariate analysis, the data were subjected to a square root transformation and similarity matrices were obtained using the Bray –Curtis similarity coefficient.

3.6.2.1. Cluster analysis

In multivariate analysis the commonly used classification method is cluster analysis. Classification analyses assign entities to groups. The most commonly used clustering technique is the hierarchical agglomerative method. The results of this are represented by a tree diagram or dendrogram with the x- axis representing the full set of samples and the y-axis defining the similarity level at which the samples or groups were fused.

3.6.2.2. MDS (non - metric Multi Dimensional Scaling)

Ordination techniques used in the present study was multidimensional Scaling (MDS). This method assigns entities spatially so that similar entities are close and dissimilar ones are distant.

3.6.3. Draftsman plot

This technique was used to check the interrelation between different environmental variables in the present study. The correlation matrix provides the co-linearity between variables indicated by a straight-line relationship with little scatter.

3.6.4. BIO – ENV procedure

In the present study, to ascertain the relationship between biological and environmental variables, the BIO-ENV procedure was employed. The basic principle behind this is to measure the agreement between the rank correlations of the biological (Bray-Curtis similarity) and environmental (Normalized Euclidean distance) matrices. A Spearman rank correlation coefficient (ρs) was used to determine the harmonic rank correlation between the biological matrix and all possible combinations of the environmental variables.

$$\rho s = 1 - \frac{6}{N\,(N^2-1)} \sum_{i=1}^{N} \frac{(ri - si)^2}{ri + si}$$

The influence of water qualities like depth (m), turbidity, water temperature (^{0}C), salinity (ppt), pH, DO (ml/l), NO_2-N (μmol/l), NO_3-N (μmol/l), PO_4-P(μmol/l), SiO_3-Si(μmol/l) and chlorophyll-*a* (μmol/l); and the sediment properties like sand (%),silt (%),clay(%),organic carbon C(%),sediment temperature (^{0}C) and interstitial water content (%) on biota were also analysed using BIOENV technique.

3.6.5. Distributional/ graphical techniques

The ABC method involves plotting of separate k - dominance curves for species abundances and species biomasses on the same graph and making a comparison of the forms of these curves. The species are ranked in the order of importance in terms of abundance or biomass on the X- axis (logarithmic scale) with percentage dominance on the Y- axis (cumulative scale). Cumulative plot is often referred to as a k - dominance curve. In undisturbed communities the k-dominance curve for biomass lies above the curve for abundance for its entire length. As pollution becomes more severe, benthic communities become increasingly dominated by one or a few very small species and the abundance curve lies above the biomass curve throughout its length. This is the basis of the ABC method of determining levels of disturbance on benthic macrofaunal communities.

CHAPTER 4

HYDROGRAPHY

4.1. INTRODUCTION

Aquatic ecosystem is a complex one comprising of interacting physicochemical and biological component whose dynamics are often integrated. Organisms are totally dependent upon the environment for their sustenance. The highly variable physicochemical environment caused by the mixing of marine and fresh water stresses most animals in the estuary. Estuarine organisms have different tolerance and response to different physicochemical parameters. A comprehensive knowledge of various physicochemical parameters is imperative to document the community structure of benthos. This chapter describes the important physico-chemical features that shape the character of the study area. The estuary is subjected to distinct seasonality in the physicochemical parameters due to strong southwest monsoon. The monthly data were pooled together for seasons to the analysis. Spatial and temporal fluctuations of various physicochemical parameters are documented in respective tables and figures.

4.2. RESULTS

4.2.1. Depth

At station 1, the depth varied between 1.84(monsoon) and 2.43m (post-monsoon). With respect to station 2, it varied from 3.03 (pre-monsoon) to 3.2m (monsoon). At station 3, it ranged from 4.24 (monsoon) to 5.33 m (post-monsoon). In station 4, the depth values fluctuated from 2.4 (monsoon) to 2.91m (post-monsoon). With respect to station 5, it varied between 3.53 (monsoon) and 3.8m (post-monsoon). As far as station 6 is concerned the depth fluctuated from 4.02 (monsoon) to 4.22 m (post-monsoon). The average values of depth at stations 1 to 6 were 2.1m, 3.1 m, 4.9 m, 2.6 m, 3.7 m and 4.1 m respectively (Table: 4.1 and Figure: 4.1). As sampling was not possible at uniform tidal condition, the depth recorded will have the impact of tide.

4.2.2. Turbidity

At station 1, the turbidity varied between 2.19 (post-monsoon) and 3.52 (monsoon). In station 2, it varied from 1.76 (post-monsoon) to 2.58 (monsoon). At station 3, it ranged from 1.45 (pre-monsoon) to 2.29 (monsoon). In station 4, the turbidity values fluctuated from 1.73 (post-monsoon) to 2.74 (monsoon). With respect to station 5, it varied between 1.36 (post-monsoon) and 2.5 (monsoon). As far as station 6 is concerned the turbidity values fluctuated from 1.67 (post-monsoon) to 2.07 (pre-monsoon). The average values of turbidity at stations 1 to 6 were 3.02, 2.08, 1.82, 2.18, 1.83 and 1.82 respectively (Table: 4.2 and Figure: 4.2).

4.2.3. Water temperature

At stations 1, 2 and 3 the surface water temperature varied from 29°C (monsoon) to 31°C (pre-monsoon). In station 4, it ranged between 29°C (monsoon) and 30°C (post-monsoon). At station 5, the surface water temperature varied from 29°C (monsoon) to 31°C (post-monsoon). In station 6, it fluctuated from 29°C (monsoon) to 32°C (pre-monsoon) (Table: 4.3 and Figure: 4.3).

At stations 1, 2 and 3 the bottom water temperature varied from 29°C (monsoon) to 31°C (pre-monsoon). In station 4, it ranged between 28°C (monsoon) and 30°C (pre-monsoon). At station 5, it fluctuated from 28°C (monsoon) to 31°C (pre-monsoon). In station 6, it ranged between 28°C (monsoon) and 32°C (pre-monsoon) (Table 4.4 and Figure 4.4).

The average values of surface water temperature at stations 1 to 6 were 29.9^{0}c, 29.8^{0}c, 29.4^{0}c, 29.5^{0}c, 29.8^{0}c and 30^{0}c respectively; and that of bottom water temperature is 30^{0}c, 29.4^{0}c, 29.4^{0}c, 29.4^{0}c, 29.8^{0}c and 29.9^{0}c correspondingly.

4.2.4. Salinity

At station 1, the surface salinity varied between 7 (monsoon) and 20 ppt (pre-monsoon). In station 2, it varied from 9 (monsoon) to 27 ppt (pre-monsoon). At station 3, it ranged from 10 (monsoon) to 28 ppt (pre-monsoon). In station 4, the salinity values fluctuated from 10 (monsoon) to 29 ppt (pre-monsoon). With respect to station 5, it varied between 7 (monsoon) and 20 ppt (pre-monsoon).As far as station 6 is concerned the surface salinity values fluctuated from 0.6(monsoon) to 1(pre-monsoon) (Table:4.5 and Figure : 4.5).

At station 1, the bottom salinity varied between 7 (monsoon) and 24 ppt (pre-monsoon). In station 2, it varied from 12 (monsoon) to 33 ppt (post-monsoon). At station 3, it ranged from 12 (monsoon) to 34 ppt (post-monsoon). In station 4, the salinity values fluctuated from 16 (monsoon) to 34 ppt (post-monsoon). With respect to station 5, it varied between 13 (monsoon) and 27ppt (post-monsoon). As far as station 6 is concerned the bottom salinity values fluctuated from 2 (monsoon) to 8ppt (pre-monsoon) (Table: 4.6 and Figure: 4.6).

The average values of surface water salinity at stations 1 to 6 were 15 ppt, 21 ppt, 22 ppt, 22 ppt, 14 ppt and 1 ppt respectively and that of bottom water were, 18 ppt at station 1, 24 ppt at station 2, 26 ppt at stations 3 and 4 and 22 ppt at station 5 and 5ppt at station 6.

4.2.5. pH

At station1, the surface water pH varied between 7.27 (monsoon) and 7.74 (pre-monsoon). At station 2, it ranged from 7.38(monsoon) to 7.98(pre-monsoon). In station 3 the pH fluctuated from 7.36 (monsoon) to 7.98 (pre-monsoon). As far as station 4 is concerned, it fluctuated from 7.22(monsoon) to 7.95(pre-monsoon). The station 5 registered the minimum value of 7.32 (monsoon) and the maximum value of 7.63 (pre-monsoon). Coming to station 6 pH ranged from 5.46(pre-monsoon) to 6.46 (monsoon) (Table: 4.7 and Figure: 4.7).

At station 1, the bottom water pH varied between 7.31(monsoon) and 7.81 (pre-monsoon). In station 2, it ranged from 7.34(monsoon) to 7.92 (post-monsoon). At station 3 the pH fluctuated from 7.49 (monsoon) to 8.14 (pre-monsoon).In station 4, it fluctuated from 7.6 to 8.04 (post-monsoon).The station 5 registered the minimum value of 7.36 (monsoon) and the maximum value of 8 (pre-monsoon). Coming to station 6 it ranged from 6.48(monsoon) to 7.12 (pre-monsoon) (Table: 4.8 and Figure: 4.8).

The average values of surface water pH were 7.6 at station 1, 7.7 at stations 2, 3 and 4, 7.5 at station 5 and 5.84 at station 6; and that of bottom water at stations 1 to 6 were 7.57, 7.7, 7.85, 7.85, 7.73 and 6.79 respectively.

4.2.6. Dissolved Oxygen (DO)

At station 1, the dissolved oxygen of surface water varied from 2.59 (pre-monsoon) to 4.22 ml/l (post-monsoon). At station 2, it fluctuated from 2.6 (pre-monsoon) to 3.89 ml/l (monsoon). At station 3, it ranged between 2.97 (pre-monsoon) and 3.7 ml/l (monsoon). In station 4,it varied from 2.91 (pre-monsoon) to 3.89 ml/l (monsoon). With respect to station 5, it ranged from 3.48(pre-monsoon) to 3.92 ml/l (post-monsoon). Coming to station 6, the dissolved oxygen of surface water varied from 3.48(pre-monsoon) to 4.2 ml/l (monsoon) (Table: 4.9 and Figure: 4.9).

At station 1, the dissolved oxygen of bottom water varied from 3.17 (pre-monsoon) to 4.07 ml/l (monsoon). In station 2, it fluctuated from 3.26 (pre-monsoon) to 3.81 ml/l (monsoon). At station 3, it ranged between 3.84 (pre-monsoon) and 3.89 ml/l (monsoon). In station 4, it varied from 3.08 (pre-monsoon) to 3.85 ml/l (post-monsoon). With respect to station 5, it ranged from 3.22 (pre-monsoon) to 3.68 ml/l (monsoon). Coming to station 6, the dissolved oxygen of surface water varied from 3.59(pre-monsoon) to 4.71 ml/l (monsoon) (Table: 4.10 and Figure: 4.10).

The average values of dissolved oxygen of surface water at different stations were 3.66 ml/l at station 1, 3.39 ml/l at station 2, 3.26 ml/l at station 3, 3.5 ml/l at station 4, 3.71 ml/l at station 5 and 3.9 ml/l at station 6. The average value of DO of bottom water at stations 1 to 6 were 3.7 ml/l, 3.6 ml/l, 3.86 ml/l, 3.48 ml/l, 3.49 ml/l and 4.27 ml/l respectively.

4.2.7. Nitrite-Nitrogen (NO_2-N)

At station 1, the nitrite content of surface water varied from 0.68 (post-monsoon) to 2.59 µmol/l (pre-monsoon). With respect to station 2, it ranged between 0.5(post-monsoon) and 0.61 µmol/l (pre-monsoon). In station 3, it fluctuated from 0.53 (post-monsoon) to 0.92 µmol/l (pre-monsoon).At station 4,the NO_2-N content varied from 0.41(post-monsoon) to 1µmol/l (monsoon).In station 5 the level varied between 1.04 µmol/l (pre-monsoon) and 1.83 (monsoon). At station 6, it fluctuated from 0.43 (post-monsoon) to 2.11 µmol/l (monsoon) (Table: 4.11 and Figure: 4.11).

At station 1, the nitrite content of bottom water varied from 0.43 (post-monsoon) to 1.27 µmol/l (pre-monsoon). In station 2,it ranged between 0.51(post-monsoon) and 0.81µmol/l pre-monsoon). At station 3, it fluctuated from 0.44 (post-monsoon) to 0.81 µmol/l (pre-monsoon). At station 4, the NO_2-N content varied from 0.57(post-monsoon) to 1.19 µmol/l (monsoon). In station 5 the level varied between0.69µmol/l (post-monsoon) and 0.75 (monsoon). At station 6, it fluctuated from 0.57 (pre-monsoon) to 2.06 µmol/l (monsoon) (Table: 4.12 and Figure: 4.12).

The average values of nitrite concentration in surface water observed for stations 1 to 6 were 1.43 µmol/l, 0.58 µmol/l, 0.73 µmol/l, 0.75µmol/l,1.2 µmol/l and 1.01µmol/l respectively and that of bottom water were 0.94 µmol/l at station1, 0.67 µmol/l at station 2, 0.65 µmol/l at station 3, 0.91µmol/l at station 4, 0.72 µmol/l at station 5 and 1.12 µmol/l at station 6.

4.2.8. Nitrate - Nitrogen (NO_3 - N)

At station 1, the surface water NO_3 - N level ranged from 4.37 (post-monsoon) to 10.68 µmol/l (monsoon). With respect to station 2, it varied between 2.87 (pre-monsoon) and 7.87 µmol/l (monsoon). In station 3, the NO_3- N content ranged between 5.33 (pre-monsoon) and 10.32 µmol/l (monsoon). In station 4, it ranged from 3.11 (pre-monsoon) to 7.71 µmol/l (monsoon). The station 5 registered a minimum value of 3.24 (pre-monsoon) and a maximum value of 11.64 µmol/l ((monsoon). At station 6, it fluctuated from 9.37 (pre-monsoon) to 22.17µmol/l (monsoon) (Table: 4.13 and Figure: 4.13).

At station 1, the bottom water NO_3- N level ranged from 2.88 (pre-monsoon) to 9.37 µmol/l (monsoon). In station 2, it varied between 2.29 (post-monsoon) and 7.26 µmol/l (monsoon). At station 3, the NO_3- N content ranged between 2.5 (pre-monsoon) and 10.79 µmol/l (monsoon). In station 4, it ranged from 3.57 (pre-monsoon) to 9.14 µmol/l (monsoon). The station 5 registered a minimum value of 2.35 (post-monsoon) and a maximum value of 9.6 µmol/l (monsoon). At station 6, it fluctuated from 6.11 (pre-monsoon) to 18.01 (monsoon) µmol/l (Table: 4.14 and Figure: 4.14).

The average values of NO_3- N concentration in surface water were 6.91µmol/l at station 1, 5.15µmol/l at station 2, 7.38µmol/l at station 3, 5.7 µmol/l at station 4, 6.68µmol/l at station 5 and 15.9µmol/l at station 6 and that of bottom water were 5.4µmol/l, 4.26µmol/l, 5.02µmol/l, 5.56µmol/l, 5.18µmol/l and 12.7 µmol/l respectively at stations 1 to 6.

4.2.9. Phosphate - phosphorus (PO4-P)

At station1, the PO_4-P level of surface water ranged between 1.91 (monsoon) and 3.59 µmol/l (pre-monsoon). With respect station 2, it fluctuated from 0.82 (pre-monsoon) to 1.53 µmol/l (monsoon). In station 3, the level varied from 0.97 (post-monsoon) to 1.33 µmol/l (monsoon). In station 4, it ranged between 0.86 (post-monsoon) and 1.47 µmol/l (pre-monsoon). With respect to station 5, the level of PO_4-P ranged from 1.07 (pre-monsoon) to 2.13 µmol/l (monsoon). At station 6, it fluctuated from 0.61 (pre-monsoon) to 4.38 µmol/l (post-monsoon) (Table:4.15 and Figure:4.15).

At station1, the PO_4-P level of bottom water ranged between 1.99 (pre-monsoon) and 2.13 µmol/l (monsoon). At station 2, it fluctuated from 1.05 (pre-monsoon) to 1.87 µmol/l (monsoon).At station 3, the level varied from 0.81 (pre-monsoon) to 1.83 µmol/l (monsoon).In station 4, it ranged between 0.90 (post-monsoon) and 2.00 µmol/l (monsoon).With respect to station 5, the level of PO_4-P ranged from 1.16 (pre-monsoon) to 2.19 µmol/l (post-monsoon).At station 6, it fluctuated from 0.58 (pre-monsoon) to 6.17µmol/l(post-monsoon) (Table:4.16 and Figure 4.16).

The average values of phosphate concentration in surface water at stations 1 to 6 were 2.5µmol/l,1.18µmol/l,1.1µmol/l,1.23µmol/l,1.6µmol/l and 2.1µmol/l respectively and that in bottom water were 2.06 µmol/l at station 1, 1.35 µmol/l at station 2, 1.2µmol/l at station 3, 1.46µmol/l at station 4, 1.73 µmol/l at station 5 and 2.67µmol/l at station 6.

4.2.10. Silicate-Silicon (SiO_3-Si)

At station 1, the silicate content of the surface water fluctuated from 20.55 (pre-monsoon) to 69.91 µmol/l (monsoon). With respect to station 2, it varied from 11.51 (pre-monsoon) to 59.02 µmol/l (monsoon). At station 3, it fluctuated between 14.71 (pre-monsoon) and 77.06 µmol/l (monsoon).At station 4, it varied from 13.34 (post-monsoon) to 43.97 µmol/l (monsoon).With respect to station 5, the SiO_3-Si concentration ranged between 20.54 (pre-monsoon) and 57.96 µmol/l (monsoon). At station 6, it fluctuated from 22.73 (pre-monsoon) to 54.01µmol/l (monsoon) (Table: 4.17 and Figure: 4.17).

At station 1, the silicate content of the surface water fluctuated from 14.99 (pre-monsoon) to 73.29 µmol/l (monsoon). With respect station 2, it varied from 8.72

(pre-monsoon) to 60.57 μmol/l (monsoon). In station 3, it fluctuated between 11.12 (pre-monsoon) and 65.13 μmol/l (monsoon). At station 4, it varied from 13.99 (post-monsoon) to 49.4 μmol/l (monsoon). With respect to station 5, the silicate content ranged between 14.06 (pre-monsoon) and 49.36 μmol/l (monsoon). At station 6, it fluctuated from 22.43 (pre-monsoon) to 57.48μmol/l (monsoon) (Table: 4.18 and Figure: 4.18).

The averages of silicate concentration in surface water at stations 1 to 6 were 42.69, 34.45, 38.26, 24.37, 37.64 and 33.7μmol/l respectively and that of bottom water were 40.69μmol/l at station 1, 27.5μmol/l at station 2, 32.24 μmol/l at station 3, 26.08μmol/l at station 4, 31.87 μmol/l at station 5 and 37.87μmol/l at station 6.

4.2.11. Chlorophyll- *a*

In station1, the Chlorophyll - *a* content of the sub surface water ranged between 10.05 (pre-monsoon) and 14.53 μmol/l (post-monsoon). At station 2, it fluctuated from 4.11 (pre-monsoon)) to 8.19 μmol/l (post-monsoon). With respect to station 3, the Chlorophyll content varied between 4.3 (post-monsoon) and 8.82 μmol/l (monsoon). At station 4, the levels fluctuated from 4.14 (pre-monsoon) to 6.57 μmol/l (monsoon). In station 5, it ranged between 4.87 (post-monsoon) and 7.3 μmol/l (pre-monsoon). At station 6, it fluctuated from 4.3 (monsoon) to 5.23 (pre-monsoon) μmol/l. The average values of chlorophyll a concentration at stations 1 to 6 were 12.08, 6.76, 6.08, 5.49, 6.77 and 4.71μmol/l respectively (Table: 4.19 and Figure: 4.19).

4.2.12. Draftsman plot

In order to determine the correlation between different environmental parameters Draftsman plot was drawn (Figure:4.20).Strong positive correlations were obtained for attenuation coefficient and chlorophyll content(0.849), water temperature and PO_4-P(0.879), temperature and SiO_3-Si (0.872), water temperature and sediment temperature (0.889), salinity and pH (0.996), DO and NO_2-N (0.822), NO_2-N and NO_3-N (.807), NO_2-Nand PO_4-P (0.855), PO_4-P and sediment temperature (0.957).

4.3. DISCUSSION

Water quality is a vital aspect for the survival and well being of estuarine organisms. Hydrographical conditions in the estuarine system mainly depend on the interaction of the seawater, freshwater, wind, rainfall, water current and tidal forces. Since the seawater is dominating during the summer and the fresh water during the monsoon months there is a seasonal pattern in the variations of different parameters.

Water clarity is a major determinant of the condition and productivity of an aquatic system. Turbidity is an important parameter for estuarine monitoring since this will give an idea about sedimentation in the estuary. Greater the amount of suspended solids in the water higher the measured turbidity. Suspended sediment can smother the benthic organisms and its habitats when it settles. The minimum value for turbidity was found during post monsoon and maximum during monsoon season. The alluvial coastal belt of Kerala is packed up with laterite mass of fine material. During the monsoon period, when the freshets from rivers containing large amounts of finer clay particles, flowed into the estuary, the turbidity generally increases to a high level and the low intensity of solar radiation makes the water less transparent. During the post monsoon period the land runoff decreases and intensity of solar radiation increases which makes the water more transparent. These observations are synchronized well with Sarala (1986).

Temperature is one of the most common ecological factors influencing all the activities of an organism. It acts as the limiting factor for growth and distribution of animals. It interacts with many other ecological factors and results in many climatic changes. The temperature in estuarine environment is largely influenced by changes in air temperature, intensity of solar radiation, evaporation, and freshwater ingression In the present study, the water temperature showed monsoonal minimum and pre-monsoonal maximum. The higher temperature during the pre-monsoon period is due to intense solar radiation. The fall in water temperature noticed during the monsoon season is due to the cold weather and rainfall. The water was nearly vertically isothermal with in the estuary. The northern limb of estuary registered a slight increase in the temperature when compared to the southern limb; this may be due to its proximity to industrial discharge.

Salinity was noticed as the major environmental variable in the present study. It varied from place to place, season-to-season and surface to bottom. It was highest near the mouth of the estuary and at upstream where fresh water flows in it was lowest. The distribution of salinity was seasonal. During monsoon, the entire estuary attains near freshwater conditions. The strong flow of fresh water in to the estuary declines the salinity during monsoon period. The post-monsoon was presenting a trend of recovery. An appreciable vertical gradient in salinity was observed at all stations. The observed changes in salinity were primarily due to various causes like annual variation in precipitation, temperature, evaporation, wind, increase of fresh water and tidal action. The present findings are in affirmative with Chandramohan (1990) and Saravanan (1999).

pH remained slightly alkaline throughout the study period at stations 1 to 5.However, Station 6 was slightly acidic nature. The fluctuation in pH may be due to localized influence of effluents from different sources. In general pH in the estuary was minimum during monsoon season and maximum during pre-monsoon. Vertical gradient of pH remained less conspicuous during the most part of the year. The chemical components of seawater resist large changes in the pH.

It is well known that the solubility of oxygen in the estuary is a function of its partial pressure on one hand and its salinity and temperature on the other. Normally highest dissolved oxygen concentration was observed during monsoon season both in surface and bottom water owing to the low salinity and temperature prevailing during this period. Comparatively low DO values recorded during Pre-monsoon were due to higher water temperature and high salinity, which reduce the solubility of oxygen in water. The trend noticed in the present study is in conformity with the findings of Saraladevi (1986) and Mitra *et al.* (1990). Generally during Pre-monsoon and post-monsoon DO of bottom water was found to be higher than that of surface water; this may be due to the high photosynthetic activity of benthic algae during these seasons.

The nutrient rhythm in backwater followed marked seasonal pattern. Among various nutrients studied, silicate showed more pronounced spatial and temporal variability. The increase in silicate concentration on the onset of monsoon is mainly due to the intrusion of fresh water containing relatively more silicate in to the system. There exhibited an inverse relationship between silicate concentration and salinity. Other nutrients generally established high concentration during monsoon season. Still, occasionally higher values were also obtained during pre monsoon and post monsoon season also. The surface–bottom differences arising out of either surface excess over bottom or vice versa were inconsistent. These fluctuations that were seen in the present study may be due to local effect. It was understood that the large input from industrial units, sewage works and agricultural runoffs determine the nutrient concentration in the water column. The regional differences of the stations to a limited extend was also observed in the estuary. The river Periyar after flowing through the industrial complex area empties near station 6, which resulted higher nutrient concentration at this station. Draft man plot demonstrated a strong correlation between concentration of PO_4 - P and SiO_3-Si with temperature of water column and sediment.

Information on primary production is essential for assessing the fertility of the aquatic systems and predicting the potential of living resources. Measurement of the amount of the Chlorophyll in water column gives a useful index of phytoplankton density and this also reflects the level of primary productivity of the estuary. The distribution and availability of nutrients in estuaries determines the productivity of phytoplankton. The occasional algal bloom and the subsequent decay of planktons are due to the nutrient enrichment in the system. Draft man plot displays a strong correlation between turbidity and Chlorophyll - *a* (0.849). The continuous, irregular as well as unpredictable pattern of the estuarine environment may influence the spatial and temporal distribution of benthic community. A regular and systematic monitoring of different physicochemical parameters is imperative to understand the response of organism to various ecosystem changes.

CHAPTER 5

SEDIMENT CHARACTERISTICS

5.1. INTRODUCTION

The sediment is the home of benthic animals. The sediment characters have been regarded as the cardinal factors, which determine the benthic community structure. Sediment organic mater is known to be the basic energy for the benthic food web (Gray, 1974 ;Snelgrove and Butman, 1994). Sanders (1960) clearly documented the strong association between community structure and grain size. The sediment also acts as a storage reservoir of nutrients. Hence a comprehensive knowledge on the sediment composition is a prerequisite to understand the benthic ecology. An attempt has been made to delineate the sediment temperature, grain size characters, organic matter and water content.

5.2 RESULTS

5.2.1. Sediment temperature

At station 1, the temperature of the sediment varied from 29.3 (monsoon) to 31.6°C (pre-monsoon). The sediment temperature in station 2 fluctuated from 29 (monsoon) to 31°C (pre-monsoon). At station 3, it varied from 28.8 (monsoon) to 31.2°C (pre-monsoon). In station 4, the sediment temperature varied between 28.6 (monsoon) and 31°C (pre-monsoon). In station 5, it fluctuated between 29 (monsoon) and 31.5°C (pre-monsoon). With respect to station 6, it fluctuated from 29 (monsoon) to 31.2°C (pre-monsoon).The average values of sediment temperature at stations 1 to 6 were 30.43^{0}c, 30.1^{0}c, 30.13^{0}c, 30.13^{0}c, 30.43^{0}c and 30.7^{0}c respectively. (Table: 5.1 and Figure: 5.1).

5.2.2. Interstitial water

At station 1, the interstitial water content varied from 36.18 (monsoon) to 44.33 % (post-monsoon). In station 2 it fluctuated from 75.62 (pre-monsoon) to 77.02 % (post-monsoon). At station 3, the interstitial water content varied from 66 (pre-monsoon) to 72.46 % (monsoon). In station 4, it varied between 71.72 (pre-monsoon) and 75.96 % (monsoon). In station 5, it fluctuated between 70.55 (pre-monsoon) and 72.86 % (post-monsoon). The interstitial water content in station 6 fluctuated from 62.7 (monsoon) to 76.18 % (pre-monsoon). The average values of water content at stations 1-6 were 41.41, 76.14, 69.7, 69.08, 72.01 and 71.61respectively (Table: 5.2 and Figure: 5.2)

5.2.3. Organic carbon

In station 1, the organic carbon content of the sediment varied from 0.54 (monsoon) to 1.6 % (post-monsoon). The organic carbon content in station 2 fluctuated from 3.59 (pre-monsoon) to 4.02 % (post-monsoon). At station 3, it varied from 2.58 % (pre-monsoon) to 3.58 % (post-monsoon). In station 4, the organic carbon content varied between 3.42 (pre-monsoon) and 4.26 % (post-monsoon). In station 5, it fluctuated between 3.62 (monsoon) and 4.08 % (post-monsoon). The organic carbon content in station 6 fluctuated from 2.44 (monsoon) to 3.11 % (post-monsoon). The average values of organic matter at stations 1 to 6 were 2.76, 6.94, 6.17, 7.35, 7.03 and 5.36% respectively (Table: 5.3.1&5.3.2 and Figure: 5.3).

5.2.4. Sediment texture

The sediment texture of different stations disclosed marked variations in the percentage composition of sand, silt and clay. The predominant textural class at stations 1 and 2 were sand and clayey silt respectively. At stations 3-5 the principal textural class was silty sand. Regarding station 6, silty sand and sand were the important textural classes.

In station1, the percentage composition of sand ranged from 78.6% (post-monsoon) to 92.75% (monsoon). The silt content varied from 4.58 % (monsoon) to 14.45% (post-monsoon). The percentage composition of clay fluctuated from 2.67% (monsoon) to 6.94.1% (post-monsoon).

With regard to station 2, the percentage composition of sand ranged from 1.61% (post-monsoon) to 2.66% (pre-monsoon). The silt content was found to vary from 53.54% (monsoon) to 54.68 % (post-monsoon). The percentage composition of clay fluctuated from 42.84% (pre-monsoon) to 44.67% (post-monsoon).

In station 3, the percentage composition of sand ranged from 63.37% (post-monsoon) to 77.53% (monsoon). The silt content varied from 14.28 % (monsoon) to 20.58 % (post-monsoon). The percentage composition of clay fluctuated from 8.2 % (monsoon) to 16 % (post-monsoon).

At station 4, the sand content in the sediment ranged from 52.19% (pre-monsoon) to 59.12 % (monsoon). The silt content was found to vary from 28.29 % (monsoon) to 33.04% (post-monsoon). The percentage composition of clay fluctuated from 12.58 % (monsoon) to 13.80 % (post-monsoon).

In station 5, the percentage composition of sand ranged from 55.55% (post-monsoon) to 63.32 % (monsoon). The silt content was found to vary from 27.16 % (monsoon) to 32.83% (pre-monsoon). The percentage composition of clay fluctuated from 9.52 (monsoon) to 12.21 % (post-monsoon).

In station 6, the percentage composition of sand ranged from 66.27 % (pre-monsoon) to 78.33 % (monsoon). The silt content was found to vary from 16.42 % (monsoon) to 20.58% (post-monsoon).The percentage composition of clay fluctuated from 5.25 (monsoon) to 13.52 % (post-monsoon). Table: 5.4.1-5.4.6 and Figure: 5.4 give a comprehensive picture of textural characters of the sediment in the estuary.

5.3. DISCUSSION

The sediment temperature followed the same pattern as that of overlying water column. In the correlation analysis, water temperature and sediment temperature showed a strong positive correlation (0.889). Highest sediment temperature was observed during pre-monsoon and lowest during monsoon period at all stations. Northern limb of estuary registered slightly higher temperature when compared to the southern limb.

The composition of sediments varied markedly over the course of the investigation at all stations. Six different types of substrata noticed were Sand, Silty sand, Clayey sand, Sandy silt, Clayey silt and Silty clay. Even if six types were observed the major sediment type was Silty sand. Grain size is a master variable that is strongly correlated with hydrodynamic regime (Coats, 1995). The sediment distribution pattern in the estuary may be depends on the sediment source, the texture of the sedimentary material supplied, the bottom topography of the area and hydrographic features of the estuary . The seasonal dredging activities by the port authorities, fluctuations in the physical conditions prevailing in the system and freshets from rivers may also have considerable bearing on the sediment dispersal pattern of the estuary. Sediments showed a clear-cut seasonal variation in composition. The percentage of sand was found to be high during monsoon. The decreased percentage of finer particle during monsoon period could be attributed to flushing of finer materials from the estuarine region to sea. The high level of clay and silt content in the sediment during post-monsoon may be due to the flocculation and settling pattern of fine fractions at high saline condition. Similar seasonal fluctuation of sediment composition was reported by Dora and Borreswara Rao (1967) , Sebastin Raja (1990) and Nair *et al.* (1993).

The variation in water content gives an idea about interstitial space available. The fine fractions of sediment retain more water than that of coarser fraction. The seasonal fluctuations of interstitial water content were not conspicuous within the stations. Distribution of organic carbon content exhibited distinct spatial and seasonal trend. Sewage discharge, primary production and land-derived materials may be the major source of the organic carbon with in estuary. A comparison of data on grain size distribution and organic carbon distribution revealed that the organic carbon distribution in estuarine sediments followed broadly the sediment distribution pattern, in that finer the sediment higher the organic carbon content. Similar result was observed earlier by Murthy and Veerayya (1972). Generally seasonal maximum was recorded during post-monsoon condition and minimum during monsoon. The higher values recorded during summer may be ascribed to the increased water salinity resulting in rapid flocculation and precipitation of major fraction of terrigenous organic matter .The inflow of water from upstream results in complete removal of upper layer of fine bottom sediment and deposition of sand particles. This was the plausible reason for the lower value of organic carbon during monsoon. Observations similar to this were made by Nair *et al.* (1983) in Ashtamudi estuary; Thangaraja (1984) and Chandran (1987) in Vellar estuary and Jegadeesan (1986) and Patterson Edward (1988) in Coleroon estuary. The flux of organic matter from surface productivity to the estuarine bottom has been proven to exert considerable control on benthic standing stocks (Soltwedel, 2000).

CHAPTER 6

THE SPATIAL AND TEMPORAL DISTRIBUTION OF MEIOBENTHOS

6.1. INTRODUCTION

Meiofauna are phyletically more diverse and the most abundant metazoa known to science. The trophic significance of meiofauna in estuarine ecosystem is well documented (Moens *et al.*, 2002; Pinckney *et al.*, 2003). In estuarine sediments they facilitate biomineralization of organic matter and enhance nutrient regeneration. They are characterized by small size, high abundance and diversity, short life span and high turnover rate which makes them excellent sentinels of estuarine pollution (Gerlach, 1971; Aller and Aller, 1992). Meiofauna may be more sensitive to sediment pollution than macrofauna. They have certain inherent advantages over macrofauna in the determination of the effects of biological pollutants at the community level. Most meiofauna taxa have direct benthic development .In contrast most macrofauna rely on pelagic dispersal phases in their life history (Marleen *et al.*, 2001). They also have higher species richness than macrofauna (Heip *et al.*, 1988). However, information on meiofaunal community is virtually less despite the important role played by this group of organisms in the energetic, trophic organisation and their use as indicators of pollution. In Indian scenario, we have limited records on the community structure of meiobenthos. Present investigation will provide a base line data of spatial, temporal and vertical pattern in the distribution of meiobenthos of the Cochin backwaters in relation to environmental parameters.

6.2. RESULTS

6.2.1. Faunal composition

The principal meiofauna groups recorded in the present study were nematoda, polychaeta, copepoda and foraminifea. The group 'Others' includes all taxa having sporadic occurrence. Nematoda were the most dominant component in the collection followed by polychaeta. The copepoda and foraminifera ranked third and fourth respectively. The numbers of taxa recorded from station 1 to 6 were 13, 13, 13, 13,11and 6 respectively (Table: 6.1.1-6.1.6).

6.2.1.1. Nematoda

Nematoda were the most dominant group at all stations. As a result of their high numerical abundance they strongly structured the patterns of total density of meiofauna in the study area. They were present at stations 1,2,3,4 and 5 throughout the investigation period. Occasional absence of nematodes was reported from station 6.

6.2.1.2. Polychaeta

In the order of abundance polychaetes was next to nematoda. They were present at all stations. Most of the forms were juvenile stages falling in the size range of meiofauna.The group was mainly composed of *Paraheteromastus* sp,*Heteromastus* sp,*Glycera* sp and *Lumbrinereis* sp. Polychaetes occurred fairly good numbers at stations 1,3,4 and 5. At station 4 they were present through out the investigation period. Occasional absence of polychaeta was observed at other stations.

6.2.1.3. Copepoda

Harpacticoid copepoda came next to the polychaeta in the order of abundance. They were present at all stations. Copepoda frequently registered high incidence at the northern limb compared to southern limb of the estuary. They furnished high affinity towards station 5.

6.2.1.4. Foraminifera

In the order of abundance, foraminifera followed copepoda. They had occasional appearance at stations 1, 2, 4 and 5. However they had fairly good representation at station 3 throughout the study period. Foraminifera were absolutely absent at station 6.

6.2.1.5. The other groups

Turbellaria, nemertea, kinorhyncha, nauplius larva, acarina, amphipoda, tanaidacea, cumacea, ostracoda, bivalve and gastropoda were occurred fortuitously in limited numbers, and all considered under the category the 'other group'. Under this category turbellaria formed the dominant group and were recurrent at stations 2,3 and 4. Acarina was the next prevalent taxa, which furnished high affinity to station 4. Crustacean nauplii appeared in considerable numbers at the northern limb of the estuary. Spatial and temporal variations with respect to the rest taxa of the 'other groups' were insignificant since they had sporadic occurrence at restricted stations in least abundance.

6.2.2. Percentage composition

At station 1, nematodes were found to be the dominant group by constituting 78% of the total benthic organisms recorded. Polychaetes formed the second dominant group with a percentage occurrence of 11%. Copepods and the group 'others' gave 4 % each. Contribution of foraminiferans was found to be 3%. At station 2 nematodes topped with a percentage incidence of 96% of the total benthic organisms enumerated. All other group together contributed only 4%. Coming to station 3, nematodes occupied the top place with 77%.The foraminiferans established to be the next best with a percentage contribution of 18%. Polychaetes, copepodes and the group 'others' contributed 2%, 1% and 2% respectively. With respect to station 4, nematodes continued to be the dominant group and constituted 77%. Polychaetes and the group 'others' had percentage occurrences of 8 % and 7%, respectively. The share of copepods and foraminifera were 5 and 3% correspondingly. At station 5 also, nematodes outnumbered with a contribution of 82%. Copepods noticed to be the next best with 12%. Polychaetes and group 'others' came next with the percentage occurrences of 3% and 2% respectively. The contribution of group foraminifera was 1%.At station 6, copepods, nematodes, group 'others' and polychaetes were accounted for 48, 26, 21 and 5% respectively (Fig.6.1.1 & 6.1.2.).

6.2.3. Vertical distribution

A close examination of vertical distribution pattern of meiobenthos indicated that maximum aggregation of the fauna was restricted to 0-2 cm layer regardless of the sediment type and the faunal density decreased with increasing depth (Table: 6.2.1-6.2.6 and Figure: 6.2.1-6.2.6). The percentage aggregation of meiofauna at 0-2,2-4,4-6 and 6-8 cm layers were 63%,20%,9% and 8% respectively at station 1; at station 2 it was in the order 78%, 17%, 3% and 2%; with regard to station 3, it was 60%, 24%, 9% and 7% respectively ;It was 66%, 20%, 8% and 6% correspondingly at station 4; Coming to station 5, it was 73%, 11%, 9% and 7% respectively and it was 86%, 8%, 5% and 1% corresponding at station 6. The population density dropped sharply below 2 cm of the sediment. It is clear that at stations 2, 5 and 6 greater than 70% of fauna was concentrated at 0-2 cm layer. Although most of the taxa were reported from 0-8 cm sediment layer, the fauna below 6 cm layer were mainly composed of nematodes and polychaetes.

6.2.4. Seasonal variation

Meiofauna shows considerable seasonal variation in numerical abundance. At station 1, the population density at pre-monsoon, monsoon and post-monsoon were 306,140 and 504 individuals/10 cm^2 respectively. With regard to station 2, it was 1324,414 and 1244 individuals/10 cm^2 correspondingly. At station 3, the population density at pre-monsoon, monsoon and post-monsoon were 1205, 1048 and 849 individuals/10 cm^2 respectively. Coming to station 4, it was 262,234 and 330 individuals/10 cm^2 accordingly. With respect to station 5, the population density at pre-monsoon, monsoon and post-monsoon were 459,283 and 424 individuals/10 cm^2 respectively. In station 6, it was 32, 11 and 5 individuals/10 cm^2 respectively (Table: 6.3.1-6.3.2).

The percentage composition of nematodes at station 1, during pre-monsoon, monsoon and post-monsoon were 82, 67 and 79 % respectively. At station 2, it was 98, 95 and 99% respectively. At station 3, the percentage composition of nematodes during pre-monsoon, monsoon and post-monsoon were 95, 55 and 84% respectively. It was 70, 84 and 79% respectively at station 4. The percentage composition of nematodes at station 5 during pre-monsoon; monsoon and post-monsoon were 75, 83 and 88% respectively. It was 19, 55 and 40 % respectively at station 6.

As far as the polychaetes were concerned, at station 1 the percentage composition during pre-monsoon, monsoon and post-monsoon were 8, 13 and 14 % respectively. At station 2, during all seasons the composition was less than 1%. The percentage composition of polychaetes at station 3, during pre-monsoon, monsoon and post-monsoon were 1, 2 and 1 % respectively. At station 4, it was 2,7and 13 % respectively during various seasons. At station 5, the percentage composition of polychaetes during pre-monsoon, monsoon and post-monsoon were 2, 1 and 4 % respectively. With respect to station 6, it was 9, 9 and 0% respectively.

The composition of copepods also changed with respect to season. At station 1, the percentage composition of copepods during pre-monsoon, monsoon and post - monsoon was 5, 11 and 1% respectively. At stations 2 and 3 percentage composition of these taxa was less than 1% during different seasons. At station 4, the percentage composition of copepods during pre-monsoon, monsoon and post-monsoon was 10, 3 and 7 % respectively. At station 5, the percentage composition of copepods during pre-monsoon, monsoon and post-monsoon was 19, 12 and 5% respectively. With respect to station 6 it was 66, 36 and 20% respectively.

The composition of foraminifera also changed with respect to season. At station 1, the percentage composition of foraminifera during pre-monsoon, monsoon and post-monsoon was 3, 0 and 4 % respectively. The representation of foraminifera was less than 1% during various seasons at station 2. The percentage composition of foraminifera at station 3 during pre-monsoon, monsoon and post-monsoon was 3, 41 and 11 % respectively. At station 4, it was 9,1and 0.3 % respectively during various seasons. At station 5, the composition of foraminifera during pre-monsoon, monsoon and post-monsoon was 2, 1 and 0.2% respectively. They were absolutely absent at station 6 during the entire survey period.

Turbellaria and acarina are more frequent during monsoon period. Since the representation of the other taxa of the group 'others' were sporadic, their seasonal variation was insignificant.

6.2.5. Ecological relationship

The BIO-ENV procedure was employed to measure the agreement between the rank correlations of the biological (Bray-Curtis similarity) and environmental (Euclidean distance) matrices. Seventeen environmental variables were allowed to match the biota. They were depth (m), turbidity, temperature (^{0}C), salinity (ppt), pH, DO(ml/l), NO_2-N(μmol/l), NO_3-N(μmol/l), PO_4-P(μmol/l), SiO_3-Si(μmol/l),chlorophyll - *a* (μmol/l), sand (%),Silt(%), Clay(%),organic carbon C(%),sediment temperature(^{0}C) and interstitial water content (%).Among this turbidity , pH, chlorophyll - *a* , salinity, DO, NO_2-N , NO_3-N, organic carbon(%) and silt(%) were principally influenced the meiofaunal distribution(Table:6.4).

6.3. DISCUSSION

In the present survey, a total of 14 taxa of meiobenthos were recorded. Nematodes were the dominant meiofaunal group in Cochin backwaters. They consist of more than 78 % of the total density of fauna at stations 1, 2,3, 4 and 5. Dominance of nematodes in meiobenthic community was reported from different parts of the world (Ansari*et al.*, 2001;Riera,2003 ; Robert*et al.*, 2005). Polychaetes constituted the second major group in the current study. However, Ansari *et al.* (2001) at Mandovi estuary reported turbellaria as the second most abundant group. Murty and Kondalarao (1987) and Anzari and Parulekar (1993) reported copepods as the second dominant group. Compared to the preliminary survey in the study area (Jayasree, 1971) the density of copepods found to be decreased in the present survey. This may be due to the changed environmental conditions in the estuary. Harpacticoid copepods are unable to tolerate low O_2 concentration (Wells, 1988). Lee *et al.* (2001) demonstrated that harpacticoid density alone can be used an indicator for the extent of pollution of the benthic environment. Generally representation of foraminifera was rather poor in the backwaters. The stations that located in the northern region of the estuary are either devoid of foraminifera (station 6) or with sporadic occurrence (station 5). This may be due to its proximity to industrial and retting zone. Complete absence of foraminifera in poor water quality conditions was reported by Aziz and Balakrishnan (1983), and Anzari and Parulekar (1998).

The present investigation showed that meiofauna distributed throughout the 8 cm long sediment layer. Organisms living in the surfacial layers of the sediment are exposed to extreme fluctuations in chemical and physical environment caused by the tidal, diurnal and seasonal cycles. Surface dwelling meiofauna must be also contending with increased pressure from the predators. Vertical migration is one way in which they can adapt to their changing environment. It has been urged that the vertical distribution of species will reduce the number of competitive or predative interactions and this would explain the occurrence of very high number of species in a certain small patch. Reise (1985) found out that it is mainly predation pressure, which structures the population of meiobenthos.Eventhough different taxa have occurrence at 0-8cm layer of the sediment, the organisms generally have the affinity for upper 0-2 cm sediment layer. This pattern is well established for meiofaunal communities at different parts of the world (Coull and Bell, 1979; Robert *et al.,* 2005). Aerobic organisms prefer the surface sediments because oxygen diffusion into the deeper sediment is limited. Damodaran, 1972 related the vertical distribution to the biogeochemical characteristic of the sediment. At station 2, having muddy substratum the 78% of the organisms was concentrated at 0-2 cm sediment layer. Where as at station 1 having sandy substratum, only 63 % of organism was concentrated at 0-2 cm sediment layer. Having less porosity and small interstitial space the exchange of food and oxygen to the deeper layers may be impoverished in muddy substratum. The rich faunal density at the top most layer of mud may be due to redox potential discontinuity layer in mud, which is a few millimeter down and often extremely abrupt (McIntyre, 1969; Deckere *et al.,* 2001).The oxygen deficiency and sulphide stress in the deeper layers of muddy sediment may result in reduction in the population density of diatoms, microphytobenthos and bacteria with depth as a result most meiobenthos were confined to the surface layers. Similar results were reported by Smith and Coull (1987).

The hydrographical features observed in the study area followed seasonal cycle. Intense precipitation and land run off during monsoon resulted in large changes of the hydrographical features. The population density declined considerably with the advent of heavy rains. Monsoonal flood may physically remove large amount of surface sediment along with the meiofaunal organisms living in it. The increase in population density after the termination of monsoon indicated the ability of meiofauna to quickly repopulate in the disturbed sediment. Studies conducted by Anzari *et al.* (2001) and Christian *et al.* (2005) also exhibited seasonal periodicities in meiofauna community. The abundance of polychaetes was rather higher during post-monsoon period and that of copepods during premonsoon period. Pre-monsoon and post-monsoon period presented high numerical abundance of foraminifera. However at Station 3 highest population count for foraminifera (1735 /10 cm^2) was obtained during monsoon (July 2003, surface salinity 4 ppt and bottom salinity 8 ppt). Varshey *et al.* (1984) reported the abundance of foraminifera during monsoon season; according to her this change is due to the shift in the substratum during monsoon period.

The population counts showed striking spatial and temporal variation. BIOENV analysis highlighted the positive influence of chlorophyll, turbidity, NO_2-N, NO_3-N, pH, salinity, DO, organic carbon and silt content on the distribution of meiofauna. Grassle *et.al* (1986) showed that benthic communities are highly resilient to increasing rates of nutrient input and subsequent phytoplankton bloom. The algal bloom results in the deposition of considerable phytodetritus in the water column that enhances the bacterial activity and subsequently can cause a significant increase abundance and diversity of meiofauna. One of the major sources of turbidity in estuary is phytoplankton. Chlorophyll content has direct influence on the distribution of meiofauna (Heip *et al.* 1985 ;Ansari and Parulekar ,1993).

Salinity was the principal factor correlated with assemblage structure. The species diversity was highest at the high salinity stations. There was a progressive decrease in the meiofaunal density along the salinity gradient, from higher to lower salinity. Ansari and Parulekar (1993) also demonstrated the positive influence of salinity on meiofauna. pH, oxygen availability, and granulometry of the substrate are also known to affect meiofaunal abundance (Gray, 1974; Heip *et al.,* 1985 ; Palmer, 1988). The present observations are also in agreement with above reports. However Gooday *et al.* (2000) affirmed that O_2 apparently play a minor role in determining the total meiofaunal abundance.

In the present survey high diversity was observed in the coarse sediment while highest population density was obtained in fine sediment. The results suggested that the variation in meiofaunal density and structure are influenced by sediment texture and availability of organic matter. A positive correlation between sediment characteristics and trophic structure of meiobenthos was investigated by Wieser (1953), Giere (1993) and Anzari and Parulekar (1993). Sajan (2003) was not able to deduce positive influence of organic carbon in the distribution of meiobenthos along the shelf waters of west coast of India.

In addition to these factors macrofauna may also have a control over the population density of meiofauna. Montagna and Yoon (1991) found that juvenile macrofauna might be important competitors to permanent benthic meiofauna. Filterfeeding macrofauna enhances the sedimentatrion of suspended organic materials, which promotes meiofaunal abundance through increasing available trophic resources. Mucus film secreted by many burrowing animals and their metabolic waste products can attract bacteria and produce a rich meiofauna (Fenchel, 1969;Alongi, 1985).

CHAPTER 7

THE COMMUNITY STRUCTURE OF FREE - LIVING NEMATODES

7.1. INTRODUCTION

The nematodes or roundworms are one of the most common phyla of animals.They have successfully adapted to nearly every niche from terestrial, fresh water to marine from the polar regions to the tropics, as well as the highest to the lowest of elevations, where they often outnumber other animals in both individual and species counts. In terms of number of species, although outnumbered on land by the arthropods, in the sea they are the most diverse metazoan taxa (Warwick *et al.*, 2002). There are a great many parasitic forms, including pathogens in most plants, animals, and also in humans. Free-living nematodes are important and abundant members of meiobenthos. They play an important role in the decomposition process, aid in recycling of nutrients; they form a significant part of the diet of many other animals and are sensitive to changes in the environment caused by pollution (Platt and Warwick, 1980; Warwick *et al.*, 2002). The use of free-living nematodes as indicators of contamination have been discussed by Ferris and Ferris (1979) and Platt and Warwick (1980).

Our knowledge of biological diversity is still very poor (Langreth, 1994) and free-living nematodes in general have been neglected. Much of our knowledge of this group is based on a few, often inadequate and older descriptions.The principal reason for neglecting nematode is the perceived difficulty with their taxonomy.The extraction of these microscopic forms, from the sediment is a laborious task and is analogous to looking for a needle in a haystack. It is a sad fact that we know more about the backside of the moon than we do about free-living nematodes of Indian estuaries.This chapter highlights different aspects of nematode assemblage of Cochin backwaters such as species composition, vertical distribution, feeding types, seasonal variation and relationships with environmental variables.

7.2. RESULTS

7.2.1. Species composition

The checklist for free living nematodes of the Cochin backwaters is given in the table (7.1). This study pointed out that Cochin backwaters have representation of nematode from all the three orders (Enoplida, Chromadorida and Monhysterida). The orders Enoplida, Chromadorida and Monhysterida were represented by 6,17 and 12 genus respectively. Altogether 40 species of nematodes belonging to 17 families were identified.

The total number of species located from stations 1 to 6 were 28,28,36, 31,24 and 5 respectively. Regional difference in the distribution of dominant species was apparent. The station 1 was dominated by *Pseudochromadora casca. Terschellingia longicaudata* was over riding at station 2. *Daptonema* sp and *Viscosia* sp were the principal component at station 3. *Metalinhomoeus longisetum* was the prevailing species at station 4. *Daptonema* sp was wide spread at station 5 .At Station 6 since the occurrence of nematodes were sporadic no dominance of a particular species were reported. Of the 40 species identified *Terschellingia longicaudata, Daptonema* sp, *Metalinhomoeus longiseta* and *Sabatieria* sp were present at all stations. *Anticyathus* sp and *Anticoma sp* showed least spread distribution. They were present only at station 2 (Table: 7.1.2).

7.2.2. Vertical distribution of nematodes.

Nematodes exhibited a strong vertical zonation (Table: 7.2). There were significant differences in the occurrence and abundance of different species within different depth fraction. *Anticyathus* sp, *Anticoma* sp, *Cyartonema* sp *and Campylaimus gerlachi* sp were normally confined to upper 0-2 cm sediment layer. *Desmoscolex* sp, *Amphimonhystera* sp, *Hopperia* sp, *Laimella* sp *and Belbolla* sp were dominated at 0-4 cm. *Sphaerolaimus macrocirculus, S.maccoticus,S.pacificus* and *Syringolaimus* sp were restricted to 2-4 cm sediment layer. *Halalaimus* sp, *Paramonohystera* sp, *Paramesonchium* sp, *Promonhystera* sp, *Bolbolaimus* sp, *Cyatholaimus* sp, *Desmodora minuta, Dichromodora* sp, *Longicyatholaimus* sp, *Neochromadora coudenovei, Spilophorella* sp and *Viscosia* sp were limited to 0-6 cm. *Oxystomina elongata Terschellingia longicaudata, Daptonema* sp, *Monhystera* sp, *Metadesmolaimus gelena, Metalinhomoeus longisetum, Parodontophora* sp, *Paracomesoma longispiculum, Sabatiera* sp, *Sabatiera pulchra, Theristus* sp, *Vasostoma* sp , *Hypodontolaimus* sp , *Microlaimus* sp and *Pseudochromadora casca* were present throughout 0-8 cm core. However in deeper layers *Sabatiera sp and Sabatiera pulchra* contributed significantly to the total numerical density.

7.2.3. Feeding habits exhibited by nematodes.

Much of the literature on nematode feeding habit is based on the contribution of Wieser (1953) who classified nematodes in to the following four basic feeding types based on lateral views of the buccal cavity of fixed Specimens. This classification has been widely used since then and adjusted in sequent years (Wieser, 1960; Wieser and Kanwisher, 1961; Boucher, 1973 and Platt, 1977).

1) Species with out true buccal cavity (1A): They are regarded as 'selective deposit feeders' which ingesting bacterial-sized particles. Food is obtained by suction power of oesophagus.

2) Species with a large buccal cavity, but unarmed with teeth (1B): These forms are considered as 'non-selective deposit feeders'. Food is obtained by sucking power of oesophagus, with additional help from active movements of lips and anterior part of buccal cavity. Larger objects are swallowed.

3) Species with a buccal cavity armed with small or moderately sized teeth (2A): They are also known as 'epigrowth' or diatom feeders. They scraped off food from the substratum.

4) Species with a buccal cavity armed with large teeth or jaws (2B): These represent the 'predator/omnivore' group which catch their living prey by protrusible claws or mandibles or catch the prey with widely open mouth, macerating it in the buccal cavity by means of articulating plates or other sclerotizations and suck fluid.

Among the 40 species recorded 7 were selective deposit feeders, 17 were non selective deposit feeders, 10 were epistrate feeders and 6 were predators/omnivore.Significant differences in the percentage composition of various feeding types were evident at different stations . At station 1 epistrate feeders (42%) are the dominant group followed by nonselective deposit feeders (35%). In Station 2 dominant and sub dominant group were nonselective deposit feeders (50%) and selective deposit feeders (33%) respectively.With regard to station 3 nonselective deposit feeders (43%) were the dominant group followed by epistrate feeders (26%).In station 4 the prevailing group was nonselective deposit feeders (54%) followed by epistrate feeders (24%). At station 5 nonselective deposit feeders (68%) was strongly dominant. At station 6 the nematodes were sporadic in occurrence. When we consider estuary as a whole,the non selective deposit feeders (50%) dominated in the study area followed by epistrate feeders (23.4%) selective deposit feeders (18.6%), and predators (8%) (Table: 7.3).

7.2.4. Seasonal variation

Clear seasonal pattern in the distribution of nematodes were observed. An apparent reduction in the population density during monsoon and subsequent recolonization in during post-monsoon was noticed. Season wise occurrence of nematodes is illustrated in Table: 7.4.

The total number of species observed during pre-monsoon, monsoon and post- monsoon were 30, 29 and 31. *Anticoma* sp, *Oxystomina elongata, Terschellingia longicaudata, Daptonema* sp, *Metadesmolaimus gelena, Metalinhomoeus longiseta, Promonhystera* sp, *Sabatieria* sp, *Sabateiria pulchra, Theristus* sp, *Bolbolaimus* sp, *Microlaimus* sp and *Pseudochromadora casca* were present all the three seasons. The representatives of the feeding groups 1A, 1B and 2A were also present all the three seasons. However the 2B were present only during monsoon and post monsoon. They were absolutely absent during pre-monsoon period.

7.2.5. Diversity indices

The diversity indices such as species richness (Margalef's index), species evenness (Pielou's index), species diversity (Shannon index) and species dominance (Simpson's index) were computed for nematodes (Table: 7.5).

I. Species richness (Margalef's index, d): This index gives an idea about total number of species. It ranged from 0.86 (Station 6) to 7.6 (Station 3) with an average of 5.27.

2. Evenness index (Pielou's index, J'): This index used to estimate how evenly the individuals are distributed among the different species. It varied from 0.90(Station 4) to 1 (Station 6) with an average of 0.95.

3. Species diversity (Shannon index, H'):It expresses the number of species per number of individuals. It fluctuated from 1.61(Station 6) to 3.43(Station 3) with an average of 2.9.

4. Simpson's index (Species dominance, 1-λ'): Species dominance is relative occurrence of species with other species, which oscillated from 0.81(Station 6) to 0.97 (Station 3) with an average of 0.94.

7.2.6. Cluster analysis

The species distribution along and between stations was compared with using hierarchical cluster analysis based on Bray-curtis similarity calculated on non-transformed species abundance data.

The clusters formed between the stations depict the patterns in the similarity matrix (Table: 7.6). The stations 3 and 4 agglomerated in one main cluster (similarity level 84.1 %). The stations 1, 2, 5 and 6 were linked to this group (Figure: 7.1).

7.2.7. MDS analysis

To get a clear picture about the distribution MDS (non-metric Multi Dimensional Scaling) based on Bray-curtis similarity was calculated on non transformed species abundance data was performed for all the stations. The similarities of the stations were preserved in the MDS ordination also. The trend with respect to grouping of stations observed in cluster analysis was in agreement with structure revealed by MDS. In the MDS analysis the stress value obtained was 0 indicating that the MDS configuration obtained was a good representation of the inter-station similarities (Figure: 7.2).

7.2.8. Ecological relationship

In the BIO-ENV procedure, which was employed to measure the agreement between the rank correlations of the biological (Bray-Curtis similarity) and environmental (Euclidean distance) matrices, seventeen environmental variables were allowed to match with the biota. They were depth (m), turbidity, temperature (^{0}C), salinity (ppt), pH, DO (ml/l), NO_2-N (μmol/l), NO_3-N (μmol/l), PO_4-P (μmol/l), SiO_3-Si (μmol/l), chlorophyll - *a* (μmol/l), sand (%), silt (%), clay (%), organic carbon C (%), sediment T (^{0}C) and interstitial water content (%).

In this case, turbidity, salinity, pH, sand (%) and sediment temperature were featured as the major variables explaining the best match with faunal distributions (Table: 7.7). The associated coefficient of environmental to biotic similarity was 0.786. In addition to this nitrate, interstitial water content, and clay (%) were also have particular importance among the best variable combinations.

7.3. DISCUSSION

Altogether 40 species of nematodes belonging to 17 families were identified. This investigation provides the baseline data of nematodes in Cochin backwaters. The dominance of nematodes throughout the year suggests their ability to withstand critical conditions. They are generally diverse because they appear to partition food resources (Platt and Warwick, 1980). The numerical abundance may confer on this group a key role in the trophic ecology of the estuary. In the backwaters its density varied from 0 (station 6,in a number of surveys) to 2440 (station 2 ,November 2003) individuals /10 cm^2. The key to their success is their physiological adaptability and ecological diversity (Warwick *et al.,* 2002). Data suggested that the reported species are cosmopolitan in distribution. The species reported in the present survey is also described from different parts of the world (Karel Essink and Harm Keidel, 1998; Gyedu-Ababio *et al.,* 1999; Warwick *et al.,* 2002). Among the three orders, Monhysterida dominated in population density in the backwaters. Xyalidae and Comesomatidae were most diversified at generic level. Stations 1,2,3,4 and 5 were characterized by the frequent appearance of majority of species; however their numbers varied from one station to another. The density and diversity of nematodes was least at station 6. At this station the fauna was represented by *Terschellingia longicaudata*, *Daptonema* sp, *Metalinhomoeus longisetum*, *Paracomesoma longispiculum* and *Sabetieria* sp. When we consider estuary as a whole only 8 species had a mean abundance greater than 4%. The most abundant species were *Metalinhomoeus longisetum*, *Daptonema* sp, *Paracomesoma longispiculum*, *Terschellingia longicaudata*, *Oxystomina elongata*, *Pseudochromadora casca*, *Sabatieria* sp and *Sabatieria pulchra*. The dominance of these species may be related to their ability to tolerate the stressed environmental conditions, abundant food supply and absence of predators.

The short generation time of nematode species means that they can react rapidly to disturbances. Different species differ in their response to environmental disturbances by increasing or decreasing their abundance. Nematode assemblage offers prospects for indicating disturbance and assessing the quality of sediments (Danovoro and Gambi, 2002). Opportunistic nematode species increase in numbers more rapidly than persistent species (Orren *et al.*, 1979; Elefther-iou *et al.*, 1982 and Smol *et al.*, 1994). Epistrate feeders dominated at station 1. The high density of epistrate feeders indicates eutrophication (Karel and Harm, 1998). Physico-chemical parameters recorded during the study suggested eutrophication is in progress at station 1. Deposit feeders and epistrate feeders are capable of using the excess of organic matter and the primary production of diatoms (Schratzberger and Warwick, 1999). *Oxystomina elongata*, *Terschellingia longicaudata*, *Daptonema* sp, *Metalinhomoeus longisetum*, *Paracomesoma longispiculum*, *Sabatieria* sp, *S. pulchra*, *Theristus* sp and *Pseudochromadora casca* were found to be colonizers in the study area. The unusual dominance of these species in the current survey suggested that nematode assemblages in the investigation area are under stress. In the estuary the diversity of nematode was low when compared to their high density . If the dominant nematode species is an opportunist the comparison of diversity indices is not relevant. The evenness of different stations varied only slightly due to the dominance of opportunistic nematode at these stations. Increasing levels of environmental stress are generally considered to decrease diversity (*H*), decrease species richness (d) and also decrease evenness (*J*) resulting in the dominance of a particular species. *Oxystomina* sp, *Sabatieria* sp, *S. pulchra, Daptonema sp, Monhystera* sp, *Theristus* sp *and Metalinhomoeus* sp were reported to be the indicators of disturbed environment (Tietjen, J.H 1984; Gyedu-Ababio *et al.,* 1999; Thomas and Nikolaos, 2002). Present finding support the above assertions and clearly demonstrate the usefulness of such characteristic species occurrence in aiding the assessment of environmental status.Study also confirms that higher taxonomic levels are convenient in indicating stress condition.Species level identification is not necessary for pollution assessment.

The ecological understanding of the functioning in the nematode communiy is enhanced by the knowledge of animal vertical distribution. In the backwaters even though nematodes were distributed throughout the 8cm long sediment layer the population density and diversity were highest at surface sediment. Investigations of the vertical distribution of nematodes and other meiofauna in estuarine and marine environments indicated that the fauna generally occupies the topmost sediments (Olafsson and Elmgren, 1997). The factors controlling the depth preference are not completely clear. It has been shown that many nematode species exhibited a typical vertical distribution which often relates to a variety of biological, physical and chemical variables (Warwick and Gee, 1984; Giere ,1993; Hendelberg and Jensen 1993; Steyaert *et al.*, 1999). There was a consistency in the vertical profile of nematodes at different stations irrespective of sediment granulometry .The niche of an organism in an environment is decided by the intra and inter competition for food.So the free-living species may partition their environment for food;which may results in species specific depth preference for nematodes as evident from the present study. The predatory /omnivorous nematodes were mainly confined to 2-4 cm layer. A greater quantity of selective deposit feeders and epistrate feeders showed predominance to the 0-6 cm. It is found that non selective deposit feeders form a fraction of nematode community at all depth layers. Vertical segregation of species will reduce the number of competitive interactions for food so that very high number of species with different feeding behavior is able to coexist in small patch of sediment. A sharp decline in density and diversity with depth was observed. Key factors for this distribution pattern are possibly related with the limited oxygen penetration and the occurrence of sulphide in deeper sediment layers. *Daptonema* sp, *Sabatieria pulchra, Terschellingia longicaudata* and *Metalinhomoeus* sp were the inhabitant of deeper sediment layers of Cochin estuary.

The topography of the dendrogram and MDS ordination was uneven indicating species variability between the stations. The shift in the diversity and dominance of nematode communities at different stations is an expression of the influence of different physicochemical parameters on the distribution of nematodes. BIOENV analysis yielded the combinations of eight environmental entities (Turbidity, Nitrate, Salinity, pH Interstitial water content, sediment temperature,% sand and % Clay) as best 'defining' the faunal distributions. BIOENV identified sediment properties as the one of the cardinal factors, which limits nematode distribution. In sandy sediment (station 1) lowest number of nematodes was noticed. Highest numerical density of nematodes was obtained from clayey silt (Station 2). Grain size can affect benthic communities by affecting availability of interstitial water content and organic carbon. It also influences their ability to capture food and escape predation. Mud has more organic matter when compared to other sediment types USEPA (2000). The muddy site amplifies the colonization of microalgae and bacteria, which forms the important food source for deposit feeders (Admiral *et al.*, 1983; Moens and Vincx, 1997). However Cook *et al.*, (2000) suggested physical properties of sediment had little correlation with nematode abundance. This view is against the observation of present study.

Since the different stations of this study represented different ecological conditions the nature of the food material available at these stations also may be different. A relationship between feeding habits of nematodes and the nature of the substratum has been noticed during the present investigation. The selective deposit feeders registered maximum density at clayey silt (station 2). Silty sand was characterized by nonselective deposit feeders (stations 3,4 and 5). Sandy substratum was characterized by the dominance of epigrowth feeders (station 1). The predators showed preference to silty sand (station 3). Although the four types of feeding groups were noticed the non-selective deposit feeders dominated in the backwaters. They can ingest a variety of particles ranging in size from individual bacteria to larger inorganic particles, their dominance in all habitat are therefore expected (Tietjen, 1984). It is confirmed that patchiness in nematode distribution observed in this study could be due to food distribution patterns as suggested by Orren *et al.* (1979), Alongi and Tietjen (1980), Eleftheriou *et al.* (1982) Hicks and Coull (1983) and Cook *et al.* (2000).

BIOENV identified turbidity as another important factor that determines community structure of nematodes. According Jasna and Irella (2004) nematode abundance was well correlated to the distribution pattern of transparency and light intensity. As suspended solids like algae, sediment, detritus or solid waste increase in the water, the amount of light traveling through the water column is reduced. According to Thomas (2004) nutrient enrichment can often cause phytoplankton blooms, which decrease water transparency. The station 1, having high content of chlorophyll - *a* levels characterized by the dominance of epigrowth feeders. Vanaverbeke *et al.* (2004) reported upward migration of nematodes from deeper layers following bloom deposition. They also noticed doubling of diversity within the epistrate-feeding nematodes after the sedimentation of phytoplankton. Gyedu-Ababio *et al.* (1999) also reported the positive influence of chlorophyll *a* concentration on the nematode community structure.

The influence of salinity and temperature was apparent from the seasonal variation in the abundace of nematodes. It has been well documented that densities of nematodes increase with increasing salinity. But the total number of species observed during different seasons did not show significant variation. The total number of species observed during pre-monsoon, monsoon and post-monsoon were 30, 29 and 31 respectively. But the species composition during different seasons was different. The disturbance of the substratum as a result of intense precipitation and land runoff during monsoon provides a challenge to nematodes and may forces them to migrate to less disturbed areas. Seasonal variation could be a result of vertical movement in response to several factors. The streamlined shape of nematoda favours deep penetration (Platt and Warwick, 1980; Schratzberger and Warwick, 1999). The positive correlation between salinity and temperature on the composition of nematode communities reported from different parts of the world (Heip *et al.*, 1985; Coull, 1988; Warwick, 1981).The availability of food (Moens and Vincx, 1997) or appearance of predator organisms may also be seasonal. This also explains seasonality of different species. However according to Alberto and Jaqueline (2002) there were no significant differences in nematode abundance among month, transects since nematodes are well adapted to physical disturbances.

BIOENV did not prove any significant correlation of horizontal scale distribution of nematodes and oxygen concentration. This is in agreement with Cook *et al.* (2000). However and Jasna and Irella (2004) documented the influence of DO in the horizontal scale distribution of nematodes.

The investigation demonstrated that controls on nematode community structure are complex. Results reported here are promising and indicate that nematode composition is a sensitive tool for describing the anthropogenic impacts on environment. The broad spectrum of feeding types present suggest that nematodes play a variety of ecological roles within the estuary, which merits further detailed study in this field. Hopefully this baseline data will serve to encourage further investigations in this area of neglected fauna.

CHAPTER 8

THE SPATIAL AND TEMPORAL DISTRIBUTION OF MACROBENTHOS

8.1. INTRODUCTION

Benthic ecosystem is the least known ecosystem on the earth, because of its immensity and inaccessibility. Benthic organisms constitute an essential component in the marine environment and play an important role in the ecology both as consumers of plankton and as food for bottom feeding fin and shellfishes (Parulekar *et al.*, 1980). Benthic macrofauna are ecologically important as they directly affect biochemical process in the sediment (Brown *et al.*, 2000). The contemporary research emphasize of the taxonomist on species of commercial importance will serve to perpetuate the lack of interest in other taxa; this obviously has complications for our full understanding of biodiversity. We have very poor knowledge of the patterns of the species richness along coastal zone habitats. Without a sound knowledge of benthos, the state of a particular ecosystem cannot fully be understood. The increased concern on the rapid ecological changes in the natural environment has provided major challenges to the scientific community (Chindah, 1998). Macrobenthic communities are composed of many species with different pollution tolerance ranges. The use of macrobenthos as indicators of water quality is convenient and economical as they are easy to collect and identify. It can improve the water quality monitoring that was only based on physical and chemical data collected and analysed in the laboratory (Davies and Day,1989).

Eventhough Pillai (1978), Batcha (1984), Sarala (1986) and Sheeba (2000) were tried to map out the bottom fauna of Cochin backwaters earlier, studies on benthos with a view to assess the environmental health are scanty. The present study on macrobenthos of the Cochin estuary will bring out the benthic diversity of the estuary in undeniable terms. Moreover a study of benthos prior to the construction of Vallarpadam container trasshipment terminal is significant. This project might be resulted in the alternation of existing community structure of benthic fauna. The data presented here will provide a valuable base line against which further changes in the benthic community can be assessed. This chapter deals with faunal composition, seasonal variation, community structure and ecological relationship of macrobenthos in the Cochin backwaters.

8.2. RESULTS

8.2.1. Faunal composition

Among the 59 species of macrofauna collected polychaetes constituted the major component with 32 species. Crustacea formed the second dominant group with 12 species. The mollusca and pisces ranked third and fourth position with 4 and 3 species respectively. The sporadic representatives were pooled together as 'others'. They were represented by 8 taxa. Since polychaetes were the predominant form, they were identified up to species level. The rest of the fauna were identified up to lowest taxonomic level possible. The detailed list of macrofaunal composition is presented in Table: 8.1.1-8.1.6.

8.2.1.1. Polychaeta

Polychaetes formed the bulk of the fauna through out the survey. On the whole 32 species of polychaetes belonging to 27 genera were identified. Errantia and

Sedentaria were represented by 16 species each. The total number of polychaetes species recorded from Station 1 to 6 were 23, 22,24,22,20 and 6 respectively.

At station 1 *Prionospio cirrifera, Paraheteromastus tenuis,* and *Heteromastus bifidus* contributed significantly to the total population density. In station 2, *Prionospio polybranchiata* and *Paraheteromastus tenuis* supplied notably to numerical abundance. With respect to station 3, *Paraheteromastus tenuis* and *Prionospio cirrifera* contributed considerably towards faunal density. In station 4, *Prionospio cirrifera, Paraheteromastus tenuis and Heteromastus bifidus* provided appreciably to the total numerical density. With respect to station 5, *Paraheteromastus tenuis, Prionospio cirrifera, P.polybranchiata* and *Heteromastus bifidus* were numerically important forms. Coming to station 6 *Prionospio cirrifera* gave the major share towards the total numerical density.

8.2.1.2. Crustacea

The crustacea formed the second dominant group in the study area. They were mainly represented by four species of amphipoda, two species of isopoda, two species of tanaidacea, one species of cumacea, one species of caridean shrimp and two species of brachyuran crabs.

8.2.1.2.1. Amphipoda

Altogether four species of amphipods,viz.,*Corophium triaenonyx, Grandidierella sp, Eriopisa chilkensis* and *Caprellidae sp* were collected from the estuary. *Corophium triaenonyx* and *Grandidierella sp* were present at all stations in appreciable number. Caprellidae were present at stations 1, 3 and 5. The representation of *Eriopisa chilkensis* was limited by a single occurrence at station 3 during monsoon. Amphipod concentration was found to be usually low at stations 2 and 6 when compared to other stations.

8.2.1.2.2. Isopoda

Altogether two species of isopods, viz., *Anthuridae* sp and *Cirrolinia fluviatilis* were collected from the estuary. Even though they were present at all stations their abundance was rather poor.

8.2.1.2.3. Tanaidacea

Two species of tanaidacea, *Apseudes chilkensis* and *A.gymnophobia* were recorded frequently from all stations in limited number throughout the year.

8.2.1.2.4. Cumacea

Cumacea was represented by *Iphinoe* sp. It had stray occurrence at stations 1, 2, 3 and 4 in limited number.

8.2.1.2.5. Caridean shrimp

This group was represented by *Alpheus* sp. Only a few of them were obtained in the present survey. They were present at all stations except at station 6.

8.2.1.2.6. Brachyuran crabs

They were represented by *Neorhynchoplax* sp and *Xenophthalmodes moebii* in limited number. They were absent during post-monsoon period. *Xenophthalmodes moebii* was present only at moderately saline zones (stations1,4 and 5). *Neorhynchoplax* sp were distributed in the high saline region of estuary (stations 2 and 3) and they were relatively scarce in number.

8.2.1.3. Mollusca

Generally the estuary was poor in respect of molluscan fauna. The molluscan fauna includes 3 species of bivalves (*Katalysia* sp, *Paphia* sp, *Muculista senhousia)* and one species of gastropod *(Thais* sp*)*. Out of these *Muculista senhousia* was the only dominant group that gave fair contribution to population density. But their representation was occasional. It generally exhibited a clumped distribution. All the other species had fortuitous incidence.

8.2.1.4. Pisces

Three benthic fishes *Trypauchen vagina, Batrachus grunniens* and *Anguilla* sp have registered in the present study. *Trypauchen vagina* was present at stations 1, 2, 3, and 4. *Batrachus grunniens* was confined to stations 3,4 and 5. The representation of *Anguilla* sp was limited by single occurrence at station 3. Pisces were totally absent at station 6.

8.2.1.5. The group others

The group others consists of the sea anemone, flatworm, nemertean. phoronida, sipunculoidea, brittle star, and chironomus larvae. Sea anemons restricted to stations 1, 2 and 3.The sea anemone *Anthroplana nigrensis* had an accidental occurrence at station 1 during premonsoon. Even though nemerteans were present through out the estuary they were more abundant at station 2.Phoronida had representation at all stations except at station 6. Sipunculoidea were present at stations 1, 2 and 3. Brittle stars were present in limited number at stations 2, 3 and 4. Only station 6 harboured Chironomus larvae.

8.2.2. Percentage composition of macrofauna

The percentage composition (based on average) of each group of macrofauna is portrayed in Fig: 8.1.1-8.1.2 .At station 1, polychaetes were found to be the dominant group by constituting 92% of the total benthic organisms recorded. Crustaceans formed the second dominant group with a percentage occurrence of 6 %. Mollusca and the group 'others' came next with 1% each. Contribution of fish was found to be insignificant. At station 2 polychaetes topped with 81% of the total benthic organisms enumerated. Group 'others' ranked second with 8 %. Crustacea and Mollusca contributed 7% and 3% respectively towards the total benthic organisms collected. The contribution of pisces was 1%. Compared to the other stations, the contribution of group 'others' here was more.Coming to station 3, polychaetes occupied the top place with 63%. The crustaceans established to be the next best with a percentage contribution of 30%. Mollusca constituted 5% and pisces and the group 'others' 1% each. With respect to the station 4, polychaetes continued to be the dominant group and constituted 91% followed by mollusca and crustaceans, with a percentage occurrences of 6% and 3% respectively. At station 5 also, polychaetes outnumbered with a contribution of 93%. Crustaceans noticed to be the next best with 5%. Mollusca and group 'others' came next with the percentage occurrences of 1% each. The contribution of pisces was insignificant towards total density.At station 6 polychaetes, crustaceans and group 'others' were accounted for 68, 21 and 11% respectively.

8.2.3. Season wise occurrence of macrofauna

Macrobenthos showed pronounced variations during different seasons in all the stations (Table: 8.2.1 & 8.2.2).

The density of macrofauna showed considerable seasonal variation. In station 1 the density of macrobenthos varied between 265/0.1m^2 (pre-monsoon) and 994/0.1m^2 (post-monsoon).At station 2, the population density of benthic macrofauna varied from 68/0.1m^2 (monsoon) to 149 /0.1m^2 (pre-monsoon) .With respect to station 3, the density of macrofauna fluctuated from 274 (pre-monsoon) to 610/0.1m^2 (post-monsoon) .In station 4, the density of organisms ranged from 79 (monsoon) to 1655 (post-monsoon) organisms/0.1m^2.With respect to station 5, the density of macrofauna fluctuated from 200 (pre-monsoon) to 624 animals/0.1m^2(post-monsoon). Coming to the station 6, the density of organisms varied from 8(monsoon) to 28 animals/0.1m^2 (pre-monsoon) (Table:8.4).

8.2.3.1. Pre-monsoon Period

During pre-monsoon, station 1 registered 22 species of polychaetes, 11species of crustaceans, 3 species of molluscs, 1 species of pisces and 5 taxa of 'group others'. During pre-monsoon at station 2 there were 19 species of polychaetes, 8 species of crustaceans, 1 species each of molluscs and pisces and 5 taxa of the 'group others'. At station 3, 23 species of polychaetes, 8 species of crustaceans, 4 species of molluscs ,2 species of Pisces and 6 taxa of 'group others' were present during pre-monsoon.In station 4, there were 20 species of polychaetes, 7 species of crustaceans, 2 species each of molluscs and pisces and 'group others'. At station 5, 18 species of polychaetes, 6 species of crustaceans and 4 species of molluscs, 1 species of Pisces and 2 taxa of 'group others' were encountered. In station 6, 6 species of polychaetes, 4 species of crustaceans and 2 taxa of 'group others' were present during pre-monsoon period.

8.2.3.2. Monsoon Period

During monsoon at station 1, 18 species of polychaetes, 9 species of crustaceans, 3 species of molluscs, 1 species each of pisces and the group others were recorded. At station 2 the polychaetes consisted of 8 species, crustaceans 5 species, 2 species each of molluscs and pisces during this period. At station 3, there were 17 species of polychaetes, 9 species of crustaceans, 3 species of molluscs and 2 species of pisces .In station 4, there were 15 species of polychaetes, 4 species of crustaceans and 2 species of pisces during monsoon season. At station 5, 14 species of polychaetes, 7 species of crustaceans were reported. At this station representation of molluscs, pisces and 'group others' were found to be absent during this period. In station 6, there were 3 species of polychaetes, 3 species of crustaceans and 2 taxa of 'group others' were present during monsoon period.

8.2.3.3. Post-monsoon Period

Station 1 registered 19 species of polychaetes, 6 species of crustaceans, 2 species of molluscs and 1 taxa of 'group others' during post-monsoon.At station 2, 16 species of polychaetes, 7 species of crustaceans, 2 species of molluscs, 1 species of pisces and 4 taxa of 'group others'were encounted at this period. At station 3, there were 19 species of polychaetes, 7 species of crustaceans, and 3 species of pisces and 6 taxa of 'group others'. In station 4, there were 19 species of polychaetes, 8 species of crustaceans, 1 species of molluscs, 2 species of pisces and 3 species of 'group others'. At station 5, 16 species of polychaetes, 8 species of crustaceans and 1 species of molluscs, and 2 taxa of 'group others' were encountered during post-monsoon. In station 6, there were 5 species of polychaetes, 5 species of crustaceans and 2 taxa of 'group others' were present during post-monsoon period.

8.2.4. Diversity indices

Species diversity is a simple and useful measure of a biological system.Any variations in the species diversity could be deduced to the dynamic nature of the estuarine environment. Species richness (Margalef's index,d) ranges from 4.04 (station 6) to 8.19 (Station 2) with an average of 6.39 .Evenness index (Pielou's index, J') ranges from 0.34 (station 4)to 0.71 (station 6) with an average of 0.55.Species diversity(Shannon–Wiener index,H') varies from 1.25(station 4) to 2.36(station 2) with an average of 1.91. Species dominance (Simpson's index,$1-\lambda'$) fluctuated from 0.71(Station 1) to 0.84(Station 2) with an average of 0.73 (Table:8.3).

8.2.5. Multivariate analysis

Analysis of the structure of macrofaunal community in the study area is best accomplished by multivariate technique. Similarity matrix for macrofauna at different stations was calculated (Table: 8.4).

8.2.5.1. Cluster analysis

A group average sorting dendrogram showing the percentage similarity of the macrofauna is shown in the figure: 8.2. Hierarchial clustering reveals that maximum similarity was occurred between station 1 and 4 (78.21%) followed by station 1 and 5 (76.94%). The similarity between stations 1,2,3,4 and 5 was more than 60%. The least similarity was occurred for stations 3 and 6 (19.84%).

8.2.5.2. MDS ordination

Based on the similarity matrix two-dimensional MDS ordination is also drawn figure: 8.3. The separation of stations 2,3,5 and 6 from stations 1 and 4 by MDS is consistent with the variation detected with cluster analysis.

8.2.6. Ecological Relationship

BIOENV identified the subset of environmental data that best correlated with the ordination of benthic community data. In the BIO-ENV procedure, which was employed to measure the agreement between the rank correlations of the biological (Bray-Curtis similarity) and environmental (Euclidean distance) matrices, seventeen environmental variables were allowed to match the biota. They were depth (m), turbidity, temperature (^{0}C), salinity (ppt), pH, DO (ml/l), NO_2-N (µmol/l), NO_3-N (µmol/l), PO_4-P (µmol/l), SiO_3-Si (µmol/l),chlorophyll – *a* (µmol/l), sand (%),silt (%), clay (%),organic carbon (%),sediment temperature (^{0}C) and interstitial water content (%).The best results are given in the Table: 8.5.

8.3. DISCUSSION

The macrofaunal community of Cochin backwaters was dominated by polychaetes both in species composition and numerical abundance. It contributed more than 90% to the total density of fauna at three stations(1,4 and 5). This dominance may be due to their high degree of adaptability to a wide range of environmental factors. Many of them were highly tolerant euryhaline forms. Ajmalkhan and Murugesan (2005) deduced that polychates dominance is normal for most estuaries. Studies conducted by Devassy and Gopinathan (1970), Ansari (1974), Harkantra and Parulekar (1981), Antony and Kuttyamma (1983), Nair *et al.* (1984),Stoner and Acevedo(1990) and Broach (2001) are in harmony with this findings. In the current study the species richness of errantia and sedentaria were 16 species each.However Harkantra and Parulekar (1981) observed the dominance of errant polychates from the nearshore waters of the west coast. *Prionospio cirrifera,Paraheteromastus tenuis and Heteromastus bifidus* were found to be colonizers at majority of stations.*Ancistrosyllis constricta, Diopatra neapolitana, Glycera trydactyla, Nephthys oligobranchiata, Notomastus latericeus, Prionospio polybranchiata and Scyphoproctus djiboutiensis* gave fairly good number through out the investigation period. Antony and Kuttyamma (1983) from their investigations concluded that *Ancistrosyllis constricta*, *Nephthys polybranchia*, *Lumbriconereis* sp and *Prionospio* sp. were the dominant and highly tolerant euryhaline forms. *Maldane* sp, *Ophelia* sp, *Syllis spongicola, Dendronereis estuarina, Lumbriconereis simplex, Lycastis indica, Notopygos, Sabella* sp, *Syllis spongicola, Eteone* sp, *Exogone* sp , *Sternapsis scutata, Sthenelais* sp, *Syllis spongicola, Prionospio pinnata, Lumbriconereis latreilli, Marphysa sanguinea* and *Syllis spongicola* occurred fortuitously in a limited number of samples.The members of the family Terebellidae also had rare occurrence. The most stressed station (Station 6) was occupied by *Ancistrosyllis constricta, Capittella sp, Dendronereis estuarina, Lycastis indica, Nephthys oligobranchiata,* and *Prionospio cirrifera*. Out of these the *Prionospio cirrifera* was the dorminant group. Ajmalkhan and Murugesan (2005) published a checklist for polychaetes in Indian estuaries. The occurrence of *Glycinde bonhourei* is not mentioned in this. So *Glycinde bonhourei* reported in the present study is the first record from Indian estuaries.

Crustaceans formed the second dominant group in the current study. High concentration of *Corophium triaenonyx* and *Grandidierella* sp was noticed at the mouth of the estuary. Harkantra *et al.* (1980) found out the dominance of crustaceans in the shallow regions and mouth of the estuaries. The high density of amphipods in estuaries is also reported by Bloom *et al.*(1972),Govindan *et al.*(1983), Chandran (1987), Stoner and Acevedo(1990) and Sheeba (2000).

Harkantra and Parulekar (1981), Nair *et al.* (1984) and Bhat and Neelakantan (1988) reported molluscs normally give good share to the total population density in estuaries. The analysis of the samples revealed that the molluscs are not as well represented. They registered a maximum average value of 6% (station 4) in the current study. The exotic mollusc *Musculista senhousia* aggregated in different regions was able to reach high densities. Its dominance in the benthic communities potentially excluded native species. The mussel mats suppresses growth of other benthic animals in the same habitat.

The polychaete *Exogone* sp, *Glycera trydactyla, Glycinde bonhourei,Ophelia capensis*, the Brachyuran crabs- *Neorhynchoplax sp* and *Xenophthalmodes moebi*, the mollusc-*Katalysia* sp,*Thais sp* and *Musculista senhousia* and *Phoronida* were found to be new invader to the Cochin backwater system, since they were absent in the earlier reports of Pillai (1978), Batcha (1984), Sarala (1986) and Sheeba (2000).

Generally, when population density is higher corresponding increase in the number of taxa can be predicted. However the total number of taxa recorded in the present study is comparatively less and the population density was significantly higher when compared to the earlier reports (Pillai, 1978; Batcha, 1984; Sarala, 1986; Sheeba, 2000). In the present study H' ranged from 1.25 to 2.36 where as evenness ranged from 0.34 to 0.71. The low values of H' in the present study is attributed to the reduction in number of species, due to the environmental stress. Benthic infaunal communities in high quality condition will be diverse and dominated by deep burrowing feeders and suspension feeders. Crossing this initial threshold shifts the benthic community to more small opportunistic deposit feeders and less dominance by deep burrowing forms (Warwick, 1986; Warwick and Clarke, 1994). At present small deposit feeders dominate the estuary, which reflects a more dynamic and less stable environment.

The BIOENV multivariate correlation procedure indicated that distribution and abundance of macrobenthos are often related to salinity, DO, p^H, NO_2-N, NO_3-N, percentage of sand, depth and PO_4-P. Estuarine organisms have different tolerance and responses to salinity changes (Edgar *et al.,* 1998). A gradient of increasing species diversity from head of the estuary (station 6-low saline region) to the mouth (station 3-high saline region) is clearly demonstrated in the present study. The greatest number of taxa was recorded from stations where surface and bottom salinity differences were minimum, with increasing the difference between surface and bottom salinities (station 5) there was a trend for the number of taxa to be decreased. This suggest that site with halocline are more environmentally stressed. Variation in salinity produces changes in species composition, distribution and abundance in estuary. Salinity is the major factor controlling the species composition of estuaries (Boesch 1977, Diaz and Schaffner 1990, and Alongi 1990). In tropics the variation in temperature over months is minimal. During the monsoon season the drastic changes in salinity may results in destruction of stenohaline species or their migration to adjacent sea. The mortality and recruitment of fauna during different seasons result in continuous seasonal variation in abundance and composition of fauna. Post-monsoon was presenting a gradual increase in fanal density. But the diversity was highest during premonsoon season. Similar variation in the macrofaunal density during different seasons was observed earlier by Ansari (1974) in the Vembanad Lake, Parulekar *et al.* (1980) in the Mandovi and Zuari estuaries, Antony and Kuttyamma (1983) in the Vembanad Lake, Chandran (1987) in Vellar estuary and Raveenthiranath Nehru (1990) in Coleroon estuary and Batcha (1984) in the Vembanad Lake.According to Kurian (1972) seasonal difference in the temperature in the backwater was from 2 to 4°c and he argued that temperature is not a deciding factor for the distribution of bottom macrofauna. Present observations did not contradict these findings. However numerical density of amphipods and molluscs were significantly higher during monsoon period. Amphipods show a negative correlation with temperature and salinity (TCEQ 2003).

p^H and DO were found to be the critical factors which control the distribution of the benthic macrofauna. p^H below 7 was found to be detrimental to the fauna (station 6). Hypoxic conditions can cause a reduction in abundance and the number of benthic species (Gaston, 1985). The USEPA (2000) stated that low DO conditions can increase the vulnerability of benthos to predation as they extend above the sediment surface to obtain more oxygen. BIOENV clearly indicated the influence of nitrite, nitrate and phosphate on benthos. (Gregory *et al.*, 2003) pointed out the influence of nutrient exposure on community structure of benthos. The nutrients do not directly induce stress to macrofauna but trigger algal production (IOC, 2000). The main impact of inorganic nutrient enrichment is through the changes of habitat and food web. The recurrent occurrence of algal mass in the estuary may obstruct the settling of larvae thus preventing the new faunal recruitment to the sediment. This also may cause periodical massive benthic mortality, which may accompany by shift from large size organisms to small opportunistic species.

The study established a definite relationship between macrofaunal groups and sediment characteristic. The analysis showed that percentage of sand is an important factor responsible for the structure and maintenance of macrobenthic community. Station 1 having sandy substratum harboured highest percentage of polychaetes. Desai and Kutty (1967) opined abundance of polychaetes and bivalves in sand with small amount of silt and clay. The station 2 having high content of clay was characterized by low density of macrofauna. Panikkar and Aiyer (1937) recorded absence of animals in thick clayey substratum and abundance of fauna in loose substratum, which in close agreement with the present observations. Oxygen content in the deeper layers of sediment may be impoverished in muddy substratum. Fine particles of clay result in the clogging of the filter feeding apparatus of the filter feeders and thus, they avoid inhabiting the fine particle sized substrate (Harkantra *et al.*, 1982). BIOENV did not prove any significant correlation between organic carbon and macrobenthos. Despite this, the importance of organic matter in the distribution and abundance of benthic communities cannot be undermined since a number of benthic animals depend heavily on as food source. Joydas (2002) pointed out that even though there is no significant correlation between organic matter and the fauna, it does not mean that the fauna is not influenced by organic matter, rather, what portion of the organic matter is actually available for benthic production is not known. This view holds good for the present study also.

CHAPTER 9

BENTHIC STANDING STOCK IN THE ESTUARY

9.1. INTRODUCTION

Organisms depend on one another for their survival. Measurement of standing stocks of ecosystem components is essential to understand ecological energetics. The significance of benthos in various trophic levels is well documented (Coull,1990). Between the primary production and the fish production, the role of benthic organisms, first as a feeder of plant material and detritus and in turn forming food of higher forms is now well understood. Estimation of benthic standing stock is essential for the assessment of demersal fishery resources, as benthos form an important source of food for demersal fishes (Damodaran,1973;Parulekar *et al.*, 1982). For the better understanding of benthic productivity and benthic food chains, simultaneous measurement of standing stock of meiobenthos and macro benthos is imperative.

9.2. RESULTS

9.2.1. Numerical abundance of meiofauna

At station 1 the population density/10cm^2 ranged from 42 (November 2003) to 1068 (January 2003) individuals. In station 2 it varied from 114(January 2003) to 2466(November 2003) individuals /10cm^2.As far as station 3 is concerned population density ranged between 273(August 2002) to 2931(July 2003) individuals /10cm^2.Coming to station 4 the population density/10cm^2 ranged from 79 (November 2002) to 569(October 2002) individuals. At station 5 it varied from 105(November

2002) to 837(October 2002) individuals /10cm^2.At station 6 the maximum density observed was 121 (March 2003) individuals /10cm^2 and this station was devoid of fauna in a number of sampling. The average density of meiofauna at stations 1 to 6 were 319, 977, 1034,278,387 and 18 individuals /10cm^2 respectively (Refer table: 6.1.1-6.1.6)

At station 1 the density of nematodes/10cm^2 ranged from 30 (November 2003) to 965(January 2003) individuals. In station 2 it varied from 108(January 2003) to 2440(November 2003) individuals /10cm^2.As far as station 3 is concerned the density ranged between 253 (August 2002) to 1575 (February, 2003) individuals /10cm^2.Coming to station 4 the density/10cm^2 ranged from 33 (November, 2002) to 447(July, 2002) individuals. At station 5 it varied from 81(November, 2002) to 775(October 2002) individuals /10cm^2. With respect to station 6 the maximum density observed was 12 (May 2003) individuals /10cm^2 and this station was devoid of fauna in a number of sampling. The average densities of nematodes at stations 1 to 6 were 250,974,810,215,316 and 5 individuals /10cm^2 respectively.

Polychaetes were occasionally absent at stations 1,2,4,5 and 6. At station 1 the maximum polychaete density observed was 216(October 2002) /10cm^2 individuals. In station 2 it was 10 individuals (February 2003) /10cm^2.As far as station 3 is concerned their density ranged between 2 (August 2002) to 59 (September 2002) individuals /10cm^2.Coming to station 4 the maximum density/10cm^2 was 190 (October 2002) individuals. At station 5 it was 34 (October 2002) individuals /10cm^2.At station 6 the maximum density observed was 12 (March 2003) individuals /10cm^2. The average density of polychaetes at stations 1 to 6 were 35, 3,16,22,10 and 1 individuals /10cm^2 respectively.

At station 1 the population density of copepods/10cm^2 ranged from 0 (December 2002) to 41(April 2003) individuals. In station 2 it varied from 0 (September 2002 and January 2003) to 22 (February 2003) individuals /10cm^2.As far as station 3 is concerned the density ranged between 0 (April 2003 and June 2003) to 33 (May 2004) individuals /10cm^2.Coming to station 4 the density/10cm^2 ranged from 2 (May 2003) to 65 (March 2003) individuals. At station 5 it varied from 0 (November 2002) to 202 (May 2004) individuals /10cm^2. At station 6 the maximum density observed was 102 (March 2003) individuals /10 cm^2 and this station was devoid of copepods in a number of sampling. The average density of copepods at stations 1 to 6 were 12,7,7,13,48 and 9 individuals /10 cm^2 respectively.

At station 1 the maximum density of foraminifera observed was 78 individuals (December 2002) /10cm^2. In station 2 it was 8 individuals (March 2003) /10cm^2.As far as station 3 is concerned population density ranged between 6 (August 2002) to 1735 (July 2003) individuals /10cm^2.At station 4 it was 55 (March 2003) individuals/10cm^2. At station 5 it was 34 (October 2002) individuals/10cm^2. Occasional absence of foraminifera was reported from station 4 and 5. However, station 6 was devoid of foraminifera during the sampling period. The average density of foraminifera at stations 1 to 5 was 10, 2, 189, 9, and 4 individuals/10cm^2 respectively.

The group 'others' had an average concentration of 4 individuals /10cm^2 at station1, 16 individuals /10cm^2 at station 2, 15 individuals /10cm^2 at station 3, 18 individuals /10cm^2 at station 4, 9 individuals /10cm^2 at station 5 and 3 individuals /10cm^2 at station 6.

9.2.2. Biomass of meiofauna

Nematodes and polychaetes were the major contributors towards meiofaunal biomass .The average biomass at station 1 to 6 were 0.637 mg/10cm^2, 1.054 mg/10cm^2, 1.056 mg/10cm^2, 0.532 mg/10cm^2, 0.403 mg/10cm^2 and 0.073 mg/10cm^2 respectively (Table 9.1.1-9.1.6).

At station 1, polychaetes contributed 0.277mg/10cm^2 which form 43.5% of biomass; nematodes, copepods and the group others contributed 38.6%, 9.73% and

8.32% respectively. With respect to station 2, nematodes contributed 0.954mg/10cm^2 which form 90.5% of biomass. The copepods, the group others and polychaetes contributed share of 3.62, 3.33 and 2.57 % respectively. When we consider station 3, nematodes contributed 0.841 mg/10cm^2 which form 79.64%; polychaetes, copepods and group others donated 11.93%, 3.41% and 5.02% respectively. Coming to station 4, nematodes contributed 0.211mg/10cm^2 which form 39.66%; polychaeta, copepoda and the group others contributed 32.71%, 12.97% and 14.66% respectively. At station 5, copepodes supplied a major share towards biomass (0.197mg/10cm^2) which form 48.88 %. Nematodes having 42.18 % shares came next. Polychaetes and group others supplied 5.46% and 3.226% respectively. With respect to station 6 copepods contributed 0.044mg/10cm^2;which form 60.27%.Nematodes, polychaetes and the group others contributed 23.29, 10.96 and 4.11% respectively.

9.2.3. Numerical abundance of macrofauna

At station 1 the population density of polychaetes /0.1m^2 ranged from 126 (February 2003) to 2896(November 2002) individuals. In station 2 it varied from 28 (August 2002) to 220 (November 2002) individuals /0.1m^2.As far as station 3 is considered population density ranged between 74(July 2003) to 1218 (October 2002) individuals /0.1m^2.Coming to station 4 the total population density/0.1m^2 ranged from 26(July 2003) to 7404 (October 2002) individuals. At station 5 it varied from 74 (July 2003) to 1380 (October 2002) individuals /0.1m^2.At station 6 it ranged from 0 (August 2002, November 2002 and May 2004) to 66(March 2002) individuals /0.1m^2. The average density of polychaetes at stations 1 to 6 was 472,121,277,606,347 and 13/0.1m^2 respectively.

At station 1 the population density of crustaceans /0.1m^2 ranged from 4 (February 2003) to 74(May 2003) individuals. In station 2 it varied from 0 (September 2002) 16 (June 2003 and July 2003) individuals /0.1m^2.As far as station 3 is considered population density ranged between 4(April 2003 and June 2003) to 822

(October 2002) individuals /0.1m^2.Coming to station 4 the density/0.1m^2 ranged from 0(August 2002 and June 2003) to 72 (October 2002) individuals. At station 5 it varied from 0 (September 2002) to 40 (January 2003) individuals /0.1m^2. At station 6 the maximum density observed was 8(January 2003 and February 2003) individuals /0.1m^2 and this station was devoid of fauna in a number of sampling. The average density of crustaceans at stations 1 to 6 was 31,11,137,17,17 and 4 individuals /0.1m^2 correspondingly.

The molluscs were sporadic in occurrence at stations 1,2,3,4 and 5. They were found to be absent at station 6. The highest density reported for molluscs at stations 1,2,3,4 and 5 were 30(March 2003), 26(July 2003), 82(April 2003),290 (April 2003) and 10 (February 2003) /0.1m^2 respectively. The average densities of molluscs at stations 1 to 5 were 6,40,22,39 and 4/0.1m^2 respectively. The average density of pisces at stations 1 to 5 were 1, 1, 3, 2 and 1/0.1m^2 respectively. The group 'others'had an average concentration of 6/0.1m^{2}at station1, 12/0.1m^2 at station 2, 50/0.1m^{2}at station 3, 20/0.1m^{2}at station 4, 20/0.1m^2 at station 5 and 20/0.1m^{2}at station 6 (Ref:Table: 8.1.1-8.1.6.)

9.2.4. Biomass of macrofauna

Molluscs were the major contributors towards biomass in the study area (Table: 9.2.1-9.2.6). They were highly significant at stations 2, 3 and 4. Polychaetes were the second dominant contributor dominated mainly at stations 1, 4 and 5. Crustaceans gave considerable contribution at stations 1, 3 and 4.The contribution of the group others to the biomass is comparatively less at all stations.

The average biomass recored from stations 1 to 6 were 32.41 g/m^2, 8.7 g/m^2, 82 g/m^2, 88.67 g/m^2, 11.54 g/m^2 and 0.139 g/m^2 .At station 1 polychaetes contributed 17.54 g/m^2 which form 54.59%. Molluscs, crustaceances and others contributed 26.77, 18.54 and 0.09 % respectively towards the average biomass.When we consider station 2, molluscs contributed 4.51 g/m^2, which form 53.68%. The remaining groups polychates, crustaceances and the group others supplied 35.95, 8.45 and 1.94 % respectively. As far as station 3 is considered, the molluscs alone contributed 68.21 g/m^2 which form 86.46%. The rest of the fauna polychaetes, crustaceans and others contributed 9.01, 4.25, and 0.27% respectively towards average biomass. With regard to station 4, molluscs supplied 74.03 g/m^2, which is 83.71% of the average biomass. Polychates, crustaceans and the other groups supplied 14.33, 1.95 and 0.02% respectively. Coming to station 5 the polychaetes contributed 10.14 g/m^2 which form 89.81%. Crustaceans, molluscs and other groups contributed 6.64, 3.3 and 0.3% respectively. As far as station 6 is considered average biomass was only 0.18 g/m^2. Of which polychaetes contributed 0.09 g/m^2 which form 50 %. The crustaceans and other groups contributed 27.3 and 22.28% respectively.

9.3. DISCUSSION

Nematodes were consistent and constituted the bulk of meiofauna at all stations. In meiofauna samples, 90-95 % of individuals and 50-90% of biomass are usually contributed by this group .The meiofauna of the Cochin backwaters showed considerable fluctuation in the total density during the study period, which coincided with parallel changes in some environmental parameters. Similar changes have been reported by earlier investigators (Kondalarao and Murty, 1988; Ansari *et al.,* 2001) from Indian coast. The maximum density observed in the present study was similar to those reported from other shallow regions of the Indian coast (Ansari and Parulekar 1993; Ansari *et al.,* 2001). Jayasree, 1971 reported a maximum value of 1229/10 cm^2 for meiofauna of Cochin backwaters.However an increment to 2931/10 cm^2 was observed in the current survey.

Biomass of benthos varied significantly among habitat. Meiofaunal biomass generally paralleled the abundance value. According to Pfannkuche (1985) the measurement of biomass can often be more meaningful than the enumeration of densities to assess the standing stock.

Corresponding to the population count the biomass displayed spatial and temporal variation. However, for macrobenthos biomass had no direct relationship with the numerical abundance of fauna, but it depends on the size of the animal. The seasonality in the standing stock is synchronised well with the seasonal occurrence of individual organism. This is in agreement with the observations of Harkandra (1975) in Kali estuary.

Meiofaunal biomass in different stations decreased in the following order: Station 3>Station 2>Station 1>Station 4> Station 5>Station 6. Where as that of macrofauna decreased in the following order: Station 4>Station 3>Station 1> Station 5> Station 2> Station 1>Station 6. The benthic densities and biomass show perceptible differences between areas with different primary productivity in surface layers (Soltwedel, 2000). The average meiofaunal and macrofaunal biomass of Cochin backwater were 0.626 g/m^2 and 37.257 g/m^2 respectively (Table: 9.3). Macrofaunal biomasses of Krisna, Godavari, Mahanadi and Hoogly estuary were 0.11 g/m^2, 3.64 g/m^2, 16.04 g/m^2 and 2.48 g/m^2 respectively (Ansari *et al.,* 1982).

In the current survey the ratio between population density of meiofauna and macrofauna of Cochin backwater was 140:1, while the biomass ratio was 1:60 (Table:9.3). Rodrignes *et al.* (1982) reported that in the sublittoral zone (<20m) population ratio of meiofauna is to macrofauna was 80:1, while the biomass ratio was 1:9. However, Gerlach (1971) reported that the total meiobenthic biomass was 15% greater than macrobenthos in marine sediments. In the Karwar region the ratio between population density of Meiofauna: macrofauna was 314:1 while the ratio between the biomass was 1:18 (Anzari, 1978). The density of meiofauna and macrofauna at Krisna, Godavari, Mahanadi and Hoogly estuary were in the ratio 2193:1, 94:1, 417:1 and 1531:1 and the biomass of meiofauna and macrofauna of these estuaries were in the ratio 2.7:1, 1:2, 1:3 and 1.7:1 (Ansari *et al.,* 1982).The quantitative differences seen in different estuaries mainly depend on the environmental factors, trophic relationship, reproduction and recruitment processes.

The meiobenthos and macrobenthos together contributed a biomass of 37883 kg wet wt/km^2 in the Cochin backwater. The average macrobenthic biomass along Cochin backwaters was found to be 37257 kg wet wt/ km^2. Using the conversion factors developed by Parulekar *et al.* (1980) the dry weight obtained is 3299.8 kg/ km^2.Since 34.5% of the dry weight is made up of carbon the above value can be expressed as 1138.4 kgc/ km^2.Macrobenthos has a production of about twice the standing crop (Sanders, 1956).Based on this the macrobenthic production is 2276.8 kg C/ km^2/yr.This will call for a demand of 22768 kg C/ km^2/yr for macrobenthoic production considering the ecological transfer energy of 10%.

The average meiobenthic biomass along Cochinbackwaters was 626 kg wet weight/ km^2. Using the conversion factors developed by Wieser(1960) and Gerlach(1971) the dry weight obtained was 156.45 kg/ km^2.Since carbon content is found to be 34.5%, the above value can be expressed as 53.98 kgc/ km^2.Most species of meiobenthos has a life span of three months , the annual meiobenthic production in the Cochin backwater is calculated as 215.9 kg C/ km^2/yr.This will call for a demand of 2159 kg C/ km^2/yr for meiobenthic production.For the production of meiobenthos and macrobenthos 24927kgC/ km^2/yr is demanded. According to Shoji *et al.* (2008) the primary production of Cochin backwaters is 2.1-608.0 µg C/ L/ d. As the degree of dependence between primary and secondary production was extremely weak, sources other than the planktonic compartment need to be explored to understand the Carbon cycling in this estuary (Shoji *et al.*, 2008). The present study also substantiates this view.

CHAPTER 10

LONG-TERM CHANGES IN THE COMMUNITY STRUCTURE OF MACROBENTHOS

10.1. INTRODUCTION

The quest of man to conquer the nature has led to ever increasing degradation of the environment than envisaged .The greatest threat that haunt Kerala, the Gods own country, is the near crisis situation owing to degradation and destruction of unique habitats, topography and biodiversity. It is most unfortunate that the strength of natural endowments and biodiversity, unique to this land has not received due appreciation and valuation. Cochin backwaters, the life line of central Kerala, are subject to development pressures, such as harbour development, land reclamation, recreational projects and other anthropogenic inputs. Biological variables are important components in water quality assessment because they may uncover problems undetected in the measurements of different physicochemical parameters or under estimated by other methods (Dauer, 1993). Benthic fauna are considered as important indicators of water quality and are used in a variety of monitoring programmes to assess overall estuarine health and to follow long-term trends in estuarine communities related to anthropogenic impacts around the world .

An individual assessment at a site provides a snapshot of current conditions, where as the sequential assessments allow analysis of environmental degradation or remediation. So an attempt has been undertaken to give information on the degree to which baseline data can be used to identify constancy or a change of benthos of Cochin backwaters. Historical data for the study area is available from Pillai (1978), Batcha (1984),Sarala(1986) and Sheeba (2000) during the periods 1974-76,1977-78,1981 and 1996-97 respectively. These studies are important basis for the analysis of temporal changes in the benthos of Cochin backwaters. The present investigation was a resurvey of five selected stations of Cochin backwaters with an eye to trace the biodiversity change that might have occurred over the period 1974-2004 .For Station 1 (Thevara) baseline data was available from Pillai (1978), Batcha (1984) and sheeba (2000); and for station 2 (Mattancherry) from Pillai (1978) and Batcha (1984). The Station 3 (Barmouth) was surveyed by all the four investigators. For Station 4 (Bolghatty) and Station 5 (Varapuzha) baseline data are available only from Sarala (1986) and Sheeba (2000).

10.2. RESULTS

10.2.1. Long-term changes in the species composition of benthos

Comparison of the data of current survey with that of previous studies revealed striking differences in the community structure of benthos (Table:10.1.1-0.1.5). Based on the abundance (Average) the different species were differentiated in to Rare-R (Population density=1/m^2); Less common-LC (Population density=2-5/m^2);Common-C (Population density=6-10/m^2);Very Common-VC(Population density=11-50/m^2);Abundant- A(Population density=51-100/m^2) and Highly abundant - HA(Population density $\geq$101/m^2).

10.2.1.1. Polychaetes

Polychaetes had the highest population density in the estuary for the past thirty years. When we consider station 1, during the period 1974-1976 *Lumbriconereis* sp, *Nephthys oligobranchiata, Prionospio polybranchiata* and

Paraheteromastus tenuis were the dominating species. Where as the period 1977-78 witnessed the preponderance of *Ancistrosyllis constricta, Nephthys oligobranchiata, Nephthys polybranchiata* and *Prionospio pinnata.*During the year 1996 *Ancistrosyllis constricta, Notomastus* sp and *Prionospio polybranchiata* contributed a major share towards the total density of polychates. However during the period 2002-04, *Prinospio cirrifera* and *Heteromastus bifidus* were exceedingly abundant. Coming to station 2, during 1974-76 period Nephthys *oligobranchiata* and *Prionospio polybranchiata* were the dominating species. During 1977-78 period *Ancistrosyllis constricta* and Diopatra neapolitana proliferated remarkably. The period 2002-04 was characterized by the abundance of *Prionospio polybranchiata* and *Paraheteromastus tenuis.* At station 3, during 1974-75 period *Ancystrosyllis constricta, Prionospio cirrifera, P.pinnata and P.polybranchiata* showed dominance over other species. During the period 1977-1978 *Ancystrosyllis constricta* and *Diopatra neapolitana* were the common species. In the year 1981 *Diopatra neapolitana, Heteromastus bifidus, Lumbriconereis simplex, Pistia* sp and *Prionospio polybranchiata* were widespread. Again during the period 1996-1997 *Ancistrosyllis constricta* and *Diopatra neapolitana* were contributed considerably to total density.The period 2002-2004 was characterized by the dominance of *Prionospio cirrifera* and *Paraheteromastus tenuis.* When we consider station 4, during the year 1981 *Heteromastus bifidus* dominated in the sample followed by *Aphrodita* sp, *Dendronereis estuarina, Lycastis indica* and *Prionospio polybranchiata.* During the period 1996-1997 the area was dominated by *Notomastus latericeus. However Diopatra neapolitana* and *Prionospio polybranchiata* also gave considerable numerical density. The period 2002- 2004 witnessed the abundance of *Heteromastus bifidus, Paraheteromastus tenuis, Prionospio cirrifera* and *P.polybranchiata.* As far as station 5, is concerned the representation of macrofauna was rather poor in the base line survey itself. In the year 1981 *Dendronereis estuarina* was the dominating group. During 1996-97 period dominance of a particular group was not reported from this station. *Prionospio cirrifera* has comparatively better representation at this station during 2002-04.

From the table 10.1.1.-10.1.5 is clear that 23 polychaete species, which, were reported once from Cochin backwaters, were absent in the present survey.At present these species may be either disappeared or severely decreased in abundance. The species like *Aphrodita* sp, *Disoma* sp, *Eulalia viridis, Eunice tubifex, Fabricis* sp, *Glycera alba, Glycera convoluta, Glycera longipinnis, Goniada emerita, Heteromastus similis, Heteromastus filiformis, Lepidontus sp, Lumbriconereis heteropoda, Mesochaetopterus sp, Mercierella elongata, Odonto syllis, Owenia* sp, *Perinereis cavifrons, Phyllodoce gracilis, Pistia* sp, *Polycirrus, Sabellidae* and *Serpula* sp were not encounted in the current study. In addition to this members of Amphinomidae also disappeared. Compared to earlier survey the abundance of *Paraheteromastus tenuis, Prionospio cirrifera, P.polybranchiata* and *Polydora kempi* were increased. However the distribution of *Prionospio pinnata* appeared to be more limitted.

The following species, of current survey like *Exogone* sp, *Glycera trydactyla, Glycinde bonhourei, Ophelia* sp were not reported in the base line surveys. In the earlier survey *Maldane* sp, *Scyphoproctus djiboutiensis* and *Syllis spongicola* were reported from some other parts of the estuary but not from their present location. So they are also new to the concerned stations. In short the species composition of polychates in the study area had been changed in each survey.

10.2.1.2. Crustaceans

In the baseline surveys itself majority of the crustacean species were sporadic in occurrence. When we consider station 1 *Grandidierella* sp was the dominating group during 1974-76.During 1977-78, *Corophium triaenonyx* was the dominant variety. During 1996-97 dominance of a particular group was not seen. *Grandidierella* sp was the dominating group during the period 2002-04.Coming to station 2 during

1974-76 period there was *the dominance of Apseudes chilkensis.* During 1977-78 *Alpheus sp, Corophium triaenonyx* and *Grandidierella* sp contributed major share towards the population density. By 2002-04 density of all these species declined sharply. At station 3 dominance of a particular group was not reported during 1974-76 period. But during 1976-77 period *Alpheus* sp and *Corophium triaenonyx* contributed a notable share.In the year 1981 *Corophium triaenonyx, Cirrolinia fluviatilis, Grandidierella* and *Quadrivisio bengalensis* were extremely dominating in the estuary. During the period 1996-97 in addition to the dominant species of 1981, *Eriopisa chilkensis* also gave considerable contribution towards total density. In 2002-04 *Corophium triaenonyx* and *Grandidierella* sp supplied a major share. As far as station 4 is concerned, in 1981 *Corophium triaenonyx, Quadrivisio bengalensis* and *Grandidierella* sp were flourished in this station. In 1996-97 periods *Corophium triaenonyx* was the dominant species .In 2002-04 dominance of a particular group was not repoted. At station 5 the representation of crustaceans was rather poor in baseline study itself and by the period of current survey the station became devoid of crustaceans. The density of following species like *Alpheus euphrosyne, A.fabricius, A.malabaricus, and A.paludicola, Acetes* sp, *Penaeus indicus, Rhynchoplax* sp, *Ampelisca zamboanga, Balanus* sp, *Eriphia smithii, Litocheira* sp, *Melita* sp, *Metapenaeus* sp, *Quadrivisio bengalensis, Squailla nepa, Scylla serrata, Synidotea variegata* and *Viaderiana sp* were found to be considerably decreased. The exotic crabs *Neorhynchoplax* sp and *Xenophthalmodes moebii* were new invaders in to the system.

10.2.1.3. Molluscs

In the baseline surveys most of the molluscs were sporadic in occurrence. For the past three decades dominance of a particular species was never reported from station 1.However at station 2 there was the dominance of *Modiolus undulatus* during the period 1977-78.At station 3 during the phase 1974-76 and 1977-78 *Modiolus* *undulatus* gave considerable number towards total population density .In 1981 substantial contribution was from *Modiolus striatulus*. In 2004 *Musculista senhousia* was the flourishing organism at this station. The dominance of a particular group was never reported from station 4. At station 5 *Littorina* sp was common in 1981.The following 18 species of molluscs may be disappeared from the estuary which include *Arca bistrigata, Balbonia* sp, *Bithina* sp, *Dendorophylax* sp, *Dentalium* sp, *Dosinia* sp, *Littorina* sp, *Leiochrides africanus, ,Meritrix casta, Modiolus metacalfei, M.striatulus, M.undulatus, Naculana* sp, *Solen* sp, *Standella* sp,*Sunetta scripta, Tellina* sp,and *Villorita* sp.The bivalve *Musculista senhousia,* which is a new invader to the system, became the prevailing species. Its byssus threads, which were forming a thick mat over the estuarine bottom, prevent the growth of other benthos. The other exotic mollusc having occasional occurrence includes *Katalysia* sp and *Thais* sp.

As shown in the table the diversity of minor groups also declined.

10.2.2. Numerical abundance

Table: 10.2 gives a picture about variation in the numerical density of benthos from 1974 to 2004 period. The base line data selected for southern region is from the investigations of Pillai (1978) and that for northern region is from the survey of Sarala (1986). It is clear that the density of polychaetes increased considerably at stations 1 to 4.Yet its density decreased at station 5.The abundance of crustaceans decreased at stations 1,2,4 and 5;still it was increased at station 3. Density of molluscs decreased noticeably at stations 3, 4 and 5. However at stations 1 and 2 molluscan density increased recently due to the preponderance of the exotic mollusc *Musculista senhousia*

10.2.3. Biomass

Table: 10.3 explains variation of benthic biomass over the period 1974-2004. The base line data was available only for southern sector (stations 1, 2 and 3). It is under stood that the biomass of polychaetes and molluscs considerably increased at all stations.The biomass of crustacea increased at stations 1 and 3; however it was decreased at station 2.

10.2.4. Diversity indices

In order to get a comparable data the diversity indices for previous years were recalculated using the computer programme PRIMER v.5 (Table: 10.4,Fig: 10.1). The diversity indices for the study area were considerably fluctuated during different periods with in the last three decades. When we consider station 1, Margalef index varied from 6.7 (2002-04) to 10.64 (1974-76) and Pielous evenness index ranged from 0.5 (2002-04) to 0.8(1977-78). Shannon index oscillated from 1.88 (2002-04) to 2.9 (1977-78). Simpson index fluctuated from 0.71(2002-04) to 0.93 (1977-78). Coming to station 2 Margalef index varied from 7.1 (1977-78) to 9.4 (1974-76) and Pielous evenness index ranged from 0.46 (1977-78) to 0.64 (2002-2004). Shannon index oscillated from 1.8 (1977-78) to 2.4 (2002-2004). Simpson index fluctuated from 0.68 (1974-1976) to 0.84 (2002-2004).

At station 3 Margalef index varied from 3.73 (1996-97) to 11.17 (1974-76) and Pielous evenness index ranged from 0.16 (1981) to 0.61(1974-76). Shannon index oscillated from 0.63 (1981) to 2.48 (1974-76). Simpson index fluctuated from 0.27 (1981) to 0.83 (2002-2004). As far as station 4 is concerned, Margalef index varied from 5.95 (2002-2004) to 8.83(1996-97) Pielous evenness index ranged from 0.57 (1981) to 0.83 (1996-1997). Shannon index oscillated from 1.94 (2002-04) to 2.95 (1996-97). Simpson index fluctuated from 0.77 (2002-04) to 0.94 (1996-97). When we consider station 5, Margalef index varied from 4.04 (2002-2004) to 4.6 (1981) and Pielous evenness index ranged from 0.59 (1981) to 0.79 (1996-97). Shannon index oscillated from 1.77 (2002-04) to 1.97 (1996-97) and the Simpson index fluctuated from0.77 (2002-04) to 0.88 (1997-98).

10.2.5. Cluster analysis.

In the cluster analysis same stations of different years never form a group. If the communities were stable during different periods each single group in the dendrogram should consists of same stations, however the analysis showed each group consisted of different stations of different time interval. This suggested that the communities recorded in different periods were evidently quite distinct among themselves. The station 5 of all surveys was linked together to form a group. These results advocate that the community in the survey area has under gone a long-term change in composition during the period 1976-2004 (Fig: 10.2).

10.2.6. MDS

In the MDS plot the overlapping of same stations during different time interval was limited. It very much revealed the trend with regard to grouping of stations observed in cluster analysis. At station 2 the drift was less pronounced during successive sampling. In all other stations the assemblages were progressively diverge from the initial stage during successive sampling (Fig: 10.3).

10.2.7. ABC – plot / k- dominance curve

The data pertaining to species abundance and biomass were allowed as inputs to ABC-curve to see whether they are subjected to any form of disturbances or not. The results were shown graphically (Fig.10.4). The W values for the periods1974-76 and 2002-04 were 0.371 and -0.182 respectively.

10.3. DISCUSSION

Cochin is the industrial capital of Kerala. Many scholars have produced clear evidences to indicate the nature of evolving resource crisis and environmental degradation in Cochin backwaters. The sewage treatment system is inadequate and untreated organic and inorganic waste material is being discharged in to the backwaters (KSPCB,1981).Retting of coconut husk is another major source of organic pollution in the backwaters.The alarmed mining activity at River Periyar also may cause drastic change in the ecology of estuary. Dredging operations associated with shipping traffic cause a variety of physical and chemical disturbances. Large areas of mangrove in the backwater have been lost by human deeds. The regional decrease of mangrove causes destabilization of sediments. Cochin backwaters have fallen prey to illegal reclamation. Acres of estuarine areas are lost every year as a result of reclamation (Menon *et al.,* 2000).Deposition of plastics in the estuary is another severe problem. Plastics have a long half life and its persistence in the marine environment posses a threat. The organisms may ingest or become entangled in the plastic waste. One of the recent estimate shows that in spite of receiving $42.4 x 10^3$ $mol.d^{-1}$ of inorganic phosphate and $37.6 x 10^3$ $mol.d^{-1}$ of inorganic nitrate from Periyar side of the estuary, the export to the coastal waters is only 28.2 $x 10^3$ $mol.d^{-1}$ of inorganic phosphate and 24 $x 10^3$ $mol.d^{-1}$ inorganic nitrates (Hema Naik,2000). The estuary acts as a sink for the nutrients, flushing out only a portion of the pollution load that it receives. The enhancement with these nutrients can lead to light deprivation by phytoplankton blooms. The death and decay of planktons result in oxygen depletion of the system. The reduced oxygenation of the sediment has the potential to reduce the capacity of the denitrification process. Fundamental ecological changes triggered by nutrient enrichment related phytoplankton bloom are now evident in large coastal systems (Johansson and Sroeijs,2002).Devassi and Bhattathiri, 1974; Remani, 1979 and Sarala, 1986 confirmed that Cochin backwater was subjected to a gradual change in different physicochemical parameters. The

Sampling and sample analysis techniques were different among researchers, which prevent a meaningful comparison of results of various investigations. However it is clear that the estuary is moving towards anoxic condition resulting from organic enrichment. The anoxia caused by organic enrichment or eutrophication is now common in the marine environment (Diaz and Rosenberg, 1995).

In the shallow water, the benthos dynamics are tightly related to the process occurring in the overlying water column. Benthos in the study area responds to above mentioned deterious effects by different ways. 23 species of polychaetes,18 species of crustaceans and 18 species of molluscs which were once the inhabitant of the estuary have not sampled during present survey. The perceived loss of these organisms may be a result of poor settlement and recolonization due to altered physical condition. Otherwise the loss could be an artifact of fortuitous sampling of a small patch of these species in earlier surveys.

A complex interplay between species richness, biomass and abundance of polychaetes was observed in this survey. A sharp decrease in species richness and increase in abundance of some polychaetes was noticed. However some species were quite permanent. But the amplitude and the frequency of these changes were different among the stations. The modification was most abrupt at stations 4 (Bolghatty) and 5 (Varapuza) and it was least at station 2 (Mattancherry). The sharp increase in the population density of the euryhaline opportunist polychaete species like *Heteromastus bifidus, Paraheteromastus tenuis, Prionospio cirrifera* and *P.polybranchiata* suggest that they have got inherent ability to quickly colonize and dominate in disturbed areas. Most researchers from different parts of the world do agree that spionids and capitellids are indicators of stressed environment (Gaston and Young 1992; Weisberg *et al.,* 1993; Carlo Heip, 1995). Compared to the baseline survey, the number of suspension feeders declined and deposit feeders increased in the present survey. This may be related to the nature of the food available in the environment. In a gradient of organic matter enrichment in the sediments, the macrobenthos change from a fauna dominated by suspension feeders to deposit feeders along with some carnivore (Pearson and Rosenberg, 1978). Eutrophication may result in removal of filter feeders (Lenithan, 1999).

Dwindling the species richness and density of crustaceans and molluscs was another striking observation. Long and Chapman (1985) agreed that certain crustaceans are generally more sensitive to environmental degradation and are usually associated with less degraded areas. Decreasing the abundance of molluscs and crustaceans may be linked to nutrient loading (James, 2001). The present findings are in affirmative with these views. In addition to the aforesaid deterious effects, construction and operation of the water-controlled structures like 'Thannermukham bund' also have influence on the declination of taxonomic richness and abundance of crustaceans and molluscs. Since this act as a barrier between the fresh water and saline water habitats the estuary may no longer serve as nursery grounds for the larvae of crustaceans and molluscs, as it did earlier. This is in agreement with Arun, 2005.

As mentioned earlier 4 species of polychaetes, 2 species of crabs and 3 species of bivalves of present survey were new invaders to the Cochin backwaters. Out of which the mussel *Musculista senhousia*, settles in aggregates and dominate itself in the benthic community. In the southern limb of the estuary it potentially excludes native species by suppressing the growth of other benthos in the same habitat. Its success in the estuary is probably due the absence of predators and its high adaptability in the disturbed environment. Vast volumes of ballast water are discharged into the estuary by overseas shipping. Different organisms can be transferred around the world in ballast water (Willan 1985). In many estuaries the exotic organisms are known to be brought as fouling on barges, drilling platforms and other stuctures (Foster and Wilan, 1979).

In the southern sector of the estuary the average standing stock of major taxa (Polychate, Crustaceans and Mollusc) was calculated to be 18.25g/m^2 in 1974-76 period and 39.8 g/m^2 in 2002-04 periods. This boot is supplied by spionids, cappitellids and *Musculista senhousia*. Since a comparable standing stock data is not available for the northern sector study was limited to southern sector of the estuary.

Cluster analysis illustrated that the macrofaunal community at the same stations during different time interval were highly variable and were linked at only a low level of similarity. Multivariate analysis has proven a useful technique to identify disturbed and undisturbed site (Growns *et al.,* 1995). MDS plot displays irregular drift of stations and showed more confused pattern. In the MDS, the distance between the successive sampling years of the same station do not indicate a progressive return to their original state; which indicate variation in faunal composition at each sampling. All sampling stations came very close by the year 2004, which gives an idea that the heterogeneous system is moving to a homogeneous condition due the reduction in species diversity.

The ABC curve is helpful in finding out the disturbance to the biota. This method, as originally described by Warwick (1986) involves the plotting of separate k -dominance curves for species abundances and species biomasses on the same graph and making a comparison of these curves. Under stable conditions, the dominants in macrobenthic communities are k - selected species having less numerical abundance, large body size and long life span. In undisturbed communities the k-dominance curve for biomass lies above the curve for abundance for its entire length. When the disturbance perturbs in a community, smaller r-selected or opportunistic species with a short life span often become the biomass dominants as well as the numerical dominants. As disturbance perturbs the abundance curve lies above the biomass curve throughout its length.

The comparison of the ABC curves during different periods showed that in 1974-76 curves for biomass lies above the curve for abundance for its entire length, confirming that the backwater was unstressed. But during 2002-04 periods the curve for abundance lies above the curve for biomass for its entire length, substantiating that the backwater is stressed. The positive value of W for 1974-76 again confirmed an unstressed condition. The negative value of W for 2002-04 periods underlined the stressed condition. Warwick and Ruswahyuni (1987) and Warwick and Clarke (1991) made a comparative study in the community structure of macrobenthic communities in some tropical and temperate waters employing this technique and detected disturbance.

This study underlined that the threats are many; increasing in magnitude and the estuary is moving towards degradation. We cannot predict which community will replace the estuary in future. Since pollution has reached in an alarming level, it raises doubt whether this backwater will become a desert in future? If this happens these are gone forever. Present investigation also highlights the need to collect benthos samples for a regional assessment of environmental health and to use this benthic knowledge for impact assessment, pollution control, and resource conservation etc. Considering the ecological importance of estuary it is our duty to introduce conservation measures to save this ecosystem. There is no shortage of guidelines, codes of practice and information on how to manage ecosystem but there is still a notable lack of commitment to implement them. Genuine effort should be made by man to introduce control measures such as construction of sewage treating facilities, controlling industrial wastes going in to the estuaries by imposing stricter standards, prohibiting the destruction of mangroves and indiscriminate land reclamation etc. The construction industry must respect environmental principals and ensure that, pollution and sedimentation are minimal. There have been isolated protests against degradation and now there is a need for an integrated approach. It has been recognized that wise management of biodiversity is likely to be critical to the very survival of humanity. We should convince ourselves that Kerala is not just another land, but the biological park of India. Every inch of this land is home to myriad, diverse and unique life forms. This invaluable biodiversity should be preserved and protected for our posterity.

CHAPTER 11

SUMMARY AND CONCLUSION

Estuaries are the critical transition zones that link land, fresh water and the sea. They are the focal points of rural, urban and industrial development. The amenities they offer render them as the most valuable national treasures; whose health affects the health and the vibrancy of our community and economy. Benthic environment is the most wide spread habitat on earth and which support high biodiversity and key ecosystem services. Benthos play a key role in the physical, chemical, and biological environment of the estuary and link the sediment to aquatic food web, through their burrowing and feeding activities. No aquatic system will function long without a healthy benthic community. The use of faunal diversity as an indicator of health is the most advantageous and cost-effective approach. Within this category the benthic fauna is the most amenable and suitable group to focus on. It appears that the benthic investigations have not obtained the required momentum.

The ecology of macrofauna community of Indian coasts has attracted the attention of many ecologists but aspects leading to the meiofauna have not obtained the needed attention so far. Little is known about the community structure of free-living nematodes inhabiting in Indian estuarine sediments. So very effective effort should be made to study this “tiny wonders” of the ecosystem. Currently taxonomy is on wane and skilled taxonomists are rapidly decreasing in number. So it is high time to protect this vulnerable branch of science. Evolution of benthic community over time has not been thoroughly investigated in Indian screen.In an attempt to address the aforesaid shortcomings, a multi disciplinary investigation was carried out in the six stations of Cochin backwaters, west coast of India. The study was concentrating on physical, chemical and biological aspects of estuary. Thesis is presented in 11 chapters.

Chapter 1 gives a brief introduction to the subject emphasizing on the scope, significance and objectives of the study. **Chapter 2** pinpoints an account of past and present benthic research activity from existing scientific information. **Chapter 3** describes the study area and methodologies employed for measuring hydrographical data, sediment characteristics and analysis of meiobenthos and macrobenthos. This chapter also explains the statistical tests used in the study.

Chapter 4 is discussing about the hydrography of Cochinbackwaters. Seasonal variations of temperature, salinity, pH, dissolved oxygen, nitrite, nitrate, phosphate, silicate and chlorophyll - *a* are described in this chapter. Hydrographical data of the study area showed marked seasonal variations. In the Draftsman plot analysis strong positive correlations were obtained for attenuation coefficient and chlorophyll content (0.849) water temperature and PO_4-P (0.879), temperature and SiO3-Si (0.872), water temperature and sediment temperature (0.889), salinity & PH (0.996), DO & NO_2 - N(0.822), NO_2 - N & NO_3 - N(0.807), NO_2 - N & PO_4 - P(0.855), PO_4 - P & sediment temperature(0.957).

Chapter 5 reveals the sediment characteristics. The six types of substrata noticed in the investigation were sand, silty sand, clayey sand, sandy silt, clayey silt and silty clay. Sediments showed a clear-cut seasonal variation in composition and organic carbon content. Water retaining capacity of sediments was also estimated. Fine sediment retains more water and organic carbon. The sediment temperature followed the same pattern as that of overlying water column.

Chapter 6 explains the spatial and temporal distribution of meiobenthos in Cochin backwaters. The survey recorded a total of 14 taxa of meiobenthos .The principal groups recorded were nematoda, polychaeta, copepoda and foraminifea. Nematoda was the most dominant group at all stations. Nematodes consisted more than 78 % of the faunal density at four stations. In the backwaters its density varied from 0 to 2440 individuals /10cm^2. A close examination of vertical distribution pattern of meiobenthos indicated that maximum aggregation of the fauna was restricted to top 0-2 cm layer regardless of the sediment type. The faunal density decreased with increasing depth. High diversity was observed at coarse sediment while highest population density was obtained in fine sediment .A reduction in population density was observed during monsoon season. BIOENV proved turbidity, pH, chlorophyll a, salinity, DO, NO_2-N, NO_3-N, organic carbon and percentage of Silt have considerable positive influence on the distribution of meiofauna.

Chapter 7 highlights the different aspects of nematode assemblage of Cochin backwaters such as species composition, vertical distribution, feeding types, seasonal variation and relationships with environmental variables. Altogether 40 species of nematodes belonging to 17 families were identified. The orders Enoplida, Chromadorida and Monhysterida are represented by 6, 17 and 12 genus respectively. *Terschellingia longicaudata, Daptonema* sp, *Metalinhomoeus longiseta* and *Sabatieria sp* were present at all stations. Nematodes exhibited a strong vertical zonation in distribution. There were significant differences in the occurrence and abundance of different species within each depth fraction. Four types of feeding habits were exhibited by nematodes. Among the 40 species recorded 7 were selective deposit feeders; 17 were non selective deposit feeders; 10 were epistrate feeders and 6 were predators/omnivore. An apparent reduction in the population density of nematodes during monsoon and subsequent recolonization during post monsoon *was* noticed .The species distribution along and between stations were compared using diversity indices, cluster analysis and MDS analysis. Turbidity, Salinity, pH, percentage of sand and sediment temperature were principally influences the distribution of nematodes.

Chapter 8 describes the spatial and temporal distribution of benthic macrofauna. This chapter deals with faunal composition, seasonal variation, community structure and ecological relationship of macrobenthos in the Cochin backwaters. Among the 59 species of macrofauna collected polychaetes constituted the major component with 32 species. Crustaceans formed the second dominant group with 12 species. The molluscs and pisces ranked third and fourth position respectively with 4 and 3 species respectively. The minor group comprised 8 taxa. In the estuary polychaetes were the dominant group both in species composition and numerical abundance. *Exogone* sp, *Glycera trydactyla, Glycinde bonhourei, Ophelia capensis, Neorhynchoplax sp* and *Xenophthalmodes moebi, Musculista senhousia.Katalysia sp, Thais sp* and *Phoronida* sp were found to be new invaders to the Cochin backwater system. At present small deposit feeders dominate the estuary, which reflects a more dynamic and less stable environment. Macrobenthos showed pronounced variations during different seasons in all the stations. Margalef's index (d) Pielou's index(J) Shannon- Wiener index(H') Simpson's index(l-λ')of different station were discussed. BIOENV revealed the positive influence of salinity, DO, NO_2-N, NO_3-N,PO_4-P,depth and percentage of sand on the distribution of macrofauna.

Chapter 9 deals with benthic standing stock in the estuary. Numerical density and biomass of meiofauna and macrofauna are discussed in this chapter. The average meiofaunal and macrofaunal biomass of Cochin backwater are 0.626 and 37.257 g/m^2 respectively. The ratio between the population density of meiofauna and macrofauna was 140:1 while that of biomass was 1:60. The macrobenthic and meiobenthic production in the Cochin backwaters was 2276.8 kg C/ km^2/yr and 215.9 kg C/ km^2/yr respectively.

Chapter 10 highlights the long-term changes undergone by macrofaunal assemblages of Cochin backwaters. Benthic fauna are considered as important indicators of water quality. They are used in a variety of monitoring programmes to assess overall estuarine health and to follow long-term changes in estuarine communities related to anthropogenic impacts. So an attempt has been undertaken to give information on the degree to which baseline data can be used to identify constancy or a change of benthos of Cochin backwaters. During the periods 1974-76, 1977-78, 1981 and 1996-97 macrobenthic fauna of the backwaters were thoroughly studied. The present investigation was a resurvey of five selected stations of above survey with an eye to trace the bio diversity change that might have occurred over the period 1974-2004. In the present survey 23 polychaete species, 18 crustacean species and 18 species of mollusc, which were once reported from Cochin backwaters, found to be absent. However 4 species of polychaetes, 2 species of crabs and 3 species of molluscs of present survey were new invaders to the Cochin backwaters.The bivalve *Muculista senhousia,* a new invader to the system whose byssus threads were forming a thick mat over the estuarine bottom, preventing the growth of other benthos. A complex interplay between species numbers, biomass and abundance of organisms was observed in this survey. The ABC curve analysis also underlined that the threats are many; increasing in magnitude and the estuary is moving towards degradation.

It has been recognized that wise management of biodiversity is likely to be critical to the very survival of humanity. We should convince ourself that Kerala is not just another land, but the biological park of India, every inch of this land is home to myriad of diverse and unique life forms, invaluable and to be protected to posterity.

The list of tables, figures and references that are discussed in the study have been presented at the end of the thesis.

TABLES

Table: 4.1. Distribution of depth of water column (m) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	1.75	3.0	3.0	2.08	3.5	4.0
August	2.25	3.75	3.22	2.0	3.5	4.0
September	1.25	3.25	3.75	2.0	3.4	3.75
October	2.25	3.25	4.95	2.25	3.8	3.95
November	2.05	3.0	5.0	2.75	4.0	4.0
December	2.6	3.6	7.5	2.8	3.85	3.9
January,2003	2.25	2.55	4.5	3.5	3.55	3.75
February	1.6	2.9	5.5	2.5	3.75	3.25
March	2.5	3.65	3.75	2.5	3.55	3.93
April	1.95	2.1	6.0	2.45	3.5	3.5
May	1.65	3.5	5.5	2.5	3.5	3.55
June	1.45	3.0	5.5	3.0	3.5	4.18
July	2.5	3.0	5.75	2.8	3.75	4.15
November	3.0	3.5	4.7	3.25	3.75	5.5
May, 2004	2.0	3.0	4.75	2.6	4.0	6.0
Average	2.1	3.1	4.9	2.60	3.7	4.1
Pre-monsoon	1.94	3.03	5.1	2.51	3.66	4.05
Monsoon	1.84	3.2	4.24	2.4	3.53	4.02
Post- monsoon	2.43	3.18	5.33	2.91	3.80	4.22

Table: 4.2. Distribution of attenuation coefficient at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	4.05	4.29	3.33	5	3	1.01
August	7.5	3.33	3.13	2	3	1.97
September	1.70	1.63	1.67	2.14	1.58	1.72
October	2	1.5	1.06	1.5	1.15	1.50
November	3	1.76	1.67	2.42	1.92	0.86
December	1.95	1.5	1.23	1.36	1.34	2.08
January,2003	2.83	2.73	3	1.76	1.30	2.05
February	6	2	1.5	1.03	1.36	2.73
March	3.75	1.5	1.07	2.73	1.61	1.50
April	2.08	2.14	0.83	3	1.5	2.03
May	3	2.73	1.58	1.58	1.5	1.76
June	2.17	1.5	1.2	1.67	1.92	1.67
July	2.14	2.14	2.14	2.88	3.00	2.14
November	1.17	1.30	1.67	1.58	1.07	1.88
May, 2004	1.92	1.2	2.27	2	2.14	2.34
Average	3.02	2.08	1.82	2.18	1.83	1.82
Pre-monsoon	3.35	1.91	1.45	2.07	1.62	2.07
Monsoon	3.52	2.58	2.29	2.74	2.50	1.70
Post- monsoon	2.19	1.76	1.72	1.73	1.36	1.67

Table: 4.3 Distribution of surface water temperature (^{0}C) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	29	29	28.5	30	29	27
August	27	28	27	27	27	26
September	28	28	28	27	28	27
October	30	30	30	29	29	30
November	30	30	29	30	30	29
December	30	30	28	29	28	29.5
January,2003	28.5	28	27	29	28	29
February	30	29.5	29	29	29.5	30.5
March	30.5	31	31	28	31	32
April	32	30	31	31	32	32
May	31	31	31	31	32	32
June	31	31	31	32	33	34
July	29	30	29	29	29	29
November	31	31	30	30	30	31
May, 2004	31	31	31	31	31.5	32
Average	29.9	29.8	29.4	29.5	29.8	30
Pre-monsoon	31	31	31	30	31	32
Monsoon	29	29	29	29	29	29
Post- monsoon	30	30	29	29	29	30

Table: 4.4. Distribution of bottom water temperature (^{0}c) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	29	29	29	29	29	27
August	27	27	27	26	26	26
September	28	27	27	27	26	27
October	30	30	30	30	29	29
November	30	30	30	30	30	29
December	29	28	28	29	29	29.5
January,2003	28.5	28	28	29	28.5	29
February	31	30	29.5	30	30	31
March	30.5	31	31	28	31	31
April	31	30	30.5	31	32	32
May	31	31	31	31	32	32
June	31	31	31	32	32	33
July	30	29	29	28	29	29
November	32	30	30	30	31	31
May, 2004	31	31	31	32	32	33
Average	30	29.4	29.4	29.4	29.8	29.9
Pre-monsoon	31	31	31	30	31	32
Monsoon	29	29	29	28	28	28
Post- monsoon	30	29	29	30	30	30

Table: 4.5. Distribution of surface water salinity (ppt) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	1	2	4	2	2	0
August	1	1	2	0	0	0
September	4	10	10	18	4	0
October	22	26	27	31	18	1
November	0	3	7	3	2	0
December	26	35	34	34	18	2
January,2003	21	33	35	33	21	0
February	21	29	27	31	21	0
March	28	22	32	31	15	0
April	22	32	30	35	15	2
May	14	24	25	18	23	2
June	26	30	31	31	30	3
July	3	3	4	1	0	0
November	21	31	32	35	18	2
May, 2004	16	27	26	29	25	1
Average	15	21	22	22	14	0.9
Pre-monsoon	20	27	28	29	20	1
Monsoon	7	9	10	10	7	0.6
Post- monsoon	18	26	27	27	15	1

Table: 4.6. Distribution of bottom water salinity (ppt) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	1	4	5	5	3	0
August	2	3	4	0	0	0
September	5	17	12	22	30	0
October	27	29	31	31	35	4
November	0	35	33	33	16	0
December	34	37	36	35	33	5
January,2003	25	33	35	33	23	0
February	22	29	33	31	33	11
March	29	22	33	31	25	6
April	24	32	32	31	31	5
May	22	24	26	24	8	1
June	25	30	33	31	32	10
July	3	4	8	22	2	0
November	28	33	33	36	30	10
May, 2004	21	27	31	28	27	16
Average	18	24	26	26	22	5
Pre-monsoon	24	27	31	29	25	8
Monsoon	7	12	12	16	13	2
Post- monsoon	23	33	34	34	27	4

Table: 4.7. Distribution of surface water pH at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	7.27	7.4	7.3	7.1	7.3	6.3
August	7	7.1	7.2	7	6.9	6.6
September	7.3	7.3	7.3	7.1	7.6	6.7
October	8.1	8.1	7.8	7.4	7	6.4
November	6.8	6.7	6.8	6.9	7	7.2
December	7.4	7.8	7.6	8.3	7.3	4.5
January,2003	7.7	8.2	8.3	8.5	8.2	6.9
February	7.3	8	8.1	8.2	7.6	3.5
March	7.8	7.9	8	7.8	7	5.6
April	7.9	8	7.9	7.8	7.8	3.5
May	7.4	7.5	7.6	7.7	7.5	6.9
June	7.7	7.9	7.7	8.1	7.6	5.9
July	7.1	7.2	7.3	6.8	7.2	6.8
November	8.3	8	8.2	8.4	8.2	3
May, 2004	8.3	8.2	8.3	8.3	8.2	7.8
Average	7.6	7.7	7.7	7.7	7.5	5.84
Pre-monsoon	7.74	7.93	7.98	7.95	7.63	5.46
Monsoon	7.27	7.38	7.36	7.22	7.32	6.46
Post-monsoon	7.66	7.76	7.74	7.9	7.54	5.6

Table: 4.8. Distribution of bottom water pH at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	7.27	7.4	7.4	7.3	7.4	5.2
August	6.9	7.1	7.13	7.3	7.3	6.6
September	7.3	7.3	7.4	7.6	7.5	6.3
October	7.5	8	7.8	7.7	7.8	6.7
November	7	7.5	7.5	7.9	7.6	6.8
December	7.2	7.2	8	8.2	7.6	6.8
January,2003	7.9	8.5	8.3	8	7.9	7
February	7.6	7.9	8.2	8.2	8.3	7.2
March	7.9	7.7	8.1	7.9	7.9	6.7
April	7.8	8	8.1	8	7.9	6.6
May	7.5	7.7	8	7.8	7.6	6.8
June	7.6	7.8	7.9	7.8	7.5	6.7
July	7.5	7.1	7.6	8	7.1	7.6
November	8.3	8.4	8.1	8.4	8.2	6.6
May, 2004	8.2	8.0	8.3	7.7	8.3	8.3
Average	7.57	7.7	7.85	7.85	7.73	6.79
Pre-monsoon	7.81	7.86	8.14	7.93	8	7.12
Monsoon	7.31	7.34	7.49	7.6	7.36	6.48
Post- monsoon	7.58	7.92	7.94	8.04	7.82	6.78

Table: 4.9. Distribution of surface water DO (ml/l) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	4.70	4.21	4.12	4.55	4.21	4.94
August	4.90	4.12	3.87	4.41	4.26	5.44
September	4.99	3.29	3.29	3.54	3.87	4.07
October	5.52	4.12	2.62	3.05	3.20	4.26
November	3.59	3.64	3.35	4.03	4.08	4.53
December	4.56	4.08	2.91	3.69	4.76	3.64
January,2003	2.76	3.23	3.79	3.93	3.60	4.21
February	2.82	3.27	3.73	3.58	4.53	3.32
March	3.36	2.78	2.82	2.24	3.21	2.97
April	2.95	2.30	2.40	3.15	3.65	3.90
May	1.87	2.25	2.82	3.25	3.35	4.16
June	3.69	3.35	3.35	3.02	2.68	2.63
July	2.62	4.46	3.85	3.95	3.64	4.00
November	4.67	3.03	2.98	3.85	3.95	3.39
May, 2004	1.94	2.73	3.04	2.31	2.68	3.04
Average	3.66	3.39	3.26	3.50	3.71	3.90
Pre-monsoon	2.59	2.67	2.97	2.91	3.48	3.48
Monsoon	4.18	3.89	3.70	3.89	3.70	4.20
Post-monsoon	4.22	3.62	3.13	3.71	3.92	4.01

Table: 4.10. Distribution of bottom water DO (ml/l) at stations 1-6 during the period July 2002- May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	4.84	4.55	4.60	4.41	4.75	5.42
August	4.75	4.21	4.21	4.70	4.90	5.93
September	4.41	2.95	3.58	2.91	1.74	4.89
October	3.92	4.41	3.68	3.63	3.73	4.31
November	4.03	3.00	3.84	3.10	2.51	4.77
December	4.37	4.27	3.98	3.74	3.79	4.27
January,2003	3.51	3.18	4.16	4.16	3.70	3.74
February	3.12	3.88	4.38	4.18	3.93	4.18
March	3.36	3.46	3.31	3.02	3.21	3.31
April	3.05	2.80	4.05	2.30	2.75	3.80
May	3.25	3.35	4.07	3.30	3.11	4.07
June	3.45	3.21	3.54	2.82	2.97	3.11
July	2.92	4.10	3.49	2.72	4.05	4.21
November	4.00	3.80	3.64	4.62	4.11	5.49
May, 2004	3.04	2.83	3.41	2.62	3.10	2.57
Average	3.70	3.60	3.86	3.48	3.49	4.27
Pre-monsoon	3.17	3.26	3.84	3.08	3.22	3.59
Monsoon	4.07	3.81	3.89	3.51	3.68	4.71
Post-monsoon	3.97	3.73	3.86	3.85	3.57	4.52

Table: 4.11. Distribution of surface water NO_2-N (micromol/l) at stations 1-6 during the period July 2002 -May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	0.41	0.69	0.41	0.69	0.69	0.43
August	0.48	0.54	0.67	1.15	1.02	0.50
September	0.71	0.61	0.71	2.21	5.98	8.80
October	0.26	0.37	0.84	0.37	1.06	0.84
November	1.04	0.56	0.54	0.50	0.54	0.26
December	0.89	1.19	0.74	0.35	0.76	0.13
January,2003	0.82	0.19	0.28	0.35	0.87	0.63
February	2.19	0.37	0.82	0.35	0.37	0.19
March	0.56	0.43	0.35	0.69	1.06	0.54
April	1.97	1.06	1.08	1.24	0.95	0.48
May	2.86	0.41	1.02	0.63	0.61	0.50
June	0.71	0.22	0.58	0.22	0.69	0.41
July	2.82	0.76	1.30	0.74	0.78	0.41
November	0.39	0.19	0.26	0.50	0.45	0.28
May, 2004	5.35	0.76	1.32	1.37	2.23	0.78
Average	1.43	0.58	0.73	0.75	1.20	1.01
Pre-monsoon	2.59	0.61	0.92	0.85	1.04	0.50
Monsoon	1.03	0.56	0.74	1.00	1.83	2.11
Post-monsoon	0.68	0.50	0.53	0.41	0.74	0.43

Table: 4.12. Distribution of bottom water NO_2-N (micromol/l) at stations 1-6 during the period July 2002 – May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	0.50	1.41	0.52	0.41	1.02	0.37
August	0.63	0.63	0.54	1.60	0.95	0.48
September	0.45	0.45	0.56	2.49	0.54	8.78
October	0.24	0.65	0.58	0.61	0.67	0.93
November	1.19	1.30	0.93	1.69	1.04	0.30
December	0.17	0.30	0.26	0.17	0.74	0.37
January,2003	0.39	0.13	0.22	0.15	0.74	1.24
February	1.60	0.58	0.32	0.58	0.50	0.52
March	0.58	0.39	0.26	0.80	0.67	0.71
April	1.32	1.65	1.24	1.37	1.15	0.61
May	1.34	0.45	1.02	0.82	0.48	0.35
June	0.71	0.45	0.22	0.61	0.28	0.19
July	3.21	0.58	1.65	0.82	0.95	0.50
November	0.17	0.17	0.22	0.24	0.28	0.80
May, 2004	1.52	0.95	1.24	1.30	0.80	0.67
Average	0.94	0.67	0.65	0.91	0.72	1.12
Pre-monsoon	1.27	0.81	0.81	0.98	0.72	0.57
Monsoon	1.10	0.71	0.70	1.19	0.75	2.06
Post- monsoon	0.43	0.51	0.44	0.57	0.69	0.73

Table: 4.13. Distribution of surface water NO_3-N (micromol/l) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	19.59	14.11	17.72	12.66	18.60	20.23
August	14.70	10.90	11.85	12.66	14.74	14.10
September	2.55	2.36	8.03	1.80	5.25	7.83
October	3.42	9.12	9.81	9.04	2.24	23.55
November	15.01	11.25	15.88	17.96	16.92	18.24
December	0.00	0.00	3.15	1.25	0.84	10.98
January,2003	3.35	2.73	3.15	2.42	5.80	16.38
February	6.26	3.23	5.84	2.50	2.27	18.56
March	0.04	0.75	1.67	0.24	0.00	5.05
April	1.70	4.32	2.09	2.52	3.06	6.61
May	2.27	3.06	12.54	2.67	2.78	8.45
June	4.08	4.42	3.30	3.75	2.11	51.07
July	12.49	7.57	10.68	7.67	17.47	17.63
November	0.05	0.33	0.47	0.81	0.00	11.70
May, 2004	18.17	3.00	4.51	7.59	8.05	8.21
Average	6.91	5.15	7.38	5.70	6.68	15.90
Pre-monsoon	5.69	2.87	5.33	3.11	3.24	9.37
Monsoon	10.68	7.87	10.32	7.71	11.64	22.17
Post- monsoon	4.37	4.69	6.49	6.30	5.17	16.17

Table: 4.14. Distribution of bottom water NO_3-N (micromol/l) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	10.86	13.77	16.90	14.10	15.62	20.63
August	13.31	9.57	12.40	11.21	12.40	12.30
September	1.85	0.77	4.28	2.06	0.27	7.81
October	2.65	2.61	2.59	10.30	1.51	28.62
November	13.61	5.99	1.87	3.85	5.59	17.16
December	0.72	0.00	0.68	0.93	0.66	8.00
January,2003	2.71	2.80	3.54	4.27	3.85	11.29
February	6.10	2.51	1.69	4.25	2.14	10.59
March	0.60	0.46	0.34	1.05	0.39	3.17
April	1.77	5.10	2.36	2.81	2.86	4.19
May	3.00	3.51	4.73	4.27	2.91	10.56
June	7.57	5.22	4.83	4.19	2.52	20.51
July	13.26	7.00	15.53	14.15	17.30	28.80
November	0.00	0.00	0.18	0.53	0.16	4.95
May, 2004	2.95	4.47	3.40	5.49	9.52	2.05
Average	5.40	4.26	5.02	5.56	5.18	12.70
Pre-monsoon	2.88	3.21	2.50	3.57	3.56	6.11
Monsoon	9.37	7.26	10.79	9.14	9.60	18.01
Post- monsoon	3.94	2.29	1.77	3.98	2.35	14.01

Table: 4.15. Distribution of surface water PO_4-P (micromol/l) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	2.65	2.77	1.99	0.98	1.72	0.40
August	2.81	2.50	2.42	3.20	4.87	3.66
September	0.98	1.14	1.68	1.49	2.89	2.07
October	0.25	0.40	1.68	2.03	3.66	7.89
November	4.63	1.49	2.23	1.68	2.38	2.96
December	2.38	1.53	0.32	0.52	0.25	2.42
January,2003	2.30	2.42	0.56	0.01	1.57	8.44
February	1.88	0.48	0.48	0.91	0.95	0.36
March	2.03	0.79	0.71	0.79	0.75	0.52
April	7.12	1.10	1.49	2.96	1.68	0.05
May	4.09	0.75	0.95	0.48	0.67	0.32
June	0.60	0.36	0.40	0.79	1.02	0.13
July	2.50	0.87	0.13	0.36	0.13	0.21
November	0.36	0.13	0.05	0.05	0.25	0.21
May, 2004	2.85	0.98	1.41	2.23	1.29	1.80
Average	2.50	1.18	1.10	1.23	1.60	2.10
Pre-monsoon	3.59	0.82	1.01	1.47	1.07	0.61
Monsoon	1.91	1.53	1.33	1.36	2.13	1.29
Post- monsoon	1.99	1.19	0.97	0.86	1.62	4.38

Table: 4.16. Distribution of bottom water PO_4-P (micromol/l) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	2.61	4.71	2.50	1.99	2.27	0.05
August	3.86	2.69	1.95	3.93	3.43	3.24
September	1.41	1.33	2.11	3.24	2.58	1.84
October	0.29	0.48	0.83	1.64	1.57	8.24
November	6.03	1.26	1.45	1.61	4.94	2.50
December	1.29	2.92	1.41	0.40	1.22	0.44
January,2003	2.61	0.87	0.98	0.75	3.04	19.07
February	1.61	0.98	0.52	0.98	0.52	0.48
March	1.02	1.88	0.52	0.83	0.71	0.87
April	3.31	0.44	0.95	2.73	2.92	0.60
May	1.37	0.91	1.10	0.98	0.83	0.09
June	0.40	0.60	2.30	0.71	0.75	0.83
July	2.34	0.01	0.29	0.13	0.13	0.32
November	0.13	0.09	0.09	0.09	0.17	0.60
May, 2004	2.65	1.02	0.95	1.88	0.83	0.87
Average	2.06	1.35	1.20	1.46	1.73	2.67
Pre-monsoon	1.99	1.05	0.81	1.48	1.16	0.58
Monsoon	2.13	1.87	1.83	2.00	1.83	1.26
Post- monsoon	2.07	1.12	0.95	0.90	2.19	6.17

Table: 4.17. Distribution of surface water SiO_4-Si (micromol/l) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	89.51	110.45	100.60	54.95	53.88	42.25
August	113.94	94.03	118.30	119.11	120.51	112.44
September	97.69	70.72	86.44	27.77	95.27	93.98
October	5.03	5.70	26.29	9.88	39.61	32.48
November	115.51	119.68	60.20	36.52	68.14	41.09
December	25.35	10.92	10.22	2.34	4.79	5.97
January,2003	25.24	21.47	10.66	8.45	37.51	23.41
February	11.19	12.22	12.38	6.51	13.29	11.84
March	26.48	14.58	16.79	11.03	21.31	18.35
April	21.96	13.13	20.56	30.84	47.15	57.05
May	13.08	8.77	14.96	19.70	15.55	22.17
June	3.87	2.58	1.61	6.56	5.54	0.27
July	44.51	17.33	78.37	11.46	14.58	21.10
November	17.06	6.40	7.70	9.53	22.12	19.05
May, 2004	30.03	8.83	8.88	7.86	5.38	4.25
Average	42.69	34.45	38.26	24.37	37.64	33.70
Pre-monsoon	20.55	11.51	14.71	15.19	20.54	22.73
Monsoon	69.91	59.02	77.06	43.97	57.96	54.01
Post- monsoon	37.63	32.84	23.01	13.34	34.44	24.40

Table: 4.18. Distribution of bottom water SiO_4 (micromol/l) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	96.02	107.75	111.52	50.65	86.55	31.59
August	105.87	109.15	102.21	116.80	115.99	105.60
September	91.45	60.01	76.54	43.70	21.53	88.92
October	7.86	8.66	11.89	15.02	15.39	6.38
November	114.32	15.82	16.06	29.39	98.17	56.84
December	16.31	17.81	30.41	1.40	5.84	0.72
January,2003	22.17	14.64	32.56	12.54	34.98	65.83
February	9.85	11.25	4.90	9.36	8.93	19.16
March	17.55	1.72	14.10	14.42	15.39	22.66
April	26.26	9.31	12.75	26.64	27.77	57.97
May	12.27	14.21	19.70	15.23	16.47	3.23
June	4.90	4.47	2.47	5.43	6.30	1.24
July	68.19	21.47	32.88	30.41	16.41	60.07
November	8.34	9.20	11.41	11.62	6.62	38.70
May, 2004	9.04	7.10	4.14	8.56	1.72	9.15
Average	40.69	27.50	32.24	26.08	31.87	37.87
Pre-monsoon	14.99	8.72	11.12	14.84	14.06	22.43
Monsoon	73.29	60.57	65.13	49.40	49.36	57.48
Post- monsoon	33.80	13.23	20.47	13.99	32.20	33.69

Table: 4.19. Distribution of chlorophyll - *a* (micromol/l) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	7.70	10.64	7.77	9.76	6.98	0.57
August	7.95	4.81	3.43	3.64	5.57	0.35
September	21.38	16.75	16.75	6.75	8.17	1.73
October	24.77	14.44	7.77	10.27	2.05	2.97
November	2.63	1.72	2.39	4.92	4.34	3.28
December	11.21	5.46	3.05	6.93	8.62	6.73
January,2003	7.63	3.73	5.28	1.15	4.47	5.28
February	4.36	4.94	9.27	1.80	2.50	3.09
March	9.29	2.04	1.83	2.36	3.31	2.31
April	12.60	3.86	4.90	5.69	12.99	1.43
May	15.33	6.54	2.59	6.06	10.09	2.95
June	15.01	5.73	12.84	7.63	11.53	15.92
July	6.32	2.08	3.30	5.06	6.44	2.96
November	26.39	15.58	2.99	-	-	-
May, 2004	8.68	3.18	6.98	4.80	7.65	16.35
Average	12.08	6.76	6.08	5.49	6.77	4.71
Pre-monsoon	10.05	4.11	5.11	4.14	7.30	5.23
Monsoon	11.67	8.00	8.82	6.57	7.74	4.30
Post- monsoon	14.53	8.19	4.30	5.82	4.87	4.57

Table: 5.1. Distribution of sediment temperature (^{0} c) at stations 1-6 during the period July 2002-May 2004

	Station1	Station2	Station3	Station4	Station5	Station6
July,2002	29	28	28	29	28	28
August	28	28	28	26	27	26
September	28	28	28	27	29	28
October	30	30	31	30	30	31
November	30	30	30	31	31	29
December	31	30.5	30	31	31	31
January,2003	29	29	29	30	30	29.5
February	30	30	30	29	30	31
March	31	31	31	31	31.5	32
April	32	31	31	31	31	33
May	32	31	31	32	32	33
June	31.5	32	32	32	32	34
July	30	29	28	29	29	29
November	32	32	32	32	32	32
May, 2004	33	32	33	32	33	34
Average	30.43	30.1	30.133	30.13	30.43	30.7
Pre-monsoon	31.6	31	31.2	31	31.5	31.2
Monsoon	29.3	29	28.8	28.6	29	29
Post-Monsoon	30.4	30.3	30.4	30.8	30.8	30.5

Table: 5.2. Distribution of interstitial water content (%) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	37.80	75.42	69.26	77.39	72.68	70.08
August	37.30	71.04	88.46	77.42	77.01	33.97
September	27.55	79.17	52.98	77.59	76.33	60.23
October	38.27	77.56	69.83	76.11	74.54	44.04
November	28.17	77.42	70.73	75.62	73.50	76.10
December	67.22	76.22	70.66	73.33	72.31	77.45
January,2003	59.96	76.04	69.43	75.21	71.29	79.99
February	51.32	75.84	65.76	72.43	74.23	75.21
March	37.99	74.87	71.15	70.81	70.08	74.36
April	39.34	76.34	61.09	70.06	69.79	73.91
May	41.42	75.62	67.20	72.04	68.89	74.58
June	37.99	76.73	66.08	73.52	68.09	72.45
July	40.26	76.55	85.50	73.89	70.16	76.81
November	28.02	77.83	72.75	75.01	71.56	75.38
May, 2004	48.61	75.43	64.76	73.27	69.75	64.30
Average	41.41	76.14	69.70	69.08	72.01	71.65
Pre-monsoon	43.73	75.62	66.00	71.72	70.55	76.18
Monsoon	36.18	75.78	72.46	75.96	72.86	62.70
Post- monsoon	44.33	77.02	70.68	75.06	72.64	70.59

Table: 5.3.1. Distribution of organic carbon (%) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	0.56	3.92	3.53	4.45	3.70	2.73
August	0.32	3.91	2.87	4.56	4.18	2.37
September	0.25	4.01	2.18	4.11	4.29	2.28
October	0.91	3.97	2.97	4.23	4.10	1.19
November	0.44	4.22	3.70	4.43	3.98	3.54
December	3.19	3.96	3.89	4.06	4.17	4.03
January,2003	2.62	3.82	3.47	4.13	3.85	4.10
February	1.13	3.30	1.67	3.33	3.44	3.33
March	0.88	4.15	3.53	3.57	4.37	2.38
April	0.74	3.79	1.90	3.75	3.84	2.95
May	0.78	3.52	2.70	3.28	3.52	2.70
June	0.60	3.87	3.52	3.36	2.93	2.38
July	0.98	3.44	2.42	3.13	3.01	2.45
November	0.85	4.15	3.86	4.46	4.29	2.68
May, 2004	0.99	3.22	3.1	3.15	3.98	3.52
Average	1.017	3.816	3.02	3.87	3.84	2.84
Pre-monsoon	0.904	3.594	2.58	3.42	3.828	2.58
Monsoon	0.54	3.83	2.90	3.92	3.62	2.44
Post-monsoon	1.60	4.02	3.58	4.26	4.08	3.11

Table: 5.3.2. Distribution of organic matter (%) at stations 1-6 during the period July 2002-May 2004

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
July,2002	0.96	6.77	6.08	7.68	6.39	4.71
August	0.56	6.74	4.95	7.87	7.21	4.09
September	0.44	6.91	3.76	7.09	7.39	3.93
October	1.57	6.84	5.13	7.30	7.07	2.05
November	0.76	7.27	6.38	7.63	6.85	6.10
December	5.51	6.82	6.70	7.00	7.18	6.94
January,2003	4.51	6.59	5.99	7.12	6.65	7.06
February	1.96	5.69	2.87	5.75	5.93	5.75
March	1.52	7.15	6.08	6.16	7.53	4.11
April	1.27	6.54	3.27	6.46	6.61	5.09
May	1.35	6.06	4.65	5.66	6.06	4.65
June	1.03	6.67	6.06	5.79	5.05	4.11
July	1.68	5.93	4.18	5.39	5.19	4.22
November	1.47	7.15	6.65	7.69	7.40	4.62
May, 2004	1.71	5.55	5.34	5.43	6.86	6.07
Average	2.76	6.94	6.17	7.35	7.03	5.36
Pre-monsoon	1.753	6.58	5.21	6.67	6.62	4.9
Monsoon	1.56	6.198	4.44	5.892	6.598	4.44
Post- monsoon	0.93	6.60	5.00	6.76	6.25	4.21

Table: 5.4.1. Sedimentary properties of station 1 during the period July 2002-May 2004

	%Sand	%Silt	%Clay	Nomenclature
July,2002	93.49	4.51	2.00	Sand
August	95.95	2.02	2.02	Sand
September	95.47	0.00	4.53	Sand
October	92.17	5.04	2.80	Sand
November	92.22	0.00	7.78	Sand
December	36.54	46.20	17.26	Sandy silt
January,2003	79.39	15.19	5.42	sand
February	77.58	16.68	5.74	sand
March	86.85	7.08	6.07	sand
April	88.81	9.16	2.04	sand
May	87.12	11.39	1.49	sand
June	83.50	12.73	3.77	sand
July	95.34	3.62	1.04	sand
November	92.71	5.83	1.46	sand
May, 2004	80.51	14.49	5.00	sand
Average	85.17	10.26	4.56	sand
Pre-monsoon	84.17	11.76	4.06	sand
Monsoon	92.75	4.58	2.67	sand
Post- monsoon	78.60	14.45	6.94	sand

Table: 5.4.2. Sedimentary properties of station 2 during the period July 2002-May 2004

	%Sand	%Silt	%Clay	Nomenclature
July,2002	0.85	54.03	45.12	Clayey silt
August	1.69	56.76	41.55	Clayey silt
September	2.34	49.83	47.83	Clayey silt
October	1.73	60.56	37.71	Clayey silt
November	0.47	54.29	45.24	Clayey silt
December	1.49	53.98	44.52	Clayey silt
January,2003	2.84	57.02	40.14	Clayey silt
February	2.59	57.18	40.23	Clayey silt
March	2.66	57.03	40.31	Clayey silt
April	0.60	58.61	40.80	Clayey silt
May	2.14	52.91	44.95	Clayey silt
June	1.15	57.38	41.47	Clayey silt
July	2.93	49.68	47.39	Clayey silt
November	1.54	47.53	50.93	Silty clay
May, 2004	5.31	46.75	47.93	Silty clay
Average	2.02	54.23	43.74	Clayey silt
Pre-monsoon	2.66	54.49	42.84	Clayey silt
Monsoon	1.79	53.54	44.67	Clayey silt
Post- monsoon	1.61	54.68	43.71	Clayey silt

Table: 5.4.3. Sedimentary properties of station 3 during the period July 2002-May 2004

	%Sand	%Silt	%Clay	Nomenclature
July,2002	72.53	20.87	6.59	Silty sand
August	89.84	7.90	2.26	Sand
September	84.10	6.58	9.32	Sand
October	61.42	28.49	10.09	Silty sand
November	76.88	4.20	18.92	Sand
December	65.95	17.03	17.03	Silty sand
January,2003	53.25	28.77	17.98	Silty sand
February	70.23	14.01	15.76	Silty sand
March	49.31	33.79	16.90	Silty sand
April	71.19	20.11	8.70	Silty sand
May	65.96	27.23	6.81	Silty sand
June	69.93	15.89	14.18	Silty sand
July	71.22	20.14	8.63	Silty sand
November	59.34	24.40	16.26	Silty sand
May, 2004	74.66	5.89	19.45	Clayey sand
Average	69.05	18.35	12.59	Silty sand
Pre-monsoon	66.27	20.21	13.52	Silty sand
Monsoon	77.53	14.28	8.20	Silty sand
Post- monsoon	63.37	20.58	16.06	Silty sand

Table: 5.4.4. Sedimentary properties of station 4 during the period July 2002-May 2004

	%Sand	%Silt	%Clay	Nomenclature
July,2002	67.89	21.22	10.88	Silty sand
August	64.25	24.75	11.00	Silty sand
September	71.98	20.01	8.01	Silty sand
October	48.31	39.76	11.93	Silty sand
November	56.28	31.23	12.49	Silty sand
December	45.14	39.02	15.84	Silty sand
January,2003	76.68	16.81	6.51	sand
February	56.27	30.17	13.56	Silty sand
March	52.44	34.37	13.19	Silty sand
April	65.12	24.36	10.52	Silty sand
May	49.22	35.71	15.07	Silty sand
June	40.32	42.55	17.13	Sandy silt
July	51.16	32.94	15.90	Silty sand
November	39.36	38.39	22.25	Silty sand
May, 2004	37.90	39.92	22.18	Sandy silt
Average	54.82	31.40	13.76	Silty sand
Pre-monsoon	52.19	32.91	14.9	Silty sand
Monsoon	59.12	28.29	12.58	Silty sand
Post- monsoon	53.15	33.04	13.80	Silty sand

Table: 5.4.5. Sedimentary properties of station 5 during the period July 2002-May 2004

	%Sand	%Silt	%Clay	Nomenclature
July,2002	71.81	21.93	6.26	Silty sand
August	53.90	33.62	12.47	Silty sand
September	78.65	15.87	5.47	Sand
October	57.90	33.90	8.20	Silty sand
November	66.83	26.31	6.86	Silty sand
December	48.82	32.35	18.83	Silty sand
January,2003	60.80	29.82	9.39	Silty sand
February	59.67	30.89	9.44	Silty sand
March	49.34	39.05	11.61	Silty sand
April	63.84	29.15	7.02	Silty sand
May	58.01	31.10	10.89	Silty sand
June	45.69	39.93	14.38	Silty sand
July	66.52	24.44	9.03	Silty sand
November	43.42	38.80	17.78	Silty sand
May, 2004	53.17	33.97	12.87	Silty sand
Average	58.56	30.74	10.70	Silty sand
Pre-monsoon	56.81	32.83	10.36	Silty sand
Monsoon	63.32	27.16	9.52	Silty sand
Post- monsoon	55.55	32.24	12.21	Silty sand

Table: 5.4.6. Sedimentary properties of station 6 during the period July 2002-May 2004

	%Sand	%Silt	%Clay	Nomenclature
July,2002	75.71	18.09	6.20	Silty sand
August	77.65	17.02	5.32	Sand
September	89.35	6.09	4.57	Sand
October	93.57	3.46	2.97	Sand
November	55.00	38.08	6.92	Silty sand
December	72.26	22.60	5.14	Silty sand
January,2003	77.73	16.06	6.22	Sand
February	55.48	38.54	5.98	Silty sand
March	87.30	8.47	4.23	Sand
April	72.18	24.28	3.54	Silty sand
May	70.29	21.52	8.20	Silty sand
June	83.63	12.79	3.58	Sand
July	65.30	28.12	6.58	Silty sand
November	69.25	22.68	8.06	Silty sand
May, 2004	55.91	29.58	14.51	Silty sand
Average	73.37	20.49	6.13	Silty sand
Pre-monsoon	66.27	20.206	13.52	Silty sand
Monsoon	78.33	16.42	5.25	Silty sand
Post- monsoon	73.56	20.58	5.86	Silty sand

Table: 6.1.1. Distribution of meiofauna (no/10 sq.cm) at station 1 during the period July 2002 -May 2004

	July,02	Aug	Sep	Oct	Nov	Dec	Jan.03	Feb	Mar	Apr	May	Jun	July	Nov	May,04
Foraminifeans	0	0	0	0	0	78	26	16	2	24	0	0	0	0	2
Turbellarians	0	0	20	6	0	0	2	0	8	4	2	8	8	6	2
Nematodes	53	191	144	310	169	557	965	732	130	123	102	40	35	30	171
Nemerteans	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Polychaetes	2	12	47	216	26	28	69	0	8	82	16	8	8	0	8
Nauplius	0	0	2	0	0	2	0	0	4	0	0	2	0	0	0
Copepods	2	14	4	10	10	0	4	2	16	41	2	24	35	2	14
Acari	6	0	2	0	4	2	0	0	1	2	0	0	0	0	0
Cumaceanes	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Amphipods	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
Ostracods	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Bivalves	0	0	4	0	0	2	2	0	2	2	0	0	0	2	0
Gastropods	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Total	63	219	223	348	211	669	1068	750	171	278	122	82	86	42	119

Table: 6.1.2. Distribution of meiofauna (no/10 sq.cm)at station 2 during the period July 2002 -May 2004

	July,02	Aug	Sep	Oct	Nov	Dec	Jan.03	Feb	Mar	Apr	May	Jun	July	Nov	May,04
Foraminiferans	2	0	2	0	0	0	2	6	8	6	4	2	0	0	0
Turbellarians	4	2	6	2	4	0	0	4	0	6	0	4	6	0	2
Nematodes	210	167	132	192	1167	2225	108	1679	1441	891	2222	1116	352	2440	265
Nemerteans	0	0	0	0	2	0	0	0	0	0	2	0	0	8	0
Polychaetes	4	2	2	2	2	0	2	10	6	2	4	0	0	8	8
Kinorhynchs	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Nauplius	0	0	0	0	0	0	0	8	0	2	0	0	2	0	0
Copepods	2	2	0	2	6	4	0	22	18	8	6	8	20	8	4
Acari	6	2	0	0	10	0	0	0	2	0	0	2	0	0	0
Amphipods	0	2	0	0	0	0	2	0	0	0	0	0	0	2	0
Ostracods	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Bivalves	0	0	0	0	0	0	0	0	6	0	0	0	2	0	0
Gastropods	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0
Total	230	177	142	202	1193	2229	114	1729	1483	915	2238	1132	382	2466	279

Table: 6.1.3. Distribution of meiofauna (no/10 sq.cm) at station 3 during the period July 2002 -May 2004

	July,02	Aug	Sep	Oct	Nov	Dec	Jan.03	Feb	Mar	Apr	May	Jun	July	Nov	May,04
Foraminiferans	37	6	81	126	126	133	35	69	59	8	20	309	1735	65	26
Turbellarians	8	0	0	6	0	0	0	0	0	0	4	14	10	10	4
Nematodes	434	253	374	816	846	549	626	1575	1500	601	1394	677	1140	738	632
Nemerteans	0	0	0	0	0	0	0	0	10	2	2	2	2	0	2
Polychaetes	6	2	59	37	4	16	10	14	14	10	6	2	18	38	6
Kinorhynchs	0	0	0	0	0	0	0	4	0	0	0	0	2	0	0
Nauplius	0	2	2	0	0	0	0	0	0	2	0	0	0	0	0
Copepods	10	6	6	4	4	10	4	2	2	0	0	0	8	12	33
Acari	2	2	4	4	6	2	0	4	6	0	0	2	8	0	0
Amphipods	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanaideans	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Ostracods	2	0	2	0	0	0	0	0	0	0	0	0	2	0	0
Bivalves	0	0	0	2	6	2	4	0	0	0	4	2	6	4	4
Total	499	273	528	995	992	712	679	1668	1593	623	1430	1008	2931	867	707

Table: 6.1.4. Distribution of meiofauna (no/10 sq.cm)at station 4 during the period July 2002 -May 2004

	July,02	Aug	Sep	Oct	Nov	Dec	Jan.03	Feb	Mar	Apr	May	Jun	July	Nov	May,04
Foraminiferans	4	0	0	2	0	2	2	18	55	14	16	4	4	0	12
Turbellarians	4	12	2	0	2	12	0	4	22	0	0	0	2	4	0
Nematodes	447	59	255	363	33	384	377	320	196	183	179	75	147	147	61
Nemertians	2	0	0	0	0	0	0	0	0	8	2	2	0	2	0
Polychaetes	2	16	55	190	4	4	10	0	10	8	0	4	18	8	6
Nauplius I	0	0	0	0	2	0	0	6	41	0	0	0	0	0	0
Copepods	6	4	2	4	2	12	0	12	65	44	2	14	6	18	10
Acari	18	0	6	8	36	4	2	0	2	0	0	0	0	2	0
Cumaceans	0	0	0	0		0	0	0	2	0	0	0	0	0	0
Amphipods	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracods	0	4	6	0	0	0	0	0	0	0	0	0	0	2	0
Bivalves	4	0	2	2	0	0	0	0	2	2	0	0	0	0	0
Gastropods	0	0	0	0		0	0	0	20	0	0	0	0	0	0
Total	489	95	328	569	79	418	391	360	415	259	199	99	177	183	89

Table: 6.1.5. Distribution of meiofauna (no/10 sq.cm) at station 5 during the period July 2002 -May 2004

	July,02	Aug	Sep	Oct	Nov	Dec	Jan.03	Feb	Mar	Apr	May	Jun	July	Nov	May,04
Foraminiferans	2	0	0	34	0	0	2	2	10	16	16	2	6	0	8
Turbellarians	0	8	4	0	0	2	2	0	0	0	2	0	2	4	0
Nematodes	197	93	198	775	81	269	283	237	597	312	339	365	323	446	225
Nemerteans	0	2	0	0	0	0	0	0	0	0	4	0	4	0	4
Polychaetes	4	6	0	34	8	20	8	22	12	0	6	4	4	8	8
Nauplius	0	2	1	2	0	4	2	4	2	1	4	4	2	2	0
Copepods	4	6	2	2	0	78	24	39	65	98	39	88	67	10	202
Acari	2	4	4	4	4	0	2	0	0	0	0	0	0	0	0
Amphipods	2	0	0	18	0	0	0	0	0	0	2	0	0	0	0
Tanaidaceans	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Bivalves	0	0	0	2	12	0	0	0	0	2	0	0	0	2	0
Total	211	121	209	871	105	373	323	306	688	429	412	463	408	472	447

Table: 6.1.6. Distribution of meiofauna (no/10 sq.cm) at station 6 during the period July 2002 -May 2004

	July,02	Aug	Sep	Oct	Nov	Dec	Jan.03	Feb	Mar	Apr	May	Jun	July	Nov	May,04
Nematodes	10	4	8	10	0	2	0	2	5	4	12	8	2	0	8
Nemerteans	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Polychaetes	0	0	2	0	0	0	0	0	12	0	2	0	0	0	0
Copepods	2	6	2	2	0	0	0	2	102	0	0	12	0	0	0
Acari	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0
Bivalves	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0
Total	12	12	12	14	0	4	0	4	121	6	14	20	2	0	8

Table 6.2.1.Vertical distribution of meiobenthos at station 1 during the period July 2002 –May 2004

July,2002

	0--2	2--4	4--6	6--8
Nematode	37	14	2	0
Copepod	2	0	0	0
Acari	0	6	0	0
Polychaete	2	0	0	0
Total	41	20	2	0

August

	0--2	2--4	4--6	6--8
Nematode	171	10	10	0
Copepod	14	0	0	0
Polychaete	4	2	6	0
Amphipod	2	0	0	0
Total	191	12	16	0

September

	0--2	2--4	4--6	6--8
Nematode	106	22	6	10
Copepod	2	0	0	2
Acari	0	0	0	2
Nauplius	2	0	0	0
Polychaete	31	8	2	6
Turbellaria	20	0	0	0
Bivalve	0	0	2	2
Total	161	30	10	22

October

	0--2	2--4	4--6	6--8
Nematode	202	55	47	6
Copepod	10	0	0	0
Polychaete	126	55	29	6
Turbellaria	6	0	0	0
Amphipod	2	0	0	0
Total	346	110	76	12

November

	0--2	2--4	4--6	6--8
Nematode	63	14	57	35
Copepod	10	0	0	0
Acari	2	0	2	0
Polychaete	12	4	8	2
Cumacean	2	0	0	0
Total	89	18	67	37

December

	0--2	2--4	4--6	6--8
Nematode	208	151	39	159
Foraminifera	10	29	33	6
Acari	2	0	0	0
Nauplius	2	0	0	0
Polychaete	2	0	12	14
Bivalve	0	0	0	2
Total	224	180	84	181

January,2003

	0--2	2--4	4--6	6--8
Nematode	549	214	129	73
Foraminifera	8	2	8	8
Copepod	2	0	0	2
Polychaete	35	14	10	10
Turbellaria	2	0	0	0
Bivalve	0	2	0	0
Total	596	232	147	93

February

	0--2	2--4	4--6	6--8
Nematode	598	114	16	4
Foraminifera	10	6	0	0
Copepod	2	0	0	0
Total	610	120	16	4

Table 6 .2.1. Continued . . .

March	0--2	2--4	4--6	6--8
Nematode	122	4	2	2
Foraminifera	2	0	0	0
Copepod	16	0	0	0
Acari	1	0	0	0
Nauplius	4	0	0	0
Polychaete	6	0	2	0
Turbellaria	8	0	0	0
Bivalve	2	0	0	0
Total	161	4	4	2

April	0--2	2--4	4--6	6--8
Nematode	37	80	6	0
Foraminifera	24	0	0	0
Copepod	41	0	0	0
Acari	2	0	0	0
Polychaete	78	2	2	0
Turbellaria	2	0	2	0
Bivalve	2	0	0	0
Total	186	82	10	0

May	0--2	2--4	4--6	6--8
Nematode	57	39	4	2
Copepod	2	0	0	0
Polychaete	4	2	4	6
Turbellaria	0	2	0	0
Total	63	43	8	8

June	0--2	2--4	4--6	6--8
Nematode	24	10	4	2
Copepod	24	0	0	0
Nauplius	2	0	0	0
Polychaete	4	2	0	2
Turbellaria	8	0	0	0
Total	62	12	4	4

July 2003	0--2	2--4	4--6	6--8
Nematode	29	2	2	2
Copepod	35	0	0	0
Polychaete	2	2	2	2
Turbellaria	8	0	0	0
Total	74	4	4	4

November,2003	0--2	2--4	4--6	6--8
Nematode	16	14	0	0
Copepod	2	0	0	0
Turbellaria	0	6	0	0
Nemertean	2	0	0	0
Bivalve	2	0	0	0
Total	22	20	0	0

May,2004	0--2	2--4	4--6	6--8
Nematode	110	35	14	12
Foraminifera	0	0	2	0
Copepod	12	0	0	2
Polychaete	4	2	2	0
Turbellaria	0	0	0	2
Nemertean	0	0	0	2
Total	126	37	18	18

Table 6. 2. 2. Vertical distribution of meiobenthos at station 2 during the period July 2002 –May 2004

July,2002	0–2	2–4	4–6	6–8
Nematode	188	8	8	6
Foraminifera	2	0	0	0
Copepod	0	0	2	0
Acari	0	4	2	0
Polychaete	0	0	2	2
Turbellaria	4	0	0	0
Kinorhyncha	2	0	0	0
Total	196	12	14	8

August	0–2	2–4	4–6	6–8
Nematode	151	8	6	2
Copepod	0	2	0	0
Acari	0	2	0	0
Polychaete	0	0	2	0
Turbellaria	0	2	0	0
Amphipod	0	2	0	0
Total	151	16	8	2

September	0–2	2–4	4–6	6–8
Nematode	88	24	12	8
Foraminifera	2	0	0	0
Polychaete	2	0	0	0
Turbellaria	6	0	0	0
Total	98	24	12	8

October	0–2	2–4	4–6	6–8
Nematode	149	39	0	4
Copepod	2	0	0	0
Polychaete	2	0	0	0
Turbellaria	2	0	0	0
Kinorhyncha	0	2	0	0
Ostracod	2	0	0	0
Total	157	41	0	4

November	0–2	2–4	4–6	6–8
Nematode	1112	49	6	0
Copepod	4	2	0	0
Acari	2	0	6	2
Polychaete	0	0	0	2
Turbellaria	4	0	0	0
Nemertean	0	2	0	0
Gastopod	2	0	0	0
Total	1124	53	12	4

December	0–2	2–4	4–6	6–8
Nematode	1889	306	24	6
Copepod	4	0	0	0
Total	1893	306	24	6

January 2003	0–2	2–4	4–6	6–8
Nematode	94	10	4	0
Foraminifera	2	0	0	0
Polychaete	0	0	2	0
Amphipod	2	0	0	0
Total	98	10	6	0

February	0–2	2–4	4–6	6–8
Nematode	1259	384	20	16
Foraminifera	6	0	0	0
Copepod	22	0	0	0
Nauplius	8	0	0	0
Polychaete	4	2	4	0
Turbellaria	4	0	0	0
Total	1303	386	24	16

Table 6.2.2. Continued . . .

March	0–2	2–4	4–6	6–8
Nematode	1210	180	33	18
Foraminifera	6	2	0	0
Copepod	18	0	0	0
Acari	2	0	0	0
Polychaete	2	2	0	2
Bivalve	2	2	0	2
Gastropod	2	0	0	0
Total	1242	186	33	22

April	0–2	2–4	4–6	6–8
Nematode	838	43	10	0
Foraminifera	6	0	0	0
Copepod	8	0	0	0
Nauplius	2	0	0	0
Polychaete	0	0	2	0
Turbellaria	6	0	0	0
Total	860	43	12	0

May	0–2	2–4	4–6	6–8
Nematode	1840	343	35	4
Foraminifera	4	0	0	0
Copepod	6	0	0	0
Polychaete	2	0	2	0
Nemertean	0	0	2	0
Total	1852	343	39	4

June	0–2	2–4	4–6	6–8
Nematode	708	267	84	57
Foraminifera	2	0	0	0
Copepod	8	0	0	0
Acari	2	0	0	0
Turbellaria	4	0	0	0
Total	724	267	84	57

July	0–2	2–4	4–6	6–8
Nematode	192	84	29	47
Copepod	18	2	0	0
Nauplius	2	0	0	0
Turbellaria	2	0	2	2
Bivalve	0	0	2	0
Total	214	86	33	49

November 2003	0–2	2–4	4–6	6–8
Nematode	1567	722	100	51
Copepod	8	0	0	0
Polychaete	6	2	0	0
Nemertean	4	0	4	0
Amphipod	0	2	0	0
Total	1585	726	104	51

stn 2 May 2004	0–2	2–4	4–6	6–8
Nematode	124	98	39	4
Copepod	4	0	0	0
Polychaete	0	2	4	2
Turbellaria	2	0	0	0
Total	130	100	43	6

Table: 6.2.3. Vertical distribution of meiobenthos at station 3 during the period July 2002 –May 2004

July,2002

	0-2	2--4	4--6	6--8
Nematode	149	124	122	39
Copepod	4	0	6	0
Foraminifera	33	4	0	0
Polychaete	4	0	2	0
Turbellaria	8	0	0	0
Acari	2	0	0	0
Ostracod	0	0	2	0
Total	200	128	132	39

August

	0-2	2--4	4--6	6--8
Nematode	75	82	55	41
Copepod	4	2	0	0
Foraminifera	6	0	0	0
Polychaete	2	0	0	0
Acari	2	0	0	0
Nauplius	0	0	2	0
Amphipod	2	0	0	0
Total	91	84	57	41

Sepember

	0-2	2--4	4--6	6--8
Nematode	273	67	18	16
Foraminifera	63	12	0	6
Copepod	6	0	0	0
Polychaete	47	12	0	0
Acari	2	2	0	0
Nauplius	0	0	0	2
Ostracod	0	0	0	2
Total	391	93	18	26

October

	0-2	2--4	4--6	6--8
Nematode	687	94	22	12
Foraminifera	63	31	0	33
Copepod	2	0	2	0
Polychaete	27	6	2	2
Acari	2	0	2	0
Turbellaria	6	0	0	0
Bivalve	2	0	0	0
Total	789	131	28	47

November

	0--2	2--4	4--6	6--8
Nematode	773	37	18	18
Foraminifera	49	24	51	2
Copepod	4	0	0	0
Polychaete	4	0	0	0
Acari	0	2	4	0
Bivalve	2	0	4	0
Total	832	63	77	20

December

	0--2	2--4	4--6	6--8
Nematode	418	112	14	4
Foraminifera	22	53	57	0
Copepod	10	0	0	0
Polychaete	2	6	4	4
Acari	2	0	0	2
Bivalve	2	0	0	0
Total	456	171	75	10

January

	0--2	2--4	4--6	6--8
Nematode	439	131	47	10
Foraminifera	4	18	6	6
Copepod	4	0	0	0
Polychaete	4	4	2	0
Bivalve	0	2	0	2
Total	451	155	55	18

February

	0--2	2--4	4--6	6--8
Nematode	1116	418	24	16
Foraminifera	22	14	20	12
Copepod	4	0	0	0
Polychaete	0	4	4	6
Acari	0	2	2	0
Kinorhyncha	0	0	2	2
Total	1142	438	52	36

Table: 6.2.3. Continued . . .

March	0–2	2–4	4–6	6–8
Nematode	1165	237	49	49
Foraminifera	8	12	0	39
Copepod	2	0	0	0
Polychaete	6	6	0	2
Acari	2	2	2	0
Nemertean	4	4	0	2
Tanaides	2	0	0	0
Total	1189	261	51	92

April	0–2	2–4	4–6	6–8
Nematode	392	151	29	29
Foraminifera	6	0	2	0
Polychaete	4	4	2	0
Nauplius	2	0	0	0
Nemertean	2	0	0	0
Total	406	155	33	29

May	0–2	2–4	4–6	6–8
Nematode	690	537	92	75
Foraminifera	2	2	12	4
Polychaete	2	0	4	0
Turbellaria	0	4	0	0
Nemertean	0	0	2	0
Bivalve	2	0	2	0
Total	696	543	112	79

June	0–2	2–4	4–6	6–8
Nematode	271	261	100	45
Foraminifera	180	88	33	8
Polychaetes	0	0	2	0
Turbellaria	14	0	0	0
Acari	0	0	0	2
Nemertean	0	0	2	0
Bivalve	0	0	0	2
Total	465	349	137	57

July	0–2	2–4	4–6	6–8
Nematode	410	320	145	265
Foraminifera	957	343	253	182
Copepod	2	2	2	2
Polychaete	2	4	8	4
Acari	2	0	4	2
Turbellaria	2	0	6	2
Nemertean	2	0	0	0
Ostracod	0	0	2	0
Bivalve	2	0	2	2
Kinorhryncha	0	0	2	0
Total	1379	669	424	459

November-2003	0–2	2–4	4–6	6–8
Nematode	449	216	55	18
Foraminifera	43	22	0	0
Copepod	12	0	0	0
Polychaete	6	6	20	6
Turbellaria	8	0	2	0
Bivalve	2	2	0	0
Total	520	246	77	24

May–04	0–2	2–4	4–6	6–8
Nematode	224	273	102	33
Foraminifera	14	12	0	0
Copepod	33	0	0	0
Polychaete	2	2	2	0
Turbellaria	2	2	0	0
Nemertean	0	0	2	0
Bivalve	2	0	2	0
Total	277	289	108	33

Table: 6.2.4. Vertical distribution of meiobenthos at station 4 during the period July 2002 –May 2004

July,2002	0–2	2–4	4--6	6–8
Nematode	361	45	37	4
Foraminifera	0	2	2	0
Copepod	4	0	2	0
Acari	8	8	0	2
Polychaete	2	0	0	0
Turbellaria	2	2	0	0
Nemertean	2	0	0	0
Amphipod	0	2	0	0
Bivalve	2	2	0	0
Total	381	61	41	6

August	0--2	2–4	4--6	6--8
Nematode	35	6	14	4
Copepod	4	0	0	0
Polychaete	12	0	2	2
Turbellaria	8	2	0	2
Ostracod	4	0	0	0
Total	63	8	16	8

September	0--2	2–4	4--6	6--8
Nematode	194	53	6	2
Copepod	2	0	0	0
Acari	2	2	0	2
Polychaete	53	0	0	2
Turbellaria	2	0	0	0
Ostracod	2	2	2	0
Bivalve	2	0	0	0
Total	257	57	8	6

October	0--2	2–4	4--6	6--8
Nematode	233	67	37	27
Foraminifera	2	0	0	0
Copepod	2	0	0	2
Acari	2	0	2	4
Polychaete	165	14	8	2
Bivalve	2	0	0	0
Total	406	81	47	35

November	0--2	2–4	4--6	6--8
Nematode	27	4	2	0
Copepod	2	0	0	0
Acari	10	12	12	2
Nauplius	2	0	0	0
Polychaete	2	0	2	0
Turbellaria	2	0	0	0
Total	45	16	16	2

December	0--2	2–4	4--6	6--8
Nematode	282	80	10	12
Foraminifera	2	0	0	0
Copepod	12	0	0	0
Acari	0	0	4	0
Polychaete	2	2	0	0
Turbellaria	6	6	0	0
Total	304	88	14	12

January 2003	0--2	2–4	4–6	6--8
Nematode	173	188	10	6
Foraminifera	2	0	0	0
Acari	2	0	0	0
Polychaete	8	0	0	2
Total	185	188	10	8

February	0–2	2–4	4–6	6–8
Nematode	239	49	20	12
Foraminifera	4	12	2	0
Copepod	12	0	0	0
Nauplius	4	2	0	0
Turbellaria	2	0	2	0
Total	261	63	24	12

Table: 6.2.4 Continued . . .

March

	0–2	2–4	4–6	6–8
Nematode	137	39	12	8
Foraminifera	45	8	0	2
Copepod	65	0	0	0
Acari	0	2	0	1
Nauplius	40	0	0	0
Polychaete	6	0	0	4
Turbellaria	22	0	0	0
Cumacean	0	2	0	0
Gastropod	12	6	2	0
Bivalve	2	0	0	0
Total	329	57	14	15

April

	0–2	2–4	4–6	6–8
Nematode	104	55	10	14
Foraminifera	8	4	0	2
Copepod	20	0	24	0
Polychaete	2	2	2	2
Nemertean	2	4	0	2
Bivalve	2	0	0	0
Total	138	65	36	20

May

	0–2	2–4	4–6	6–8
Nematode	47	61	49	22
Foraminifera	8	2	4	2
Copepod	2	0	0	0
Nemertean	0	2	0	0
Total	57	65	53	24

June 2003

	0–2	2–4	4–6	6–8
Nematode	31	22	18	4
Foraminifera	2	0	2	0
Copepod	14	0	0	0
Polychaete	2	2	0	0
Nemertean	0	0	2	0
Total	49	24	22	4

July

	0–2	2–4	4–6	6–8
Nematode	16	49	35	47
Foraminifera	2	0	0	0
Copepod	6	0	0	0
Polychaete	12	2	2	2
Turbellaria	4	0	0	0
Total	40	51	37	49

November,2003

	0–2	2–4	4–6	6–8
Nematode	133	10	2	2
Copepod	18	0	0	0
Acari	0	2	0	0
Polychaete	4	4	0	0
Turbellaria	4	0	0	0
Nemertean	2	0	0	0
Ostracod	2	0	0	0
Total	163	16	2	2

May,2004

	0–2	2–4	4–6	6–8
Nematode	55	4	0	2
Foraminifera	10	2	0	0
Copepod	10	0	0	0
Polychaete	2	2	2	0
Total	77	8	2	2

Table: 6.2.5. Vertical distribution of meiobenthos at station 5 during the period July 2002 –May 2004

July,2002

	0--2	2--4	4--6	6--8
Nematode	116	49	16	16
Foraminifera	0	2	0	0
Copepod	2	2	0	0
Acari	0	2	0	0
Polychaete	0	2	2	0
Amphipod	0	2	0	0
Total	118	59	18	16

August

	0--2	2--4	4--6	6--8
Nematode	73	8	8	4
Copepod	4	0	2	0
Acari	2	0	2	0
Nauplius	2	0	0	0
Polychaete	4	0	0	2
Turbellaria	8	0	0	0
Nemertean	0	0	2	0
Total	93	8	14	6

September

	0--2	2--4	4--6	6--8
Nematode	114	47	27	10
Copepod	2	0	0	0
Acari	2	2	0	0
Nauplius	0	0	1	0
Turbellaria	4	0	0	0
Total	122	49	28	10

October

	0--2	2--4	4--6	6--8
Nematode	730	27	12	6
Copepod	2	0	0	0
Acari	4	0	0	0
Nauplius	2	0	0	0
Polychaete	18	12	2	2
Amphipod	14	0	4	0
Bivalve	2	0	0	0
Total	772	39	18	8

November

	0--2	2--4	4--6	6--8
Nematode	71	4	4	2
Acari	2	0	0	2
Polychaete	6	2	0	0
Bivalve	12	0	0	0
Total	91	6	4	4

December

	0--2	2--4	4--6	6--8
Nematode	261	2	0	6
Copepod	78	0	0	0
Nauplius	4	0	0	0
Polychaete	16	0	2	2
Turbellaria	2	0	0	0
Total	361	2	2	8

January 2003

	0--2	2--4	4--6	6--8
Nematode	208	35	22	18
Foraminifera	2	0	0	0
Copepod	22	2	0	0
Acari	2	0	0	0
Nauplius	2	0	0	0
Polychaete	6	2	0	0
Turbellaria	2	0	0	0
Total	244	39	22	18

February

	0--2	2--4	4--6	6--8
Nematode	149	33	33	22
Foraminifera	0	2	0	0
Copepod	35	2	0	2
Nauplius	4	0	0	0
Polychaete	4	8	6	4
Tanaidacean	0	0	0	2
Total	192	45	39	30

Table: 6.2.5 Continued . . .

March	0--2	2--4	4--6	6--8
Nematode	424	78	71	24
Foraminifera	10	0	0	0
Copepod	63	2	0	0
Nauplius	2	0	0	0
Polychaete	6	2	4	0
Tanaidacean	0	2	0	0
Total	505	84	75	24

April	0--2	2--4	4--6	6--8
Nematode	253	31	20	8
Foraminifera	16	0	0	0
Copepod	92	2	2	2
Nauplius	1	0	0	0
Bivalve	2	0	0	0
Total	364	33	22	10

May	0--2	2--4	4--6	6--8
Nematode	216	88	35	0
Foraminifera	10	4	2	0
Copepod	37	2	0	0
Nauplius	4	0	0	0
Polychaete	2	2	2	0
Turbellaria	2	0	0	0
Nemertean	0	2	2	0
Amphipod	2	0	0	0
Total	273	98	41	0

June	0--2	2--4	4--6	6--8
Nematode	126	102	137	0
Foraminifera	2	0	0	0
Copepod	88	0	0	0
Nauplius	4	0	0	0
Polychaete	4	0	0	0
Total	224	102	137	0

July	0--2	2--4	4--6	6--8
Nematode	69	88	86	80
Foraminifera	2	4	0	0
Copepod	59	0	0	8
Nauplius	0	0	0	2
Polychaete	4	0	0	0
Turbellaria	0	0	0	2
Nemertean	0	2	2	0
Total	134	94	88	92

November 2003	0--2	2--4	4--6	6--8
Nematode	422	12	8	4
Copepod	10	0	0	0
Nauplius	2	0	0	0
Polychaete	6	2	0	0
Turbellaria	2	0	2	0
Bivalve	2	0	0	0
Total	444	14	10	4

May 2004	0--2	2--4	4--6	6--8
Nematode	75	124	16	10
Foraminifera	8	0	0	0
Copepod	194	8	0	0
Polychaete	0	0	4	4
Nemertean	0	4	0	0
Total	277	136	20	14

Table: 6.2.6. Vertical distribution of meiobenthos at station 6 during the period July 2002 –May 2004

		July,2002		
	0–2	2–4	4–6	6–8
Nematode	8	2	0	0
Copepod	2	0	0	0
Total	10	2	0	0
		August		
	0–2	2–4	4–6	6–8
Nematode	4	0	0	0
Copepod	4	0	0	2
Acari	0	0	2	0
Total	8	0	2	2
		September		
	0–2	2–4	4–6	6–8
Nematode	6	0	0	2
Copepod	2	0	0	0
Polychaete	2	0	0	0
Total	10	0	0	2
		October		
	0–2	2–4	4–6	6–8
Nematode	4	2	2	2
Copepod	2	0	0	0
Bivalve	2	0	0	0
Total	8	2	2	2
		November		
	0–2	2–4	4–6	6–8
Meiofauna	0	0	0	0
		December		
	0–2	2–4	4–6	6–8
Nematode	2	0	0	0
Acari	2	0	0	0
Total	4	0	0	0

		January		
	0–2	2–4	4–6	6–8
Meiofauna	0	0	0	0
		February		
	0–2	2–4	4–6	6–8
Nematode	2	0	0	0
Copepod	2	0	0	0
Total	4	0	0	0
		March		
	0–2	2–4	4–6	6–8
Nematode	8	2	0	0
Copepod	100	2	0	0
Bivalve	2	0	0	0
Polychaete	10	2	0	0
Total	120	6	0	0
		April		
	0–2	2–4	4–6	6–8
Nematode	4	0	0	0
Nemertian	0	2	0	0
Total	4	2	0	0
		May		
	0–2	2–4	4–6	6–8
Nematode	6	2	4	0
Polychaete	0	0	2	0
Total	6	2	6	0
		July		
	0–2	2–4	4–6	6–8
Nematode	2	0	0	0
		May		
	0-2	2-4	4-6	6-8
Nematode	2	2	2	2

Table: 6.3.1 Seasonal variation in the numerical density of meiofauna (no/10sq.cm) at stations 1 to 3

	Station 1			Station 2			Station 3		
	Pre-monsoon	Monsoon	Post - monsoon	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Foraminiferans	9	0	21	5	1	1	37	433	97
Turbellarians	3	7	3	2	4	1	1	6	3
Nematodes	252	94	399	1293	395	1227	1140	575	715
Nemerteans	1	0	1	1	0	2	3	1	0
Polychaetes	23	18	68	6	2	3	10	17	21
Kinorhynchus	0	0	0	0	1	1	1	1	0
Nauplius	1	1	1	2	1	0	1	1	0
Copepods	16	16	5	12	6	4	7	6	7
Cumaceanes	0	0	1	0	0	0	0	0	0
Amphipods	0	1	1	0	1	1	0	1	0
Acari	1	2	1	1	2	2	2	4	2
Tanaideans	0	0	0	0	0	0	1	0	0
Ostracods	0	0	1	0	0	1	0	1	0
Bivalves	1	1	1	1	1	0	2	2	4
Gastropods	0	0	1	1	0	1	0	0	0
Total	306	140	504	1324	414	1244	1205	1048	849

Table: 6.3.2. Seasonal variation in the numerical density of meio fauna (no/10sq.cm) at stations 4 to 6

	Station 4			Station 5			Station 6		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Foraminiferans	23	2	1	10	2	1	0	0	0
Turbellarians	5	2	4	1	3	2	0	0	0
Nematodes	184	197	261	342	235	371	6	6	2
Nemarteans	2	1	1	2	1	0	1	0	0
Polychaetes	5	17	43	10	4	16	3	1	0
Nauplius larvae	9	0	1	2	2	2	0	0	0
Copepods	27	6	7	89	33	23	21	4	1
Acari	1	5	11	0	2	2	0	0	1
Amphipods	0	1	0	1	1	4	0	0	0
Tanaides	0	0	0	1	0	0	0	0	0
Cumaceans	1	0	0	0	0	0	0	0	0
Ostracods	0	2	1	0	0	0	0	0	0
Bivalves	1	1	1	1	0	3	1	0	1
Gastropods	4	0	0	0	0	0	0	0	0
Total	262	234	330	459	283	424	32	11	5

Table: 6.4 .BIOENV Analysis for meiofauna

Sl.No.	No.of Variables	Correlation	Best variable combintions
1	4	0.907	Turbidity, pH, NO_2-N and chlorophyll
2	5	0.907	Turbidity, salinity, pH, NO_2-N and organic carbon
3	5	0.904	Turbidity salinity, DO, NO_2-N- N and organic carbon
4	4	0.900	Salinity, DO, NO_3-N and Silt

Table 7.1. Checklist for Nematodes in Cochin Backwaters

Genus/Species	Order	Family
Class Adenophorea		
Subclass Enoplia		
Anticoma Bastian, 1865	Enoplida	Anticomidae
Syringolaimus De Man, 1888	Enoplida	Ironidae
Halalaimus De Man, 1888	Enoplida	Oxystominidae
Oxystomina elongata, Butschli,1874	Enoplida	Oxystominidae
Viscosia De Man, 1890	Enoplida	Oncholaimidae
Belbolla Andrassy, 1973	Enoplida	Enchelidiidae
Subclass Chromadoria		
Dichromadora Kreis, 1929	Chromadorida	Chromadoridae
Hypodontolaimus De Man, 1886	Chromadorida	Chromadoridae
Neochromadora coudenovei Micoletzky, 1924	Chromadorida	Chromadoridae
Spilophorella Filipjev, 1917	Chromadorida	Chromadoridae
Hopperia Vitiello, 1969	Chromadorida	Comesomatidae
Laimella Cobb, 1920	Chromadorida	Comesomatidae
Paracomesoma longispiculum Timm, 1961	Chromadorida	Comesomatidae
Pramesonchium Hopper, 1967	Chromadorida	Comesomatidae
Sabatieria Rouville, 1903	Chromadorida	Comesomatidae
Sabatieria pulchra Schneider,1906	Chromadorida	Comesomatidae
Vasotoma Wieser, 1954	Chromadorida	Comesomatidae
Cyatholaimus Bastian, 1865	Chromadorida	Cyatcholaimidae
Longicyatholaimus Micoletzky,1924	Chromadorida	Cyatcholaimidae
Desmodora minuta Wieser, 1954.	Chromadorida	Desmodoridae
Pseudochromadora casca Daday, 1889	Chromadorida	Desmodoridae
Bolbolaimus Cobb, 1920	Chromadorida	Microlaimidae
Microlaimus De Man, 1880	Chromadorida	Microlaimidae
Cyartonema Cobb, 1920	Chromadorida	Aegialoalaimidae
Desmoscolex, Claparede, 1863	Chromadorida	Desmosocolecidie
Subclass Monhysterida		
Monhystera Bastian, 1865	Monhysterida	Xyalidae
Amphimonhystera Allgen, 1929	Monhysterida	Xyalidae
Daptonema Cobb, 1920	Monhysterida	Xyalidae
Metadesmolaimus gelena Stekhoven, 1935	Monhysterida	Xyalidae
Paramonohystera Steiner, 1916	Monhysterida	Xyalidae
Promonhystera Wieser, 1956	Monhysterida	Xyalidae
Theristus Bastian, 1865	Monhysterida	Xyalidae
Sphaerolaimus macrocirculus Filipjev, 1918	Monhysterida	Sphaerolaimidae
S.maccoticus Bastian, 1865	Monhysterida	Sphaerolaimidae
S.pacificus Allgen, 1947	Monhysterida	Sphaerolaimidae
Anticyathus Cobb, 1920	Monhysterida	Linhomoeidae
Metalinhomoeus longiseta De Man, 1907	Monhysterida	Linhomoeidae
Terschellingia longicaudata de Man, 1907	Monhysterida	Linhomoeidae
Parodontophora Timm, 1963	Monhysterida	Axonolaimidae
Campylaimus gerlachi Tim ,1961	Monhysterida	Diplopeltidae

Table: 7.1.2. Identity and abundance (as percentage) of Nematodes in the Cochin backwaters.

	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6
Anticyathus sp	0	3	0	0	0	0
Anticoma sp	0	4	0	0	0	0
Cyartonema sp	3	2	0	0	0	0
Desmoscolex sp	0	3	3	4	0	0
Halalaimus sp	4	4	2	3	0	0
Oxystomina elongata	5	6	2	10	6	0
Terschellingia longicaudata	4	11	5	1	8	20
Amphimonhystera sp	1	2	0	1	3	0
Campylaimus gerlachi	0	3	1	0	4	0
Daptonema sp	4	6	6	7	14	20
Hopperia sp	0	1	1	1	0	0
Laimella sp	3	2	1	2	1	0
Monhystera sp	0	0	3	2	2	0
Metadesmolaimus gelena	3	2	2	1	0	0
Metalinhomoeus longiseta	5	7	4	11	11	20
Parodontophora sp	4	2	1	0	0	0
Paracomesoma longispiculum	4	7	6	9	8	0
Paramonohystera sp	0	0	2	0	3	20
Paramesonchium sp	0	0	1	1	2	0
Promonhystera sp	0	0	1	1	4	0
Sabatieria sp	3	5	4	6	6	20
Sabateiria pulchra	3	6	5	5	4	0
Theristus sp	5	3	3	3	4	0
Vasostoma sp	0	4	2	4	2	0
Bolbolaimus sp	6	0	5	4	0	0
Cyatholaimus sp	2	0	2	0	4	0
Desmadora minuta	3	0	3	3	0	0
Dichromadora sp	2	0	2	4	2	0
Hypodontolaimus sp	9	1	1	3	0	0
Longicyatholaimus sp	3	0	2	3	0	0
Microlaimus sp	3	3	1	1	2	0
Neochromadora coudenovei	2	0	3	1	0	0
Pseudochromadora casca	10	3	4	4	6	0
Spilophorella sp	2	4	3	1	0	0
Belbolla sp	0	1	4	0	1	0
Sphaerolaimus macrocirculus	3	2	1	1	1	0
Sphaerolaimus maccoticus	1	1	3	1	1	0
Sphaerolaimus pacificus	1	2	2	1	1	0
Syringolaimus sp	0	0	3	1	0	0
Viscosia sp	2	0	6	0	0	0

7.2. Vertical distribution of Nematodes at different depth ranges*

	Feeding type	0…2	2…4	4…6	6…8
Anticyathus sp	1A	√	×	×	×
Anticoma sp	1A	√	×	×	×
Cyartonema sp	1A	√	×	×	×
Desmoscolex sp	1A	√	√	×	×
Halalaimus sp	1A	√	√	√	×
Oxystomina elongata	1A	√	√	√	√
Terschellingia longicaudata	1A	√	√	√	√
Amphimonhystera sp	1B	√	√	×	×
Campylaimus gerlachi	1B	√	×	×	×
Daptonema sp	1B	√	√	√	√
Hopperia sp	1B	√	√	×	×
Laimella sp	1B	√	√	×	×
monhystera sp	1B	√	√	√	√
Metadesmolaimus gelena	1B	√	√	√	√
Metalinhomoeus longiseta	1B	√	√	√	√
Parodontophora sp	1B	√	√	√	√
Paracomesoma longispiculum	1B	√	√	√	√
Paramonohystera sp	1B	√	√	√	×
Paramesonchium sp	1B	√	√	√	×
Promonhystera sp	1B	√	√	√	×
Sabatieria sp	1B	√	√	√	√
Sabateiria pulchra	1B	√	√	√	√
Theristus sp	1B	√	√	√	√
Vasostoma sp	1B	√	√	√	√
Bolbolaimus sp	2A	√	√	√	×
Cyatholaimus sp	2A	√	√	√	×
Desmadora minuta	2A	√	√	√	×
Dichromadora sp	2A	√	√	√	×
Hypodontolaimus sp	2A	√	√	√	√
Longicyatholaimus sp	2A	√	√	√	×
Microlaimus sp	2A	√	√	√	√
Neochromadora coudenovei	2A	√	√	√	×
Pseudochromadora casca	2A	√	√	√	√
Spilophorella sp	2A	√	√	√	×
Belbolla sp	2B	√	√	×	×
Sphaerolaimus macrocirculus	2B	×	√	×	×
Sphaerolaimus maccoticus	2B	×	√	×	×
Sphaerolaimus pacificus	2B	×	√	×	×
Syringolaimus sp	2B	×	√	×	×
Viscosia sp	2B	√	√	√	×

* √ = Present × = absent

Table: 7.3. Feeding habits exhibited by Nematodes in the Cochin backwaters

Nonselective deposit feeders (1A)	Selective deposit feeders (1B)
Anticyathus sp	*Amphimonhystera* sp
Anticoma sp	*Campylaimus gerlachi*
Cyartonema sp	*Daptonema* sp
Desmoscolex sp	*Hopperia* sp
Halalaimus sp	*Laimella* sp
Oxystomina elongata	*monhystera* sp
Terschellingia longicaudata	*Metadesmolaimus gelena*
	Metalinhomoeus longiseta
	Parodontophora sp
	Paracomesoma longispiculum
	Paramonohystera sp
	Paramesonchium sp
	Promonhystera sp
	Sabatieria sp
	Sabateiria pulchra
	Theristus sp
	Vasostoma sp

Epistrate feeders (2A)	Predators/Omnivores (2B)
Bolbolaimus sp	*Belbolla* sp
Cyatholaimus sp	*Sphaerolaimus macrocirculus*
Desmadora minuta	*Sphaerolaimus maccoticus*
Dichromadora sp	*Sphaerolaimus pacificus*
Hypodontolaimus sp	*Syringolaimus* sp
Longicyatholaimus sp	*Viscosia* sp
Microlaimus sp	
Neochromadora coudenovei	
Pseudochromadora casca	
Spilophorella sp	

7.4. Seasonal distribution of Nematodes in Cochin backwaters*

	Pre-monsoon	Monsoon	Post- monsoon
Anticyathus sp	√	×	√
Anticoma sp	√	√	√
Cyartonema sp	√	×	×
Desmoscolex sp	√	×	√
Halalaimus sp	√	√	×
Oxystomina elongata	√	√	√
Terschellingia longicaudata	√	√	√
Amphimonhystera sp	√	×	√
Campylaimus gerlachi	√	×	√
Daptonema sp	√	√	√
Hopperia sp	√	×	×
Laimella sp	√	×	√
monhystera sp	√	×	×
Metadesmolaimus gelena	√	√	√
Metalinhomoeus longiseta	√	√	√
Parodontophora sp	√	√	×
Paracomesoma longispiculum	√	√	×
Paramonohystera sp	×	√	√
Paramesonchium sp	×	√	√
Promonhystera sp	√	√	√
Sabatieria sp	√	√	√
Sabateiria pulchra	√	√	√
Theristus sp	√	√	√
Vasotoma sp	√	×	√
Bolbolaimus sp	√	√	√
Cyatholaimus sp	√	×	×
Desmadora minuta	×	√	√
Dichromadora sp	√	×	√
Hypodontolaimus sp	√	√	×
Longicyatholaimus sp	√	×	×
Microlaimus sp	√	√	√
Neochromadora coudenovei	√	√	×
Pseudochromadora casca	√	√	√
Spilophorella sp	×	√	√
Belbolla sp	×	√	√
Sphaerolaimus macrocirculus	×	√	√
Sphaerolaimus maccoticus	×	√	√
Sphaerolaimus pacificus	×	√	√
Syringolaimus sp	×	√	√
Viscosia sp	×	√	√

* √ = Present × = absent

Table: 7.5. Diversity Indices for the Nematodes at Cochin backwaters

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Margalef's index (d)	5.86	5.86	7.6	6.5	4.95	0.86
Pielou's index(J)	0.96	0.94	0.96	0.90	0.91	1
Shannon- Wiener index(H')	3.19	3.15	3.43	3.1	2.9	1.61
Simpson's index(I-λ')	0.96	0.96	0.97	1	0.94	0.81

Table 7.6 Similarity Matrix of Nematodes at Cochin backwaters

	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5
Stn 2	70.71				
Stn 3	76.45	70.93			
Stn 4	76.47	71.51	84.09		
Stn 5	61.27	67.5	71.54	69.84	
Stn 6	28.64	32.26	25.98	27.91	31.89

Table: 7.7. BIOENV analysis for Nematodes

SL.No	No.of. Variable	Correlations	Best variable combinations
1	5	0.786	Turbidity,salinity,pH,sand (%) and sediment temperature
2	3	0.779	Salinity, NO_3-N and clay (%)
3	4	0.779	Salinity, pH, Nitrate and clay (%)
4	3	0.779	pH, NO_3-N and clay(%)
5	5	0.779	Turbidity,salinity, pH, NO_3-N and sand (%)
6	5	0.779	Salinity, pH, NO_3-N, sand (%) and interstitial water content
7	4	0.775	Turbidity,salinity, pH and sand(%)
8	5	0.775	Turbidity,salinity, NO_3-N , sand(%) and sediment temperature
9	5	0.775	Turbidity, pH, NO_3-N , sand(%) and sediment temperature

Table: 8.1.1. Population density of macro benthos (no/0.1 sq.m) at station 1 during the period July 2002 to May 2004

Polychaetes	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Ancistrosyllis constricta	2	2	2	12	0	16	12	2	2	2	2	2	0	0	4
Capitella capitata	0	0	2	0	6	0	0	0	0	0	0	0	0	0	0
Cossura coasta	0	0	0	0	0	0	0	0	2	0	4	2	0	2	8
Dendronereis estuarina	2	4	20	8	8	0	0	0	2	0	0	2	0	0	0
Diopatra neapolitana	4	4	2	0	2	0	2	0	124	42	18	4	4	8	4
Glycera trydactyla	2	8	0	44	48	2	4	4	4	24	16	2	4	2	2
Glycinde bonhourei	0	0	0	0	4	0	0	2	2	2	2	2	2	0	0
Heteromastus bifidus	54	74	8	112	18	92	0	40	0	8	16	24	160	100	22
Lumbriconereis latreilli	0	0	0	0	0	0	0	0	0	2	2	0	2	0	2
L.simplex	0	2	0	2	0	0	0	0	2	6	0	0	0	0	0
Lycastis indica	0	2	0	0	0	0	0	0	0	0	2	2	0	0	4
Maldane sp	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0
Nephthys oligobranchiata	4	2	2	2	0	2	2	0	4	0	2	0	0	0	2
Nereis sp	2	0	0	0	0	0	2	0	2	2	0	2	0	0	8
Notomastus latericeus	2	14	2	12	8	2	36	14	0	0	36	10	50	56	6
Ophelia capensis	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Paraheteromastus tenuis	0	46	30	0	60	400	556	52	20	20	22	14	0	6	174
Prionospio cirrifera	144	132	178	214	2704	6	24	2	44	14	28	40	178	50	2
P.pinnata	0	0	0	0	2	22	10	0	0	0	0	2	0	0	0
P.polybranchiata	0	0	0	70	20	4	0	2	0	4	0	2	0	0	0
Polydora kempi	0	2	0	0	0	0	0	0	2	4	2	2	0	4	0
Scyphoproctus djiboutiensis	16	16	2	10	16	2	8	8	0	0	4	20	20	16	0
Syllis spongicola	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Total	*232*	*308*	*248*	*486*	*2896*	*548*	*658*	*126*	*210*	*130*	*162*	*132*	*420*	*244*	*238*

Table 8.1.1 Continued . . .

Crustacea															
Alpheus sp.	0	0	0	0	0	0	0	0	4	6	2	0	0	0	0
Apseudes chilkensis	6	2	2	0	0	0	0	0	0	0	0	2	0	0	2
A.gymnophobia	0	2	0	0	0	4	2	2	0	0	2	0	0	0	2
Anthuridae sp	2	0	0	0	0	2	4	0	4	0	2	0	0	0	0
Caprellidae	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0
Cirrolinia fluviatilis	0	2	0	0	1	0	0	0	0	2	0	0	0	0	0
Corophium triaenonyx	8	6	4	0	6	0	2	0	2	2	6	36	10	8	30
Iphinoe sp	0	4	0	0	0	2	2	0	2	0	2	0	0	0	0
Grandidierella sp	4	32	16	44	4	0	2	0	2	4	4	38	30	4	40
Xenophthalmodes moebii	2	2	0	0	2	6	2	2	2	2	2	0	0	2	0
Total	22	50	24	44	13	14	14	4	16	16	20	78	40	14	74
Mollusca															
Katalysia sp	2	2	0	0	0	2	0	0	0	0	0	0	0	0	0
Paphia sp	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Muculista senhousia	2	0	0	0	0	0	0	0	30	0	0	0	0	0	2
Thais sp	2	2	0	0	0	0	2	2	0	8	0	4	4	4	4
Total	6	4	0	0	0	2	2	2	30	8	2	4	4	4	8
Pisces															
Trypauchen vagina	2	2	0	0	0	0	0	0	2	0	0	2	0	0	0
Other Groups															
Siphunculoidea	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Phoronida	2	2	0	12	6	0	0	0	0	0	2	2	0	0	0
Nemertean	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Sea anemon	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
Anthroplana nigrensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
Total	2	2	0	12	6	0	0	0	0	0	8	4	0	0	24

Table: 8.1.2. Population density of macro benthos (no/0.1 sq.m) at station 2 during the period July 2002 to May 2004

Polychaeta	Jy02	Aug	Spt	Oct	Nov	Dec	Jan03	Feb	Mar	Apr	May	Jun	Jy	Nov	My04
Ancistrosyllis constricta	2	2	2	0	2	0	2	2	2	2	2	2	0	2	8
Cossura coasta	0	2	0	0	0	0	0	2	4	4	20	12	6	6	14
Dendronereis estuarina	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Diopatra neapolitana	0	2	0	0	2	0	0	0	0	0	0	0	2	0	0
Glycera trydactyla	0	0	0	2	6	4	4	2	2	0	0	0	0	0	0
Glycinde bonhourei	0	0	0	0	0	2	4	4	2	2	0	0	0	0	0
Heteromastus bifidus	0	0	0	0	22	14	34	6	0	0	0	0	0	20	2
Lumbriconereis latreilli	0	0	0	0	0	0	0	0	4	2	2	0	0	0	0
L.simplex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Lycastis indica	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Nephthys oligobranchiata	8	2	2	4	12	12	8	12	2	4	8	6	18	18	6
Nereis sp	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0
Notomastus latericeus	0	0	0	2	2	6	14	4	0	0	0	0	0	8	2
Notopygos	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Paraheteromastus tenuis	92	14	34	52	30	42	16	18	16	50	24	18	34	30	32
Prionospio cirrifera	2	2	2	0	0	0	2	0	2	0	0	0	2	6	114
P.pinnata	0	0	0	2	0	0	4	2	2	2	2	0	0	2	0
P.polybranchiata	2	2	8	8	140	96	42	28	28	34	28	32	18	114	2
Polydora kempi	0	0	0	0	0	0	0	2	2	0	0	0	0	2	0
Sabella sp	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Scyphoproctus djiboutiensis	0	0	0	0	0	0	14	2	0	2	2	0	0	12	6
Syllis spongicola	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
Total	108	28	48	70	216	176	148	88	66	102	92	74	80	220	188

Table: 8. 1. 2. Continued . . .

Crustacea															
Alpheus sp.	0	0	0	0	0	0	0	2	0	2	2	6	8	0	4
Apseudes chilkensis	0	0	0	2	0	2	0	0	0	0	0	4	2	0	4
A.gymnophobia	0	2	0	0	0	0	0	0	0	0	0	2	0	2	0
Anthuridae sp	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0
Cirrolinia fluviatilis	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Corophium triaenonyx	0	6	0	0	2	0	0	1	0	0	0	1	4	2	0
Grandidierella sp	2	4	0	2	2	0	4	1	0	4	0	1	2	2	0
Iphinoe sp	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0
Neorhyncoplax sp	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0
Total	2	12	0	4	4	2	8	6	4	8	4	16	16	6	8
Mollusca															
Katalysia	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0
Muculista senhousia	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0
Thais sp	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0
Total	0	2	0	0	2	2	2	0	2	0	0	0	26	0	0
Pisces															
Trypauchen vagina	0	0	0	0	2	0	0	0	0	0	2	0	2	0	0
Other Groups															
Brittle star	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Phoronidae	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0
Nemertean	0	0	0	0	58	16	4	4	12	18	0	6	0	2	0
Sea anemon	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
Siphunculoidea	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Total	0	0	0	2	58	18	10	6	14	18	0	6	0	2	0

Table : 8 .1.3. Population density of macro benthos (no/0.1 sq.m) at station 3 during the period July 2002 to May 2004

Polychaeta	Jy02	Aug	Spt	Oct	Nov	Dec	Jan03	Feb	Mar	Apr	My	Jun	Jy	Nov	My04
Ancistrosyllis constricta	10	22	10	0	2	2	4	6	2	0	0	4	4	16	4
Capitella sp	20	16	0	16	0	20	0	0	0	0	0	2	0	0	0
Cossura coasta	0	0	0	0	2	2	2	2	16	12	8	2	2	2	10
Dendronereis estuarina	0	0	2	0	0	0	0	0	0	0	0	0	0	0	6
Diopatra neapolitana	4	4	0	10	2	16	48	20	4	4	2	14	0	8	0
Eteone sp	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
Exogone sp	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Glycera trydactyla	0	0	0	6	4	2	4	2	0	0	0	2	2	2	2
Glycinde bonhourei	0	0	0	0	2	0	6	2	0	0	0	0	0	2	2
Heteromastus bifidus	2	4	6	0	2	4	6	2	6	0	0	2	0	20	6
Lumbriconereis latreilli	12	68	2	0	0	0	0	0	0	0	2	0	2	2	4
L.simplex	0	0	2	0	0	0	0	2	2	2	2	2	0	0	0
Nephthys oligobranchiata	2	0	0	2	2	6	6	0	0	2	0	2	2	16	2
Nereis sp	10	4	2	0	0	0	2	0	0	0	2	2	0	2	4
Notopygos sp	0	4	0	0	4	0	2	2	2	0	0	2	0	6	2
Paraheteromastus tenuis	110	126	160	80	40	40	13	9	230	90	160	82	56	374	90
Prionospio cirrifera	10	56	288	1082	8	6	14	24	12	2	16	16	4	16	24
P.pinnata	0	0	0	16	18	18	22	4	2	2	0	4	0	4	2
P.polybranchiata	0	0	0	2	10	4	10	4	4	2	2	4	2	2	2
Polydora kempi	0	16	0	2	0	0	0	2	0	0	0	4	0	0	0
Scyphoproctus djiboutiensis	0	6	6	2	0	2	0	0	0	0	0	0	0	2	2
Sternapsis scutata	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Sthenelais sp	0	0	0	0	0	0	0	2	0	0	2	2	0	0	0
Syllis spongicola	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Total	180	326	478	1218	96	122	143	87	280	116	198	146	74	474	162

Table : 8.1.3. Continued . . .

Crustacea															
Alpheus sp.	8	10	2	0	0	0	0	2	2	0	2	0	2	2	6
Apseudes chilkensis	0	0	2	2	0	0	2	0	0	0	0	0	0	0	2
A.gymnophobia	2	8	2	0	0	0	2	4	0	2	0	0	2	34	2
Anthuridae sp	0	2	0	2	2	2	16	6	2	0	2	0	0	2	0
Caprellidae	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
Cirrolinia fluviatilis	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium triaenonyx	48	460	24	360	18	2	4	4	2	0	2	2	2	2	2
Eriopisa chilkensis	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Grandidierella sp	34	321	48	456	16	2	18	6	2	2	2	2	2	0	4
Iphinoe sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Neorhyncoplax sp	4	2	0	0	0	0	0	8	0	0	0	0	0	0	2
Total	98	809	78	822	36	6	44	30	8	4	8	4	8	40	20
Mollusca															
Katalysia	2	2	0	0	0	0	0	2	2	2	4	4	0	0	2
Paphia sp	2	2	0	0	0	0	0	0	2	0	0	0	0	0	0
Muculista senhousia	12	50	0	0	0	0	0	2	48	78	46	44	0	0	0
Thais sp	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0
Total	16	54	0	0	0	0	0	4	52	82	50	50	0	0	2
Pisces															
Batrachus sp	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0
Trypauchen vagina	0	2	2	2	0	0	0	0	0	2	2	2	2	0	2
Anguilla sp	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Total	0	2	2	2	2	0	2	2	0	2	2	2	2	0	2
Other groups															
Brittle star	0	0	0	0	0	0	4	2	2	2	0	0	0	0	0
Flat worm	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Nemertean	0	0	0	0	4	0	0	2	0	0	0	0	0	4	2
Phoronida	0	0	0	6	0	0	0	0	0	0	2	0	0	0	0
Sea anemon	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
Siphunculoidea	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Total	0	0	0	6	4	0	6	6	2	2	4	0	0	4	4

Table : 8.1.4. Population density of macro benthos (no/0.1 sq.m) at station 4 during the period July 2002 to May 2004

Polychaetes	Jy02	Aug	Spt	Oct	Nov	Dec	Jan03	Feb	Mar	Apr	My	Jun	Jy	Nov	My04
Ancistrosyllis constricta	2	2	0	60	2	2	6	8	6	4	4	2	0	2	6
Cossura coasta	2	2	0	0	0	0	0	2	2	4	4	0	0	0	4
Capitella sp	2	0	6	0	0	0	0	0	0	0	0	0	0	0	2
Dendronereis estuarina	0	0	2	4	0	0	2	0	0	0	2	0	0	0	0
Diopatra neapolitana	2	2	4	16	14	14	12	14	10	14	22	38	2	0	0
Glycera trydactyla	0	0	0	68	6	2	4	4	8	6	2	0	2	0	0
Glycinde bonhourei	0	0	0	0	0	2	4	2	2	0	0	0	2	0	0
Heteromastus bifidus	8	4	0	40	30	176	60	28	10	10	4	0	4	12	0
Lumbriconereis latreilli	0	0	0	0	0	0	2	2	2	0	0	0	0	0	2
L.simplex	0	0	0	0	0	0	4	2	4	6	2	6	2	0	0
Lycastis indica	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Marphysa sanguinea	0	0	0	0	2	0	2	2	2	0	2	2	0	0	0
Nephthys oligobranchiata	0	0	0	0	4	6	0	0	0	0	2	0	0	0	0
Nereis sp	0	0	0	6	0	2	2	2	2	2	4	0	0	0	10
Notomastus latericeus	0	0	2	0	2	26	18	22	8	8	6	0	2	4	2
Paraheteromastus tenuis	106	70	50	160	20	24	18	28	18	72	14	0	6	66	78
Prionospio cirrifera	12	6	26	7022	40	24	8	6	2	0	0	2	2	2	16
P.pinnata	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
P.polybranchiata	0	2	2	20	12	6	2	8	8	0	2	0	0	16	6
Polydora kempi	0	0	0	4	0	0	0	8	2	2	4	4	0	0	0
Scyphoproctus djiboutiensis	2	2	0	2	4	12	8	6	2	2	0	0	2	2	0
Terebellidae	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Total	136	90	92	7404	136	298	152	144	88	130	74	54	26	104	128

Table 8:1.4. Continued . . .

Crustacea															
Alpheus sp.	2	0	0	0	2	0	0	0	2	2	6	0	4	0	4
Apseudes chilkensis	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
A.gymnophobia	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0
Anthuridae sp	0	0	0	0	0	2	4	2	0	0	0	0	0	0	0
Cirrolinia fluviatilis	0	0	0	0	2	2	4	2	2	0	0	0	0	0	0
Corophium triaenonyx	2	0	0	0	2	2	16	4	0	0	0	0	2	2	2
Grandidierella sp	2	0	2	72	4	2	14	8	4	2	2	0	2	2	2
Xenophthalmodes moebii	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2
Iphinoe sp	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Total	8	0	2	72	10	12	45	18	8	4	8	0	8	4	10
Mollusca															
Katalysia sp	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0
Muculista senhousia	0	0	0	0	0	2	2	6	230	288	40	8	0	0	0
Total	0	0	0	0	0	2	2	8	230	290	40	8	0	0	0
Pisces															
Batrachus sp	0	0	2	0	0	2	2	0	2	2	0	2	2	0	0
Trypauchen vagina	0	0	6	2	0	0	2	0	2	2	0	2	2	0	0
Total	0	0	8	2	0	2	4	0	4	4	0	4	4	0	0
Other Groups															
Brittle star	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Nemertean	0	0	0	0	2	0	2	2	0	2	0	0	0	0	0
Phoronidae	0	0	0	0	0	0	0	0	2		2	2	0	0	2
Total	0	0	0	0	2	0	2	4	2	2	2	2	0	0	2

Table: 8.1.5. Population density of macrobenthos (no/0.1 sq.m) at station 5 during the period July 2002 to May 2004

Polychaetes	Jy02	Aug	Spt	Oct	Nov	Dec	Jan03	Feb	Mar	Apr	My	Jun	Jy	Nov	My04
Ancistrosyllis constricta	4	2	8	2	2	0	6	2	4	4	4	2	2	6	2
Cossura coasta	0	0	0	0	0	0	0	2	8	0	4	0	0	0	22
Dendronereis estuarina	0	2	0	2	2	0	0	0	0	2	0	0	0	0	0
Diopatra neapolitana	0	2	0	32	30	10	50	2	8	2	2	0	0	10	2
Glycera trydactyla	2	0	0	4	10	6	6	0	2	4	4	4	2	2	0
Glycinde bonhourei	0	0	0	0	2	0	2	0	0	0	2	2	0	0	0
Heteromastus bifidus	10	12	16	58	230	50	78	22	14	2	2	2	2	60	0
Lumbriconereis latreilli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
L.simplex	2	2	0	0	0	0	0	0	0	0	2	2	2	0	2
Marphysa sanguinea	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0
Nephthys oligobranchiata	10	8	2	4	8	4	8	2	2	2	4	2	6	10	2
Nereis sp.	4	2	0	2	0	0	0	0	2	2	0	2	2	0	0
Notomastus latericeus	16	6	12	12	20	18	38	20	18	2	4	2	0	50	0
Paraheteromastus tenuis	306	274	480	128	250	196	92	74	74	76	176	60	0	80	0
Prionospio cirrifera	10	8	0	672	34	22	14	8	8	2	2	8	26	28	12
P.pinnata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
P.polybranchiata	2	4	2	442	20	6	38	14	12	34	22	28	32	42	80
Polydora kempi	0	0	0	2	0	0	0	4	0	0	0	0	0	0	0
Scyphoproctus djiboutiensis	0	2	0	18	8	16	8	0	2	0	0	2	0	0	0
Syllis spongicola	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Total	366	326	520	1380	618	328	340	150	154	132	228	116	74	288	126

Table 8.1.5 Continued . . .

Crustacea															
Alpheus sp.	4	2	0	0	0	2	4	0	2	2	4	4	2	0	2
Apseudes chilkensis	0	2	0	4	0	0	2	4	2	2	2	2	4	0	2
A.gymnophobia	2	2	0	0	0	0	8	4	6	0	0	0	0	6	0
Anthuridae sp	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Caprellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Cirrolinia fluviatilis	2	0	0	2	0	0	0	0	2	0	0	0	0	0	0
Corophium triaenonyx	4	0	0	8	4	10	14	4	2	0	0	2	4	4	0
Grandidierella sp	4	4	0	24	0	8	12	0	2	0	2	2	2	4	0
Xenophthalmodes moebii	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	18	10	0	38	4	20	40	12	16	4	8	10	12	18	4
Mollusca															
Katalysia sp	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Paphia sp	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Muculista senhousia	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
Thais sp	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	2	10	0	0	2	0	0	0	0
Pisces															
Batrachus sp	2	0	0	0	0	0	0	2	0	0	2	0	0	0	0
Other Groups															
Nemertean	0	2	2	0	0	0	2	2	0	2	0	2	0	0	0
phoronidae	0	0	0	2	2	4	0	0	0	0	0	0	0	0	0
Total	0	2	2	2	2	4	2	2	0	2	0	2	0	0	0

Table: 8.1.6. Population density of macrobenthos (no/0.1 sq.m) at station 6 during the period July 2002 to May 2004

Polychaetes	Jy02	Aug	Spt	Oct	Nov	Dec	Jan03	Feb	Mar	Apr	My	Jun	Jy	Nov	My04
Ancistrosyllis constricta	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0
Capitella sp	0	0	0	2	0	2	2	0	8	0	0	2	2	0	0
Dendronereis estuarina	0	0	0	4	2	0	2	2	2	0	0	6	2	0	0
Lycastis indica	0	0	0	2	2	0	0	0	2	0	0	0	0	0	0
Prionospio cirrifera	0	0	0	0	0	0	30	16	48	2	6	8	2	0	0
Nephtys oligobranchiata	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Total	0	0	0	8	4	2	36	18	60	2	8	20	6	0	0
Crustacea															
Apseudes chilkensis	2	0	0	0	0	2	6	6	2	0	0	0	0	0	0
A.gymnophobia	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Corophium triaenonyx	0	0	2	2	0	2	2	2	2	0	0	2	0	0	0
Total	2	0	2	2	0	4	8	8	6	0	0	2	0	0	0
Other Groups															
Chironomus larvae	0	0	8	6	4	2	2	0	0	0	0	0	0	0	0
Flatworms	0	0	2	2	2	0	0	0	0	0	0	0	0	0	0
Nemertean	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Total	0	0	10	8	6	2	4	0	0	0	0	0	0	0	0

Table: 8.2.1. Seasonal variation of macro benthos (no/0.1sq.m) at stations 1 to 3

	Station 1			Station 2			Station 3		
	Pre - monsoon	Monsoon	Post- monsoon	Pre monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon
Polychaetes									
Ancistrosyllis constricta	3	1	8	4	1	1	3	9	5
Capitella capitata	0	1	1	0	0	0	1	7	7
Cossura coasta	3	0	1	11	2	1	10	1	2
Dendronereis estuarina	1	5	3	1	0	0	1	1	0
Diopatra neapolitana	38	3	2	0	1	1	9	2	17
Eteone sp	0	0	0	0	0	0	1	0	1
Exogone sp	0	0	0	0	0	0	1	0	0
Glycera trydactyla	10	3	20	1	0	3	1	1	4
Glycinde bonhourei	2	1	1	2	0	1	1	0	2
Heteromastus bifidus	22	59	64	2	0	18	3	2	6
Lumbriconereis latreilli	1	1	0	2	0	0	1	17	1
L.simplex	2	1	1	1	0	0	2	1	0
Lycastis indica	2	1	0	0	0	1	0	0	0
Maldane sp	1	0	1	0	0	0	0	0	0
Nephthys oligobranchiata	2	2	1	8	6	11	1	1	6
Nereis sp	3	1	1	1	0	0	2	3	1
Notomastus latericeus	13	14	23	1	0	6	0	0	0
Notopygos	0	0	0	0	1	0	2	1	2
Ophelia capensis	1	0	0	0	0	0	0	0	0
Paraheteromastus tenuis	60	15	204	32	35	34	132	90	109
Prionospio cirrifera	26	126	600	23	2	2	19	72	225
P.pinnata	1	0	7	2	0	2	3	0	16
P.polybranchiata	2	0	19	30	6	80	4	1	6
Polydora kempi	2	1	1	1	0	1	1	3	1
Sabella sp	0	0	0	1	0	0	0	0	0
Scyphoproctus djiboutiensis	6	11	10	2	0	5	1	2	1
Sternapsis scutata	0	0	0	0	0	0	0	0	1
Sthenelais sp	0	0	0	0	0	0	1	0	0
Syllis spongicola	1	0	0	1	0	1	1	0	0
Total	202	246	968	126	54	168	201	214	413

Table: 8.2.1. Continued . . .

Crustacea									
Alpheus sp.	2	0	0	3	2	0	2	4	1
Apseudes chilkensis	1	2	0	2	1	1	1	1	1
A.gymnophobia	1	1	1	1	1	1	2	3	7
Anthuridae sp	1	1	1	1	0	1	2	1	5
Caprellidae	1	1	0	0	0	0	0	0	1
Cirrolinia fluviatilis	1	1	0	0	0	1	0	1	0
Corophium triaenonyx	15	6	3	1	2	1	2	107	77
Eriopisa chilkensis							0	1	0
Iphinoe sp	1	1	1	1	0	0	1	0	0
Grandidierella sp	18	16	11	1	2	2	4	81	98
Neorhynchoplax sp	0	0	0	1	0	0	2	1	0
Xenophthalmodes moebii	2	1	2	0	0	0			
Total	43	30	20	11	7	7	16	200	190
Mollusca									
Katalysia sp	0	1	1	0	1	1	3	1	0
Paphia sp	1	0	0				1	1	0
Muculista senhousia	6	1	0	0	5	0	44	12	0
Thais sp	4	2	1	1	0	1	1	0	0
Total	11	3	2	1	6	2	49	14	0
Pisces									
Anguilla sp	0	0	0	0	0	0	1	0	0
Batrachus sp	0	0	0	0	0	0	0	0	1
Trypauchen vagina	1	1	0	1	1	1	2	1	1
Total	1	1	0	1	1	1	3	1	2
Other Groups									
Brittle star	0	0	0	0	0	1	1	0	1
Anthroplana nigrensis	4	0	0	0	0	0	0	0	0
Flat worm	0	0	0	0	0	0	0	0	1
Phoronida	1	1	4	0	0	1	1	0	1
Nemertean	1	0	0	8	0	16	1	0	2
Sea anemon	1	0	0	1	0	1	1	0	0
Siphunculoidea	1	0	0	1	0	0	1	0	0
Total	8	1	4	10	0	19	5	0	5

Table 8.2.2. Seasonal variation of macrobenthos (no/0.1sq.m) at stations 4 to 6

	Station 4			Station 5			Station 6		
	Pre monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon
Polychaetes									
Ancistrosyllis constricta	6	1	14	4	3	3	1	0	0
Cossura coasta	3	1	0	7	0	0	0	0	0
Capitella sp	1	2	0	0	0	0	2	1	1
Dendronereis estuarina	1	1	1	1	1	1	2	1	2
Diopatra neapolitana	20	2	11	3	1	26	0	0	0
Glycera trydactyla	4	1	16	3	1	6	0	0	0
Glycinde bonhourei	1	1	1	1	0	1	0	0	0
Heteromastus bifidus	10	3	64	8	8	95	0	0	0
Lumbriconereis latreilli	1	0	1	1	0	0	0	0	0
L.simplex	4	1	1	1	1	0	0	0	0
Lycastis indica	0	1	0	0	0	0	1	0	1
Marphysa sanguinea	2	0	1	0	1	1	0	0	0
Nephthys oligobranchiata	1	0	2	3	5	7	0	0	1
Nereis sp	4	0	2	1	2	1	0	0	0
Notomastus latericeus	9	1	10	9	7	28	0	0	0
Paraheteromastus tenuis	42	46	58	92	212	149	2	0	0
Prionospio cirrifera	5	9	1419	8	9	154	16	1	6
P.pinnata	1	0	1	1	0	0	0	0	0
P.polybranchiata	5	1	11	38	8	110	0	0	0
Polydora kempi	4	0	1	1	0	1	0	0	0
Scyphoproctus djiboutiensis	2	1	6	1	1	10	0	0	0
Syllis spongicola	0	0	0	0	0	1	0	0	0
Terebellidae	0	0	1	0	0	0	0	0	0
Total	126	79	1665	200	260	624	28	8	11

Table 8.2.2 Continued . . .

Crustacea									
Alpheus sp.	3	1	1	3	2	1	0	0	0
Apseudes chilkensis	0	1	1	3	1	1	2	1	2
A.gymnophobia	0	0	1	2	1	3	1	0	0
Anthuridae sp	1	0	1	0	0	1	0	0	0
Caprellidae	0	0	0	0	0	1	0	0	0
Cirrolinia fluviatilis	1	0	2	1	1	1	0	0	0
Corophium triaenonyx	1	1	4	2	2	8	1	1	1
Grandidierella sp	4	1	19	1	2	10	0	0	0
Xenophthalmodes moebii	1	0	1	0	1	0	0	0	0
Iphinoe sp	1	0	0	0	0	0	0	0	0
Total	11	4	30	11	9	26	4	2	3
Mollusca									
Katalysia	1	0	0	1	0	0	0	0	0
Paphia sp	0	0	0	1	0	0	0	0	0
Muculista senhousia	114	0	1	1	0	0	0	0	0
Thais sp	0	0	0	1	0	1	0	0	0
Total	115	0	1	4	0	1	0	0	0
Pisces									
Batrachus sp	1	1	1	1	1	0	0	0	0
Trypauchen vagina	1	2	1	0	0	0	0	0	0
Total	2	3	2	1	1	0	0	0	0
Other Groups									
Brittle star	1	0	0	0	0	0	0	0	0
Chironomus larvae	0	0	0	0	0	0	0	2	3
Flatworms	0	0	0	0	0	0	0	1	1
Nemertean	1	0	1	1	1	1	0	0	1
Phoronidae	2	0	0	0	0	2	0	0	0
Total	3	0	1	1	1	3	0	3	5

Table: 8.3 Diversity indices for Macrofauna at stations 1 to 6

	Stations						
	1	2	3	4	5	6	Average
Margalef's index (d)	6.74	8.19	7.74	5.7	5.94	4.04	6.39
Pielou's index(J)	0.5	0.64	0.58	0.34	0.54	0.71	0.55
Shannon- Wiener index(H')	1.88	2.36	2.25	1.25	1.94	1.77	1.91
Simpson's index(l-λ')	0.71	0.84	0.833	0.46	0.77	0.77	0.73

Table: 8.4. Similarity index between stations with respect to benthic macrofauna

stations	1	2	3	4	5
2	63.23				
3	68.13	60.14			
4	78.21	61.09	63.79		
5	76.94	70.4	65.15	69.72	
6	21.94	28.28	19.84	23.04	21.16

Table: 8.5 BIOENV analysis for macrofauna

SL.No	No.of. Variable	Correlations	Best variable combinations
1	5	0.882	Salinity, DO, NO_2-N, NO_3-N and sand(%) .
2	5	0.882	pH, DO, NO_2-N, NO_3-N and sand(%).
3	1	0.868	NO_3-N
4	4	0.864	DO,NO_2-N, NO_3-N and sand (%).
5	5	0.864	Depth , salinity, NO_2-N, NO_3-N and sand(%).
6	5	0.864	Depth , pH, NO_2-N, NO_3-N and sand(%).
7	5	0.864	Salinity ,DO, NO_2-N, PO_4-P and sand(%).
8	5	0.864	pH, DO, NO_2-N, PO_4-P and sand(%).
9	5	0.864	DO, NO_2-N, NO_3-N,PO_4-P and sand(%)
10	5	0.861	Salinity, pH,DO,NO_2-N and sand(%)

Table: 9.1.1 Meiofaunal biomass (mg/10 cm^2) at station 1 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Nematoda	0.052	0.187	0.141	0.304	0.166	0.546	0.946	0.717	0.127	0.1	0.099	0.04	0.03	0.03	0.2
Polychaeta	0.016	0.094	0.368	1.69	0.204	0.219	0.54	0.00	0.063	0.6	0.125	0.06	0.06	nn	0.1
Copepoda	0.01	0.073	0.021	0.052	0.052	B234	0.021	0.01	0.083	0.2	0.01	0.13	0.18	0.01	0.1
Other groups	0.027	0.009	0.128	0.055	0.274	0.027	0.018	0.00	0.068	0	0.009	0.05	0.04	0.05	0
Total	0.105	0.363	0.658	2.101	0.696	0.792	1.525	0.727	0.341	0.9	0.243	0.28	0.31	0.09	0.322

Table: 9.1.2. Meiofaunal biomass (mg/10 cm^2) at station 2 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Nematoda	0.206	0.164	0.129	0.188	1.144	2.18	0.106	1.65	1.41	0.9	2.18	1.09	0.35	2.39	0.3
Polychaeta	0.031	0.016	0.016	0.016	0.016	0	0.017	0.078	0.047	0	0.031	0	0	0.06	0.1
Copepoda	0.01	0.01	0	0.01	0.031	0.021	0	0.114	0.093	0	0.031	0.04	0.1	0.04	0
Other groups	0.055	0.027	0.027	0.027	0.082	0	0.009	0.064	0.046	0	0.009	0.04	0.05	0.05	0
Total	0.302	0.217	0.172	0.241	1.273	2.201	0.132	1.906	1.596	0.9	2.251	1.17	0.5	2.54	0.4

Table: 9.1.3. Meiofaunal biomass (mg/10 cm^2) at station 3 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Nematoda	0.425	0.248	0.366	0.799	0.829	0.537	0.614	1.543	1.47	0.59	1.366	1.366	1.117	0.723	0.6
Polychaeta	0.046	0.016	0.462	0.289	0.031	0.125	0.078	0.109	0.109	0.08	0.047	0.016	0.141	0.297	0
Copepoda	0.052	0.031	0.031	0.021	0.021	0.052	0.021	0.021	0.01	0	0	0	0.042	0.062	0.2
Other groups	0.054	0.027	0.036	0.064	0.055	0.027	0.018	0.036	0.082	0.02	0.046	0.091	0.136	0.064	0
Totai	0.577	0.322	0.895	1.173	0.936	0.741	0.731	1.709	1.671	0.69	1.459	1.473	1.436	1.146	0.8

Table: 9.1.4.Meiofaunal biomass (mg/10 cm^2) at station 4 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Nematoda	0.438	0.058	0.25	0.357	0.032	0.376	0.369	0.314	0.193	0.18	0.175	0.074	0.144	0.144	0.1
Polychaeta	0.016	0.125	0.43	1.48	0.03	0.031	0.078	0	0.078	0.06	0	0.031	0.141	0.063	0
Copepoda	0.031	0.02	0.01	0.021	0.01	0.062	0	0.062	0.338	0.23	0.01	0.073	0.031	0.093	0
Other groups	0.136	0.073	0.07	0.046	0.182	0.073	0.009	0.046	0.406	0.05	0.015	0.009	0.018	0.046	0
Total	0.621	0.276	0.76	1.904	0.254	0.542	0.456	0.422	1.015	0.52	0.2	0.187	0.334	0.346	0.1

Table: 9.1.5. Meiofaunal biomass (mg/10 cm^2) at station 5 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Nematoda	0.193	0.091	0.194	0.76	0.079	0.263	0.277	0.232	0.585	0.31	0.332	0.358	0.317	0.437	0.2
Polychaeta	0.031	0.047	0	0.266	0.063	0.157	0.063	0.172	0.094	0	0.047	0.031	0.031	0.063	0.1
Copepoda	0.021	0.031	0.01	0.01	0	0.406	0.125	0.203	0.338	0.51	0.203	0.458	0.348	0.052	1.1
Other groups	0.018	0.073	0.041	0.119	0.073	0.027	0.027	0.027	0.018	0.01	0.055	0.018	0.036	0.036	0
Total	0.263	0.242	0.245	1.155	0.215	0.853	0.492	0.634	1.035	0.83	0.644	0.865	0.732	0.588	1.4

Table: 9.1.6. Meiofaunal biomass (mg/10 cm^2) at station 6 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Nematoda	0.098	0.004	0.008	0.098	0	0.002	0	0.002	0.01	0	0.012	0.008	0.002	0	0
Polychaeta	0	0	0.016	0	0	0	0	0	0.094	0	0.016	0	0	0	0
Copepoda	0.01	0.031	0.01	0.01	0	0	0	0.01	0.53	0	0	0.062	0	0	0
Other groups	0	0.009	0	0.016	0	0.009	0	0	0.01	0.01	0		0	0	0
Total	0.108	0.044	0.034	0.124	0	0.011	0	0.012	0.643	0.01	0.028	0.07	0.002	0	0

Table: 9.2.1. Macrofaunal biomass ($g/1m^2$) at station 1 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Polychaetes	17.99	15.29	8.52	50.33	56.91	8.74	7.37	1.06	4.92	15.07	13.42	5.14	13.56	4.53	40.19
Crustaceans	0.13	0.50	0.14	0.40	0.50	26.58	28.24	21.16	0.79	2.98	1.18	1.84	0.37	0.17	4.38
Molluscs	1.85	0.93	0.00	0.00	0.00	0.06	0.91	1.83	33.87	11.87	0.00	24.80	32.88	3.65	16.33
Others	2.025	1.98	0.02	0.01	0.00	0.00	0.00	0.00	0.23402	0.00	0.01	0.23	0.00	0.00	0.33
Total	22.00	18.70	8.68	50.74	57.41	35.38	36.52	24.05	39.81	29.93	14.61	32.01	46.81	8.35	61.22

Table: 9.2.2. Macrofaunal biomass ($g/1m^2$) at station 2 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Polychaetes	0.491	0.16	0.46	0.75	8.02	5.78	2.90	6.69	1.89	1.46	3.69	1.86	1.80	6.09	3.26
Crustaceans	0.024	0.13	0.00	0.18	0.12	0.01	0.29	0.19	0.26	0.09	0.00	0.40	0.56	0.04	8.36
Molluscs	0.000	0.02	0.00	0.00	3.56	1.19	0.91	0.00	0.91	0.00	0.00	0.00	61.06	0.00	0.00
Others	0.000	0.00	0.00	0.00	3.45	0.13	0.03	0.12	0.24	0.28	2.46	0.12	1.64	0.02	1.01
Total	0.515	0.31	0.46	0.93	15.15	7.10	4.14	7.00	3.31	1.83	6.15	2.37	65.05	6.14	12.63

Table: 9.2.3. Macrofaunal biomass ($g/1m^2$) at station 3 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Polychaetes	0.10	14.30	12.97	21.25	3.11	2.95	9.44	6.72	2.46	1.93	17.95	2.27	0.40	8.20	2.59
Crustaceans	6.50	18.71	12.13	4.06	0.24	0.20	2.21	1.49	0.57	0.03	0.14	0.06	0.05	3.66	0.22
Molluscs	17.85	122.13	0.00	0.00	0.00	0.00	0.00	2.39	83.19	644.30	43.50	105.83	0.00	0.00	4.00
Others	0.00	2.6969	2.39	0.54	0.17	0.00	0.84	1.35	0.03	1.97	1.60	1.72	1.35	0.74	1.26
Total	24.44	157.83	27.48	25.85	3.53	3.15	12.49	11.94	86.25	648.23	63.20	109.87	1.80	12.60	8.07

Table: 9.2.4. Macrofaunal biomass ($g/1m^2$) at station 4 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Polychaetes	1.29	0.80	0.60	65.17	7.73	10.73	14.16	11.27	6.04	7.48	4.83	14.03	42.77	1.56	1.69
Crustaceans	0.34	0.00	0.09	2.66	0.16	0.54	6.57	0.27	0.24	0.03	1.19	0.00	3.65	0.01	10.08
Molluscs	0.00	0.00	0.00	0.00	0.00	0.00	0.60	21.85	414.00	426.81	71.80	155.16	20.25	0.00	0.00
Others	0.00	0.00	2.0395	0.67632	0.00	0.1095	0.10643	0.00	0.12342	0.113	0.18	0.038	0.12	0.03	0.00
Total	1.63	0.80	2.73	68.50	7.90	11.38	21.43	33.39	420.40	434.44	78.00	169.22	66.79	1.59	11.77

Table: 9.2.5. Macrofaunal biomass (g/1m^2)) at station 5 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Polychaetes	6.08	4.76	7.52	26.32	29.88	13.31	12.83	4.02	6.10	2.42	5.70	4.36	11.66	9.31	7.82
Crustaceans	3.34	0.53	0.00	0.32	0.04	0.13	1.07	0.10	0.23	0.58	0.16	0.27	0.12	0.16	4.21
Molluscs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.50	0.363	0.00	0.00	0.00	0.00
Total	9.66	5.29	7.52	26.64	29.92	13.44	13.90	9.99	6.33	3.50	6.22	4.63	11.78	9.47	12.03

Table: 9.2.6. Macrofaunal biomass (g/1m^2)) at station 6 during the period July 2002 to May 2004

	Jy 02	Aug	Spt	Oct	Nov	Dec	Jan 03	Feb	Mar	Apr	My	Jun	Jy	Nov	My 04
Polychaetes	0	0	0	0.090	0.000	0.014	0.500	0.344	0.086	0.015	0.112	0.132	0.058	0.000	0.000
Crustaceans	0.02	0	0.18	0.140	0.070	0.101	0.090	0.070	0.042	0.000	0.000	0.020	0.000	0.000	0.000
Molluscs	0	0	0	0.000	0.008	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000
Others	0	0	0.01	0.030	0.452	0.000	0.106	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.02	0	0.19	0.260	0.530	0.115	0.696	0.414	0.148	0.015	0.112	0.152	0.058	0.000	0.000

Table: 9.3. Relationship between biomass of meiofauna and macrofauna at stations 1 to 6

	Biomass(wet weight) (kg/km^2)		Numerical density (no/ km^2)		(Meiofauna:Macrofauna)	
stations	Meiofauna	Macrofauna	Meiofauna	Macrofauna	Biomass	Numerical density
1	637	32410	319×10^9	516×10^7	1:51	62:1
2	1054	8740	994×10^9	147×10^7	1:8	676:1
3	1056	82000	1034×10^9	444×10^7	1:78	233:1
4	532	88670	278×10^9	670×10^7	1:167	41:1
5	403	11540	387×10^9	373×10^7	1:29	104:1
6	73	139	18×10^9	19×10^7	1:2.5	95:1
Average	626	37257	505×10^9	362×10^7	1:60	140:1

Table :10.1.1.Long-term changes in the species composition of macrobenthos at station 1*

	1974-76	1977-78	1996-97	2002-04
Amphinomidae	---	---	R	---
Ancistrosyllis constricta	LC	VC	C	LC
Aphrodita	---	---	R	---
Cossura coasta	R	R	R	LC
Capitella sp	C	---	R	R
Dendronereis estuarina	LC	R	---	LC
Diopatra neapolitana	C	LC	LC	VC
Disoma sp	---	LC	---	---
Fabricis sp	---	R	---	---
Glycera alba	LC	R	---	---
Glycera longipinnis	LC	LC	---	---
Glycera trydactyla	---	---	---	VC
Glycinde bonhourei	---	---	---	LC
Heteromastus bifidus	---	---	LC	HA
Heteromastus filiformis	---	---	LC	---
Heteromastus similis	---	---	R	---
Mediomastus capensis	---	---	R	---
Lumbriconereis heteropoda	R	R	---	---
Lumbriconereis latreilli	C	LC	---	R
L.simplex	R	LC	---	R
Lumbriconereis sp	VC	R	R	---
Lycastis indica	R	---	R	R
Maldane sp	---	---	---	R
Mesochaetopterus	R	---	---	---
Neries sp	---	LC	R	LC
Nephthys oligobranchiata	VC	VC	---	LC
Nephthys polybranchiata	---	VC	---	---
Notomastus sp	---	---	C	VC
Ophelia sp	---	---	---	R
Owenia sp	LC	---	---	---
Paraheteromastus tenuis	VC	LC	LC	AB
Phyllodoce gracilis	---	R	---	---
Pistia sp	---	---	R	---
Prionospio cirrifera	LC	LC	---	HA
P.pinnata	LC	VC	LC	LC
P.polybranchiata	VC	C	C	C
Prionospio sp	---	---	LC	---
Polydora kempi	---	R	---	LC
Scyphoproctus djiboutiensis	---	---	---	C
Sternapsis scutata	R	---	---	---
Syllis spongicola	---	---	---	R
Talehsapia sp	---	---	R	---
Alpheus malabaricus	R	C	---	R
Apseudes chilkensis	C	LC	LC	R
A.gymnophobia	LC	---	LC	R
Ampelisca zamboanga	---	LC	---	---

Table 10.1.1. Continued . . .

	1974-76	1977-78	1996-97	2002-04
Anthuridae sp	---	---	---	R
Caprellidae	---	LC	---	R
Cirrolinia fluviatilis	R	LC	--	R
Corophium triaenonyx	C	C	R	C
Eriopisa chilkensis	R	---	---	---
Grandidierella sp	VC	LC	R	VC
Iphinoe	C	---	---	R
Macropthalmus sp	R	---	---	---
Metapenaeus sp	---	R	---	---
Synidotea variegata	R	---	---	---
Rhynchoplax	---	LC	---	---
Penaeus sp	---	LC	R	R
Scylla serrata	---	R	---	---
Viaderiana sp	C	---	---	---
Xenophthalmodes moebii	---	---	---	LC
Other crabs	---	---	LC	---
Mysid	---	---	R	---
Arca sp	R	---	---	---
Balbonia sp	---	R	---	---
Bithina sp	R	---	---	---
Dosinia sp	---	---	R	---
Modiolus metacalfei	---	R	---	---
M.striatulus	---	---	R	---
M.undulates	---	R	---	---
Muculista senhousia	---	---	---	LC
Naculana sp	R	---	R	---
Katalysia sp	---	---	---	R
Paphia sp	---	---	---	R
Solen sp	R	---	---	---
Standella SP	R	---	---	---
Tellinia sp	R	---	---	---
Thais sp	---	---	---	LC
Villorita sp	---	---	R	---
Gastropod	---	---	R	---
Gobiidae	R	---	---	---
Trypauchen vagina	R	---	---	---
Sipunculoidea	R	---	---	---
Cerianthus sp	R	---	---	---
Milne sp	R	---	---	---
Obelia sp	R	---	---	---
Sea anemone	R	LC	---	---
Nemertean	---	LC	---	---
Oligochaete	---	---	LC	---

*(R-Rare(no=1),LC-Less common(no=2-5),C-Common(no=6-10), VC-Very Common(no=11-50),AB-Abundant(no=51-100),HA-Highly abundant(≥101))

Table: 10.1.2. Long-term changes in the species composition of macrobenthos at station 2*

	1974-76	1977-78	2002-04
Ancistrosyllis constricta	LC	VC	LC
Cossura coasta	R	R	C
Dendronereis estuarina	R	LC	R
Diopatra neapolitana	R	VC	R
Disoma sp	---	R	---
Eulalia viridis	---	R	---
Fabricis sp	---	R	---
Glycera alba	R	R	---
Glycera longipinnis	R	R	---
Glycera trydactyla	---	---	LC
Glycinde bonhourei	---	---	LC
Heteromastus bifidus	---	---	C
Lumbriconereis heteropoda	R	R	---
Lumbriconereis latreilli	R	LC	R
L.simplex	R	C	R
Lumbriconereis sp	C	LC	---
Lycastis indica	R	---	R
Mercierella elongata	---	R	---
Mesochaetopterus	R	---	---
Nereis sp	---	LC	LC
Nephthys oligobranchiata	VC	R	C
Nephthys polybranchiata	---	R	---
Notopygos sp	---	---	R
Notomastus sp	---	---	LC
Owenia sp	R	---	---
Paraheteromastus tenuis	LC	C	VC
Phyllodoce gracilis	R	R	---
Polydora kempi	---	R	R
Prionospio cirrifera	C	R	C
P.pinnata	LC	C	LC
P.polybranchiata	VC	C	VC
Sabellidae	---	---	R
Syllis spongicola	---	---	R
Scyphoproctus djiboutiensis	---	---	LC
Sternapsis scutata	R	R	---

Table: 10.1.2. Continued . . .

	1974-76	1977-78	2002-2004
Alpheus malabaricus	R	---	---
Alpheus sp	---	AB	LC
Apseudes chilkensis	AB	VC	R
A.gymnophobia	LC	C	R
Anthuridae sp	---	R	R
Cirrolinia fluviatilis	R	VC	R
Corophium triaenonyx	LC	AB	LC
Eriopisa chilkensis	R	C	---
Eriphia smithia	R	---	---
Grandidierella sp	C	AB	LC
Iphinoe sp	R	R	R
Metapenaeus affinis	R	R	---
Neorhynchoplax sp	---	---	R
Penaeus sp	---	R	---
Rhynchoplax sp	---	LC	---
Scylla serrata	---	R	---
Squailla nepa	R	R	---
Maccophthalmus sp	R	---	---
Synidotea variegata	R	C	---
Viaderiana sp	R	---	---
Arca sp	R	---	---
Disoma sp	---	R	---
Katalysia sp	---	---	R
Leiochrides africanus	R	---	---
Naculana sp	R	---	---
Paphia sp	---	R	---
Tellina sp	R	---	---
Thias sp	---	---	R
Muculista senhousia	---	---	LC
Modiolus undulatus	---	C	---
Modiolus metacalfei	---	LC	---
Solen sp	R	---	---
Standella sp	R	---	---
Gobiidae	R	R	---
Cynoglossus	---	R	---
Trypauchen vagina	R	R	---
Sipunculoidea	R	R	---
Cirianthus sp	R	R	---
Milne edwardsia	R	R	---
Obelia bicucspidata	R	R	---
Sea anemone	R	R	---
Nemertean	---	C	---
Brittle star	---	R	---
Oligochaete	---	R	---

*(R-Rare(no=1),LC-Less common(no=2-5),C-Common(no=6-10), VC-Very Common(no=11-50),AB-Abundant(no=51-100),HA-Highly abundant(≥101))

Table: 10.1.3. Long-term changes in the community structure of benthos at station 3*

	1974-76	1977-78	1981	1996-97	2002-04
Ancistrosyllis constricta	C	V.C	C	V.C	C
Cossura coasta	L.C	R	—	—	L.C
Capitella sp	—	—	—	C	C
Dendronereis estuarina	R	L.C	L.C	R	R
Diopatra neapolitana	L.C	V.C	V.C	V.C	C
Disoma sp	R	R	—	—	—
Eteone sp	—	—	—	—	R
Eunice tubifex	—	—	L.C	—	—
Exogone sp	—	—	—	—	R
Fabricis sp	L.C	L.C	—	—	—
Glycera alba	—	R	LC	—	—
Glycera convotuta	—	—	LC	—	—
Glycera longipinnis	R	R	—	R	—
Glycera trydactyla	R	—	L.C	—	—
Goniada emerita	—	—	L.C	—	—
Glycinde bonhourei	—	—	—	—	LC
Heteromastus bifidus	—	—	V.C	R	L.C
Heteromastus similis	—	—	LC	—	—
Lepidontus sp	R	—	—	R	—
Lumbriconereis heteropoda	R	R	—	—	—
Lumbriconereis latreilli	L.C	L.C	—	—	C
L.simplex	R	C	V.C	L.C	L.C
Lumbriconereis sp	L.C	R	C	L.C	—
Lycastis indica	R	—	L.C	—	—
Marphysia sp	—	—	—	LC	—
Mesochaetopterus	R	—	—	—	—
Mercierella elongata	R	—	—	—	—
Nephthys oligobranchiata	L.C	R	L.C	—	L.C
Nephthys polybranchiata	—	R	R	—	—
Nereis sp	—	L.C	—	C	LC
Notopygos sp	—	—	R	—	L.C
Odonto syllis	—	—	R	—	—
Owenia sp	R	L.C	R	—	—
Paraheteromastus tenuis	L.C	C	C	—	H.A
Perinereis cavifrons	R	—	R	—	—
Phyllodoce gracilis	R	—	—	—	—
Pistia sp	—	LC	VC	R	—
Prionospio cirrifera	C	R	—	—	HA
P.pinnata	C	R	LC	R	C
P.polybranchiata	C	C	VC	LC	LC
Polycirrus sp	—	—	—	R	—
Polydora kempi	R	R	—	—	LC
Sabellidae	—	—	LC	—	—
Serpula sp	—	—	R	—	—

Table: 10.1.3. Continued . . .

Sthenelais boa	R	---	C	R	R
Sternapsis sp	R	---	R	---	R
Scyphoproctus djiboutiensis	---	---	---	---	LC
Syllis spongicola	---	---	---	---	R
Alpheus euphrosyne	R	---	---	---	---
A.fabricius	R	---	---	A	---
Alpheus sp	LC	HA	R	R	LC
A.malabaricus	R	---	---	---	---
A.paludicola	R	---	---	---	---
Acetes	---	---	R	---	---
Metapenaeus sp	R	R	---	---	---
Penaeus sp	R	R	---	---	---
Apseudes chilkensis	R	C	C	R	R
A.gymnophobia	LC	C	LC	AB	LC
Anthuridae sp	---	LC	LC	---	LC
Ampelisca zamboanga	LC	---	---	---	---
Balanus	---	---	R	---	---
Caprellidae	---	---	LC	---	R
Cirrolinia fluviatilis	R	AB	HA	HA	R
Corophium triaenonyx	---	HA	HA	HA	AB
Decapoda	---	---	---	C	---
Eriphia smithii	R	---	---	---	---
Eriopisa chilkensis	LC	R	R	HA	R
Gammaridae	---	R	---	---	---
Grandidierella sp	LC	VC	HA	HA	AB
Cumacea	R	---	---	R	R
Litocheira sp	R	---	---	---	---
Melita sp	---	R	C	---	---
Quadrivisio bengalensis	---	---	HA	HA	---
Rhynchoplax sp	R	LC	---	---	---
Neorhynchoplax sp	---	---	---	---	LC
Squailla nepa	R	R	---	---	---
Scylla serrata	R	R	---	---	---
Synidotea variegata	R	R	---	---	---
Insect	---	R	---	R	---
Arca bistrigata	R	---	---	---	---
Arca sp	R	---	LC	---	---
Tellina sp	R	---	---	---	---
Dendorophylax	R	R	LC	R	R
Dentalium	---	---	---	R	---
Dosinia	---	R	---	LC	---
Katalysia	---	---	---	---	LC

Table: 10.1.3. Continued . . .

Littorina sp	—	—	LC	—	—
Meretrix casta	—	—	R	R	—
Modiolus metacalfei	R	R	—	—	—
M.striatulus	—	—	VC	—	—
M.undulatus	C	C	R	R	R
Muculista senhousia	—	—	—	—	C
Naculana sp	—	R	—	—	—
Paphia sp	R	R	R	R	R
Standella sp	R	—	—	—	—
Sunetta scriptta	—	R	—	—	—
Thais sp	—	—	—	—	R
Brittle star	LC	R	—	—	—
Chaetostoma sp	R	—	—	—	—
Sea anemon	—	R	VC	—	—
Sipunculoidea	LC	R	LC	—	—
Nemertea	—	LC	—	—	—
Gobiidae	R	R	—	—	—
Solea ovata	R	—	—	—	—
Trypauchen sp	R	R	—	—	—

* (R-Rare(no=1),LC-Less common(no=2-5),C-Common(no=6-10), VC-Very Common(no=11-50),AB-Abundant(no=51-100),HA-Highly abundant(≥101))

Table: 10.1.4. Long-term changes in the community structure of benthos at station 4*

	1981	1996-97	2002-04
Ancistrosyllis constricta	LC	LC	LC
Aphrodita sp	C	R	---
Capitella sp	R	LC	---
Cossura coasta	---	---	LC
Dendronereis estuarina	VC	LC	R
Diopatra neapolitana	LC	C	C
Disoma sp	---	R	---
Eunice tubifex	R	---	---
Glycera alba	R	---	---
Glycera trydactyla	---	---	LC
Glycera convotuta	R	---	---
Glycera longipinnis	---	R	---
Goniada emerita	R	---	R
Heteromastus bifidus	AB	LC	VC
Heteromastus filiformis	---	R	---
Heteromastus similis	LC	LC	---
Lumbriconereis latreilli	---	---	R
L.simplex	---	---	R
Lumbriconereis sp	R	---	---
Lycastis indica	C	LC	---
Marphysia sp	---	---	LC
Mediomastus capensis	---	LC	---
Nephthys oligobranchiata	---	---	C
Nephthys polybranchiata	LC	---	---
Nereis sp	---	LC	LC
Notomastus aberans	---	LC	---
Notomastus latericeus	---	VC	---
Notopygos sp	---	R	---
Owenia sp	LC	LC	---
Paraheteromastus tenuis	LC	---	AB
Perinereis cavifrons	LC	---	---
Pistia sp	R	R	---
Prionospio cirrifera	---	LC	AB
P.pinnata	---	---	R
P.polybranchiata	VC	C	AB
Polydora kempi	---	---	R
Scolane sp	---	R	---
Scyphoproctus djiboutiensis	---	LC	LC
Syllis spongicola	---	---	R

Table: 10.1.4. Continued . . .

	1981	1996-97	2002-04
Anthuridae sp	---	R	LC
Alpheus sp	R	LC	LC
A.gymnophobia	R	LC	LC
Apseudes chilkensis	R	R	R
Caprellidae	R	R	R
Chironomus larvae	R	---	---
Cirrolinia fluviatilis	R	LC	R
Corophium triaenonyx	VC	VC	LC
Cumacea	R	---	---
Decapoda	LC	R	R
Eriopisa chilkensis	---	LC	---
Crab	---	R	---
Grandidierella sp	AB	LC	LC
Melita sp	LC	R	---
Quadrivisio bengalensis	VC	LC	---
Tanytarsus sp	R	---	---
Plectronema sp	LC	---	---
Insect	R	---	---
Xenophthalmodes moebii	---	---	R
Arca sp	LC	---	---
Dosinia sp	---	R	---
Leiochrides africanus	---	LC	---
Littorina sp	R	---	---
Modiolus striatulum	---	R	---
Muculista senhousia	---	---	R
Katalysia sp	---	---	R
Gastropod	R	R	---
Pendoroflexosa	R	---	---
Paphia sp	R	R	R
Thais sp	---	---	R
Villorita sp	LC	---	---
Fish	R	---	---
Sipunculoidea	R	---	---
Echinodermata	R	---	---
Oligochaete	---	R	---
Flat worm	R	---	---

*(R-Rare(no=1),LC-Less common(no=2-5),C-Common(no=6-10), VC-Very Common(no=11-50),AB-Abundant(no=51-100),HA-Highly abundant(≥101))

Table: 10:1.5. Long term changes in the community structure of benthos at station 5*

	1981	1996-97	2002-2004
Ancistrosyllis constricta	---	---	R
Capitella sp	R	R	LC
Dendronereis estuarina	VC	LC	LC
Heteromastus bifidus	R	R	---
Lumbriconereis latreilli	---	R	---
Lycastis indica	R	---	R
Paraheteromastus tenuis	R	R	---
Prionospio cirrifera	---	---	C
P.polybranchiata	LC	LC	---
Scyphoproctus djiboutiensis	---	LC	---
Cardium sp	---	LC	---
Dosimia sp	---	LC	---
Littorina sp	VC	---	---
Pendoflexosa sp	LC	LC	---
Villorita sp	R	---	---
Anthuridae sp	---	R	---
Decapod	LC	---	---
Caprellidae	LC	---	---
Chironomus larvae	R	---	---
Cricotopus sylvestris	R	---	---
Corophium triaenonyx	R	---	---
Eriopisa chilkensis	R	---	---
Grandidierella sp	R	R	---
Melita sp	LC	---	---
Quadrivisio bengalensis	LC	---	---
Simulium sp	R	---	---
Tanitarsus sp	R	---	---
Insect	R	---	---

*(R-Rare(1),LC-Less common(2-5),C-Common(6-10), VC-Very Common(11-50),AB-Abundant(51-100), HA-Highly abundant(≥101))

Table: 10.2. Comparison of numerical density of macrobenthos(no/0.1m^2) during the period 1974 - 2004

	Station1		Station 2		Station 3		Station 4		Station 5	
	1974-76	2004	1974-76	2004	1974-76	2004	1981	2004	1981	2004
Polychates	187	427	45	120	51	277	226	347	38	13
Crustaceans	35	31	84	10	11	137	151	17	15	4
Mollusc	3	6	1	4	52	22	8	4	31	0
Total	225	464	130	134	114	436	385	368	84	17

Table: 10.3. Comparison of Biomass (gm/m^2) of macrobentos during the period 1974-2004

	Station 1			Station 2			Station 3		
	1974-76	1977-78	2002-04	1974-76	1977-78	2004	1974-76	1977-78	2004
Polychaetes	2.45	2.9	17.54	0.58	7.6	3.02	1.48	14.4	7.11
Crustaceans	4.21	0.7	5.96	1.76	5.5	0.71	0.81	17.0	3.35
Mollusc	0.33	0.05	8.6	0.072	25	4.51	40.23	8.8	68.21
Total	6.99	3.65	32.1	2.412	38.1	8.24	42.52	40.2	78.67

FIGURES

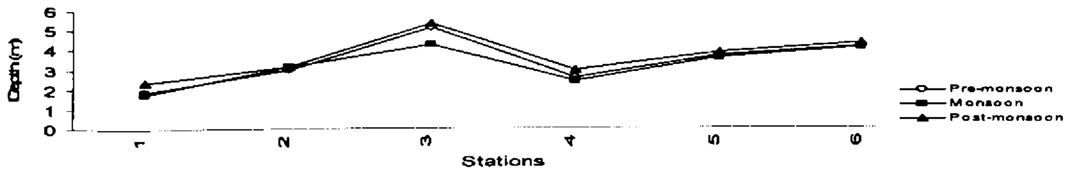


Fig: 4.1 Seasonal distribution of depth at stations 1 to 6

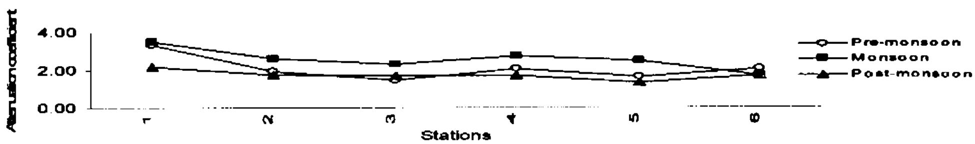


Fig: 4.2 Seasonal distribution of attenuation coefficient at stations 1 to 6

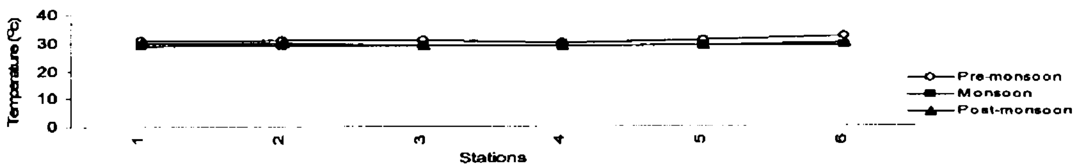


Fig: 4.3 Seasonal distribution of suface water temperature at stations 1 to 6

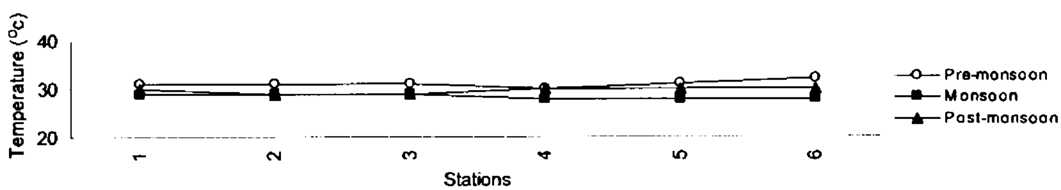


Fig: 4.4 Seasonal distribution of bottom water temperature at stations 1 to 6

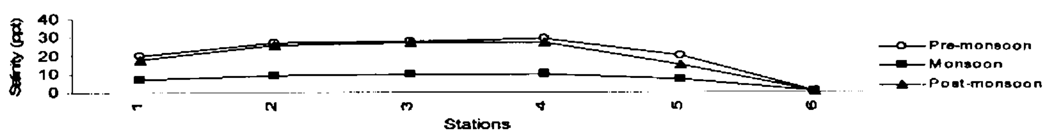


Fig: 4.5 Seasonal distribution of surface water salinity at stations 1 to 6

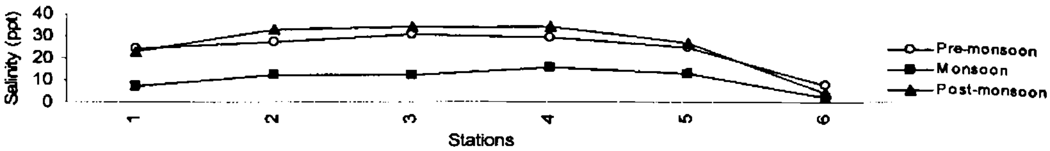


Fig: 4.6 Seasonal distribution of bottom water salinity at stations 1 to 6

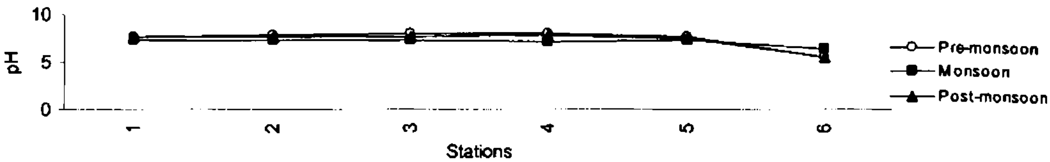


Fig: 4.7 Seasonal distribution of surface water pH at stations 1 to 6

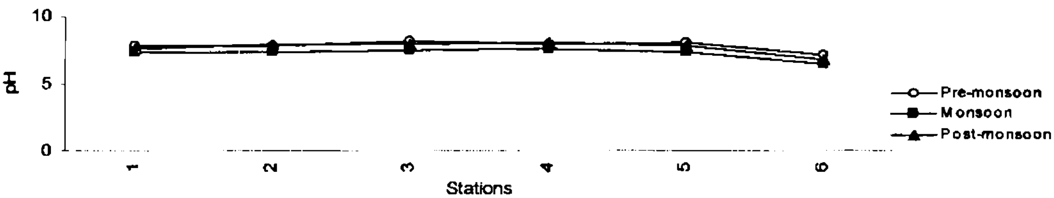


Fig: 4.8 Seasonal distribution of bottom water pH at stations 1 to 6

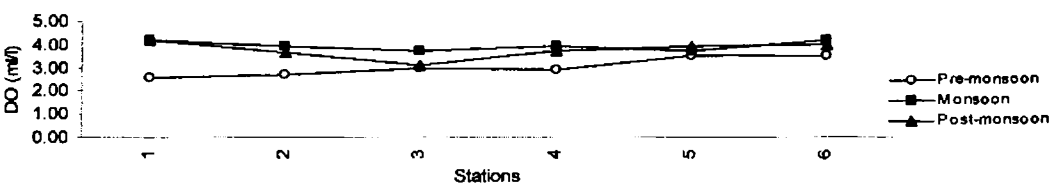


Fig: 4.9 Seasonal distribution of suface water dissolved oxygen at stations 1 to 6

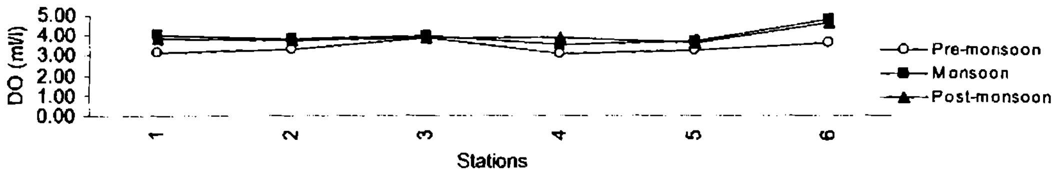


Fig: 4.10 Seasonal distribution of bottom water dissolved oxygen at stations 1 to 6

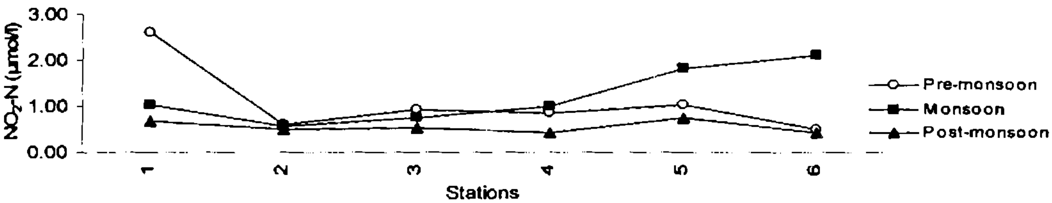


Fig: 4.11 Seasonal distribution of surface water NO_2-N at stations 1 to 6

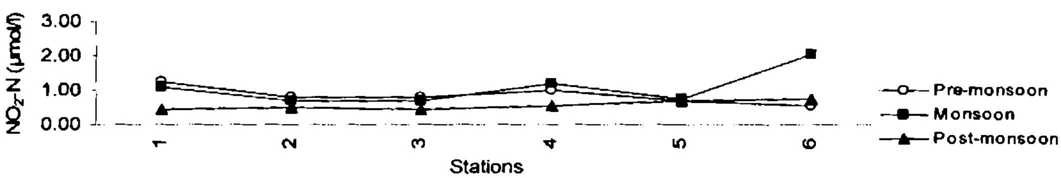


Fig: 4.12 Seasonal distribution of bottom water NO_2-N at Stations 1 to 6

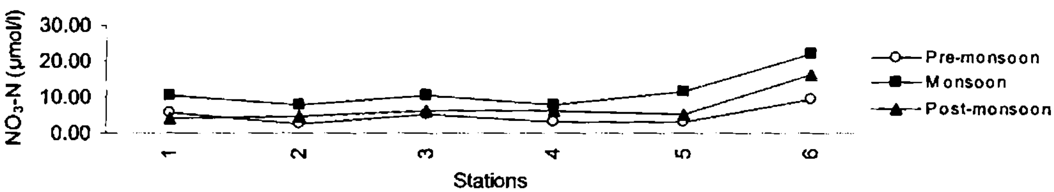


Fig: 4.13 Seasonal distribution of surface water NO_3-N at stations 1 to 6

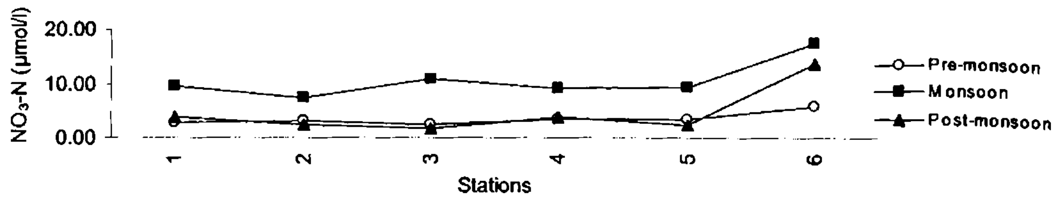


Fig: 4.14 Seasonal distribution of bottom water NO_3-N at stations 1 to 6

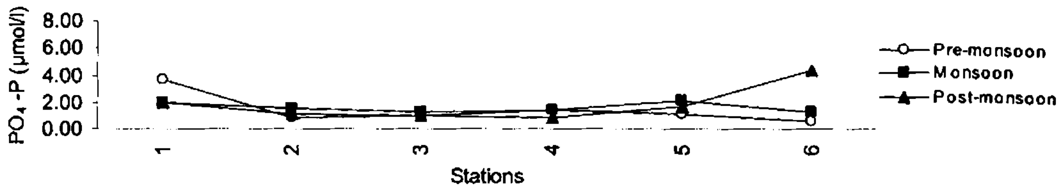


Fig: 4.15 Seasonal distribution of surface water PO_4 -P at stations 1 to 6

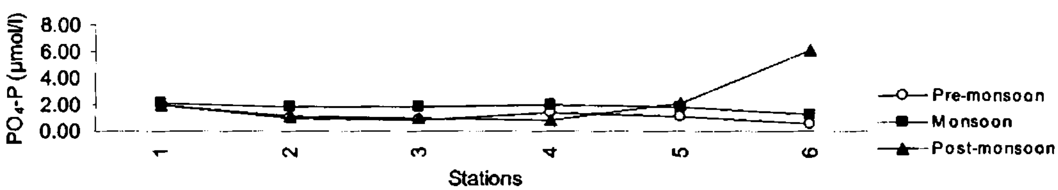


Fig: 4.16 Seasonal distribution of bottom water PO_4-P at stations 1 to 6

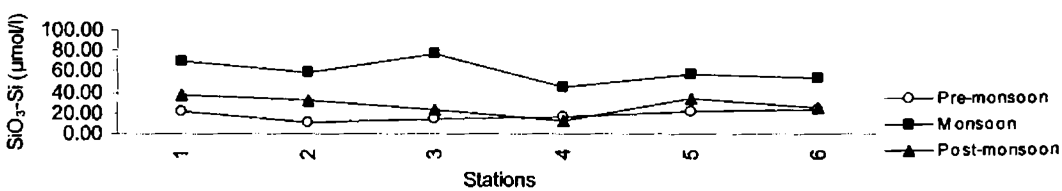


Fig: 4.17 Seasonal distribution of surface water SiO_3-Si at stations 1 to 6

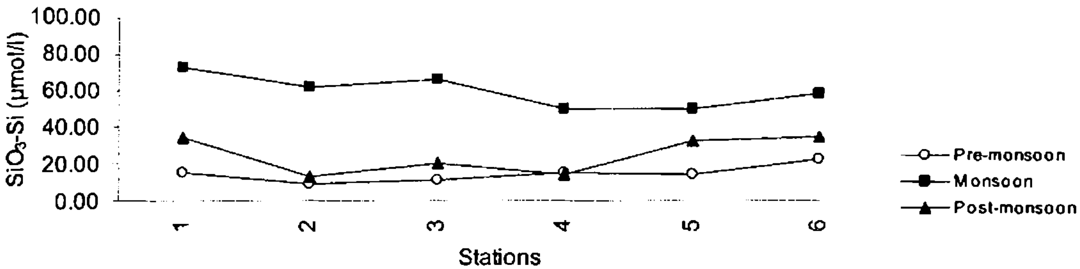


Fig: 4.18 Seasonal distribution of bottom water SiO_3-Si at at stations 1 to 6

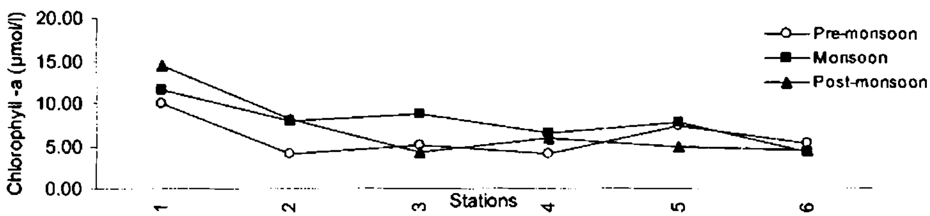


Fig: 4.19 Seasonal distribution of Chlorophyll-*a* in water column at stations 1 to 6

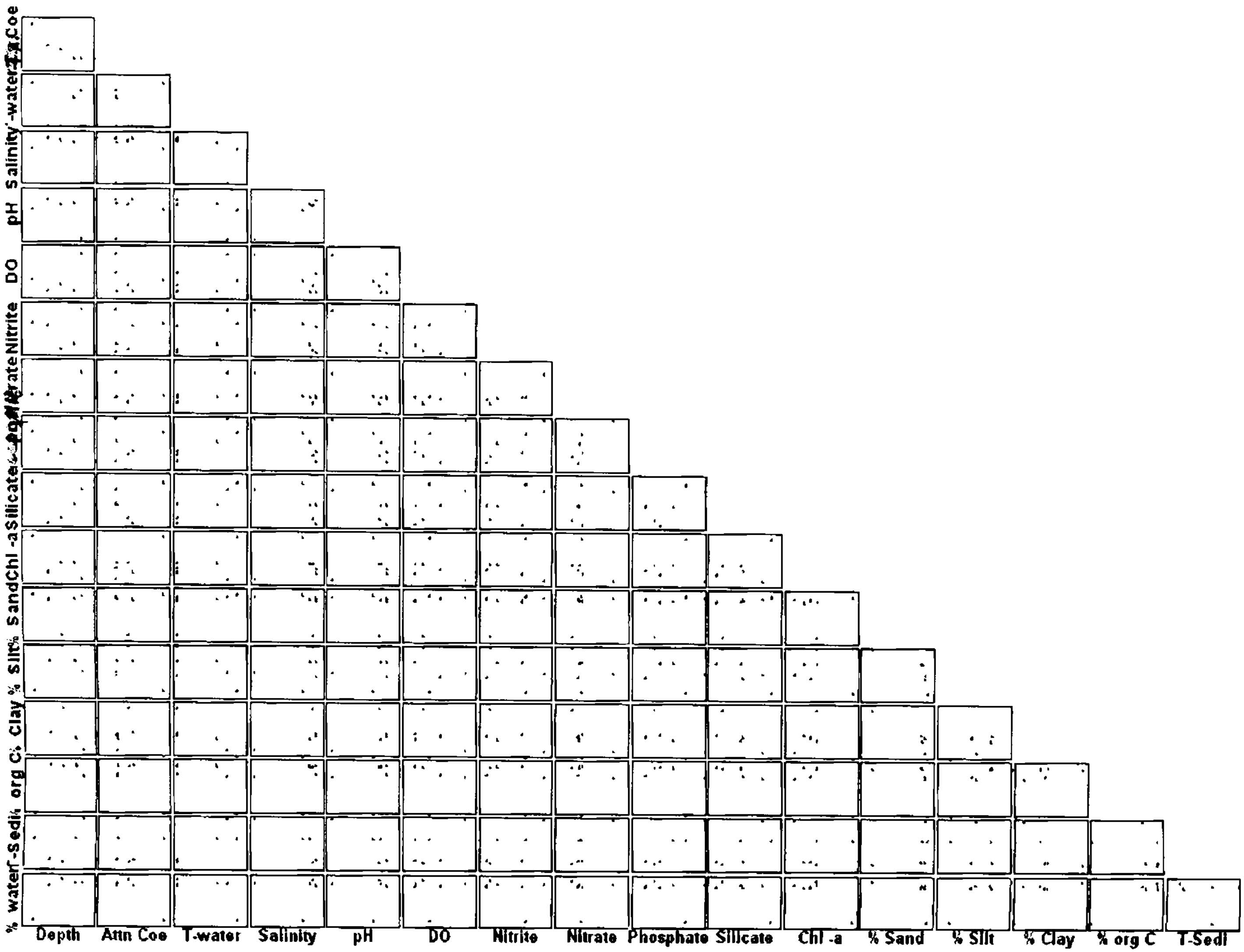


Fig. 4.20 Draftman plot

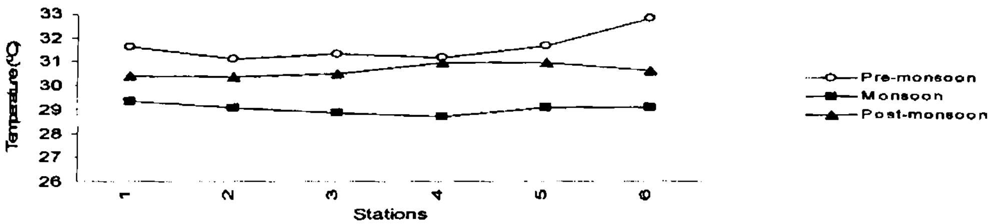


Fig: 5.1 Seasonal distribution of sediment temperature at stations 1 to 6

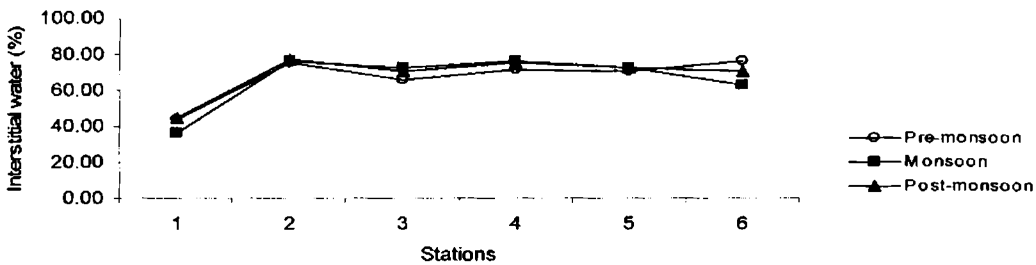


Fig: 5.2.Seasonal distribution of interstitial water content at stations 1 to 6

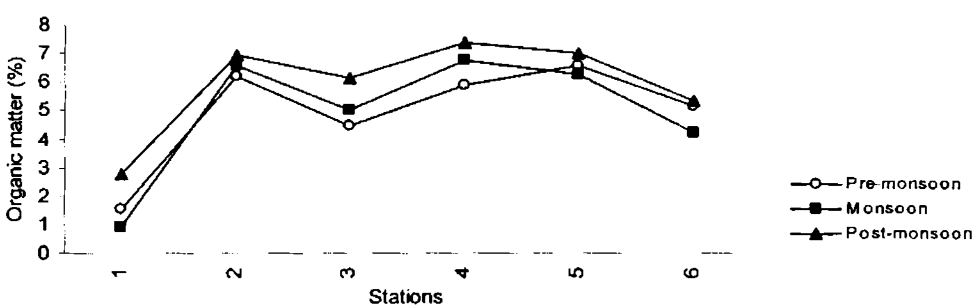
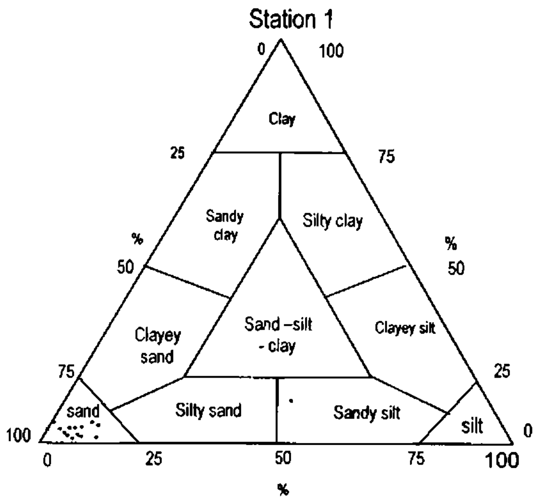


Fig: 5.3 Seasonal distribution of organic matter at stations 1 to 6

Fig: 5.4. Sediment composition of different stations



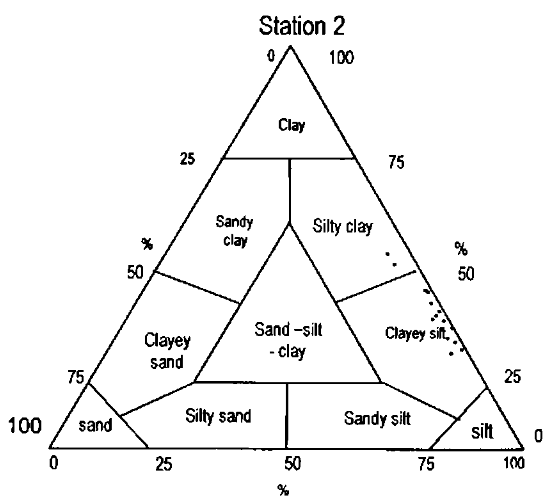
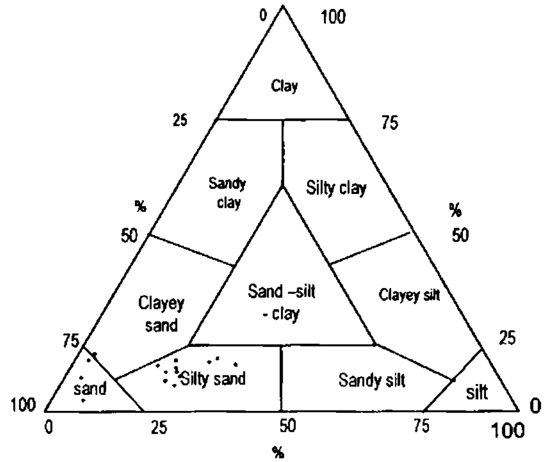


Fig. 5.4. Continued . . .

Station 3



Station 4

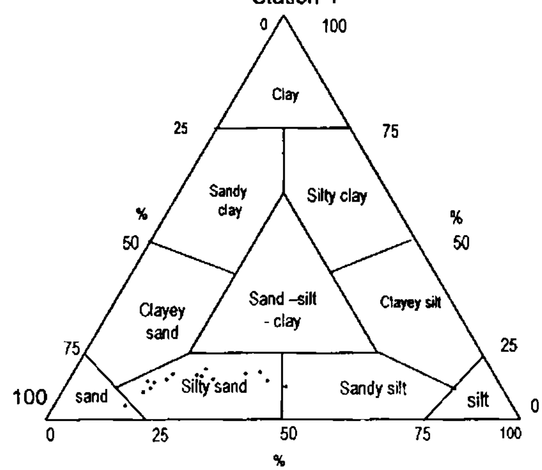
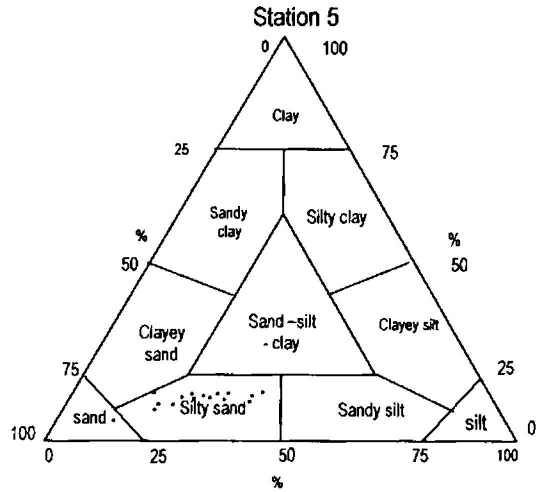
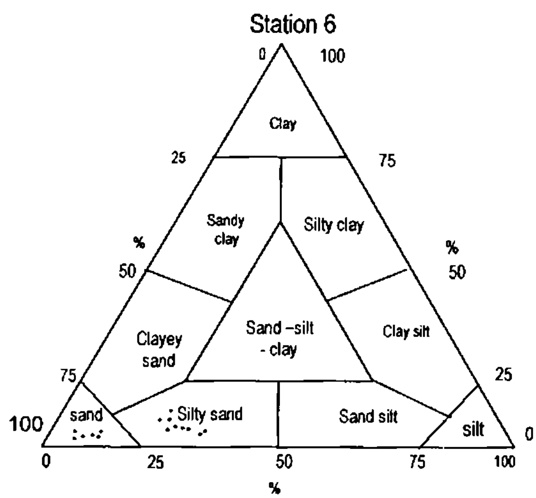


Fig. 5.4. Continued . . .





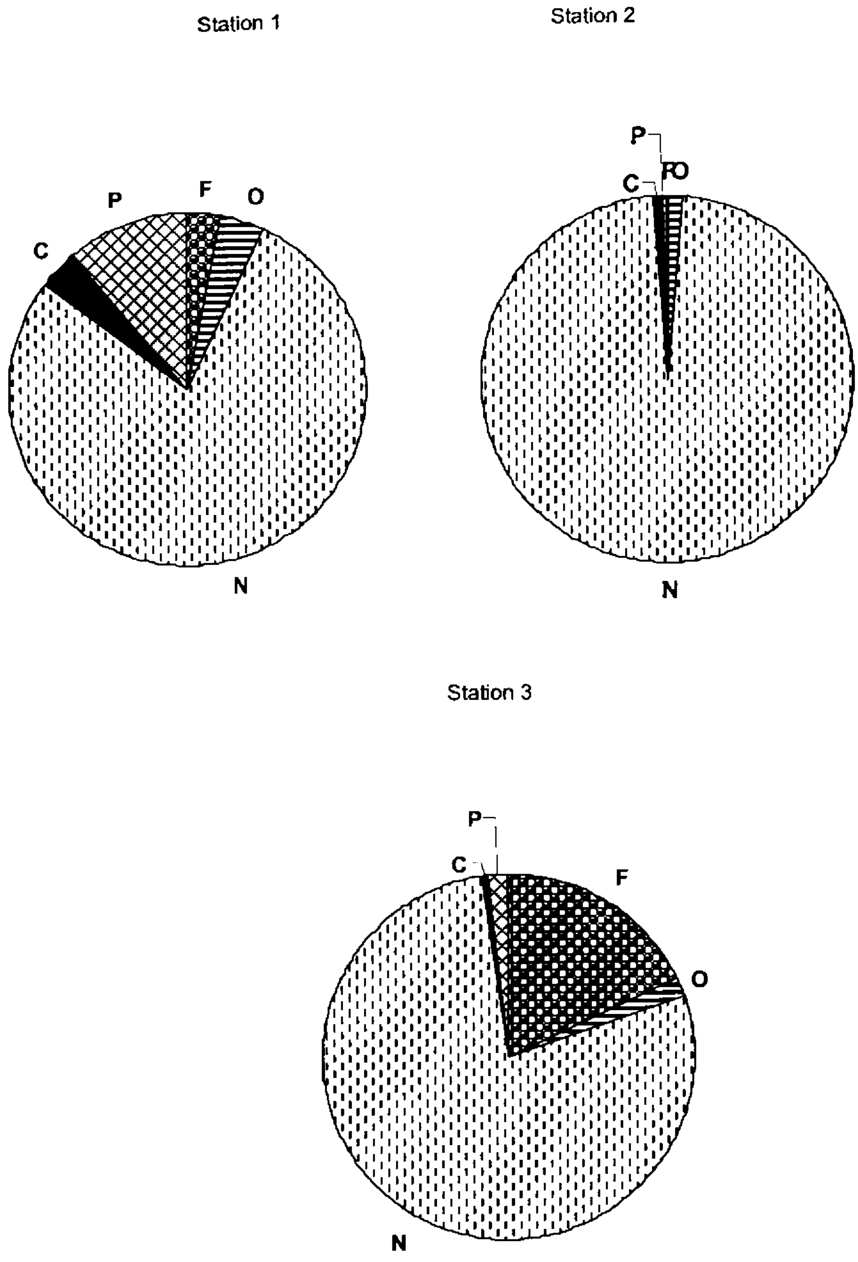


Fig: 6.1.1 Percentage composition of meiofauna at stations 1 to 3*.

*** F=Foraminiferans,N=Nematodes,C=Copepodes,P=Polychaetes,O=Others**

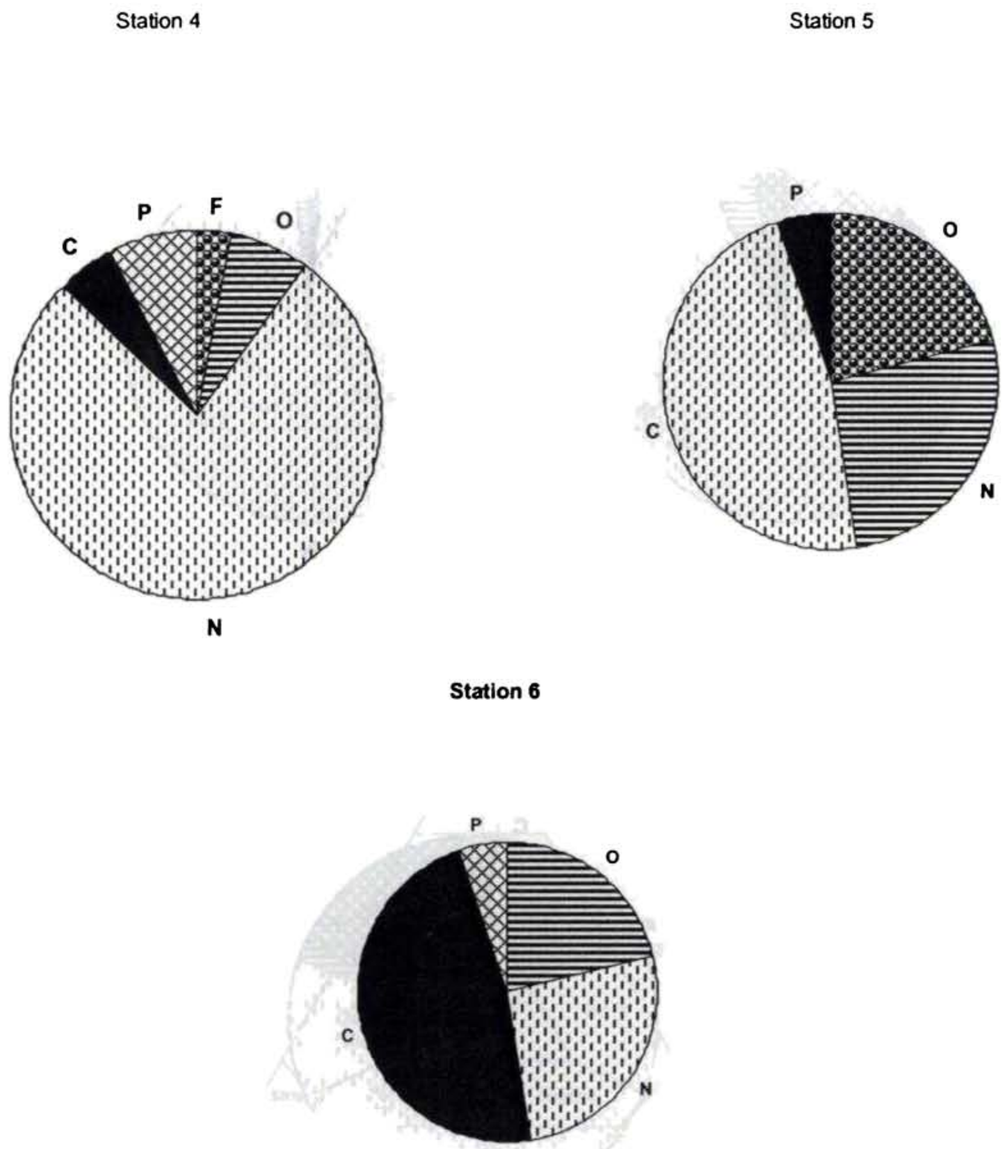
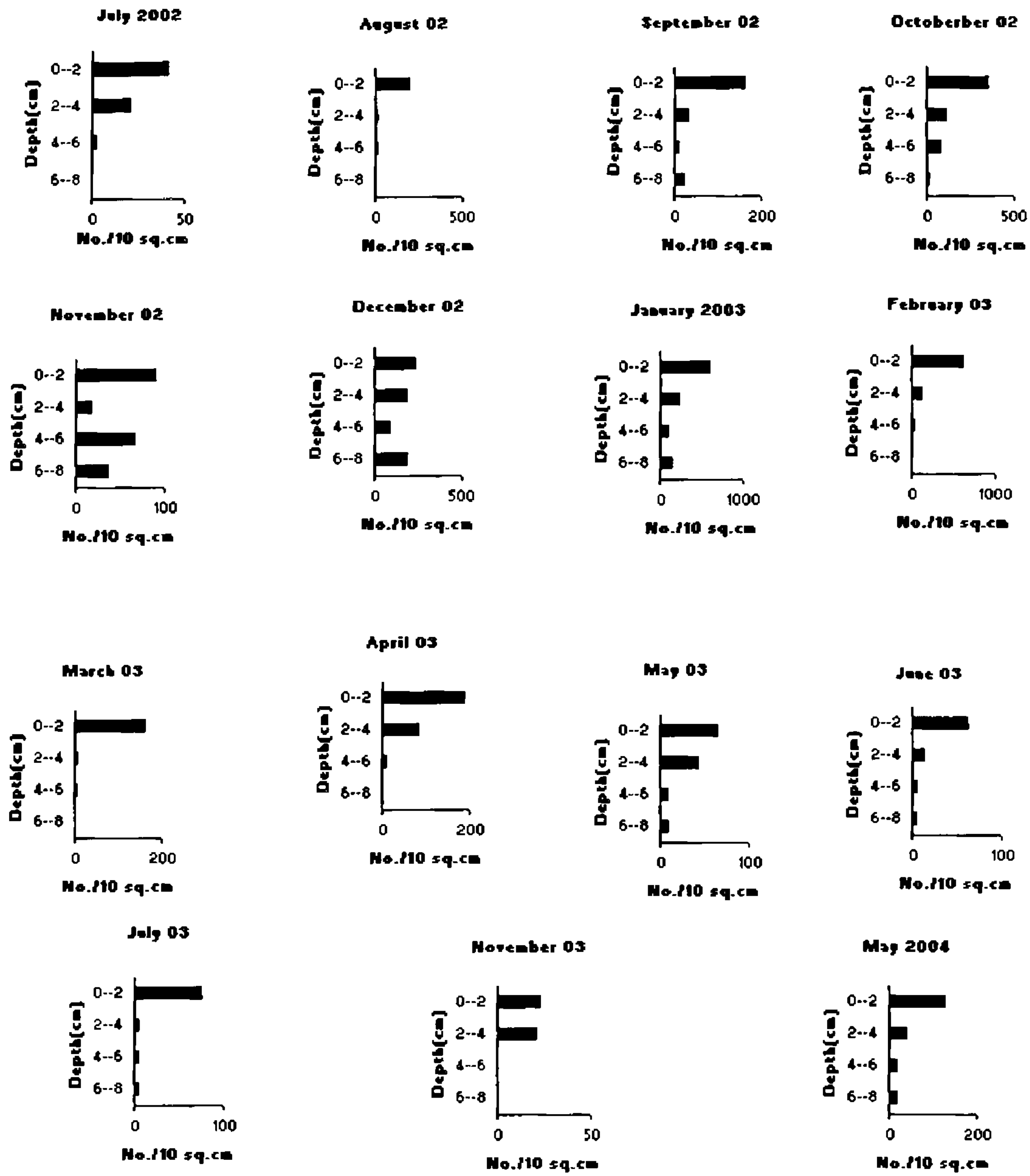


Fig: 6.1.2. Percentage composition of meiofauna at stations 4 to 6*

***F=Foraminiferans, N=Nematodes,C=Copepodes,P=Polychaetes,O=Others**



Fig; 6.2.1.Vertical distribution of meiofauna down to 8cm sediment depth at station 1

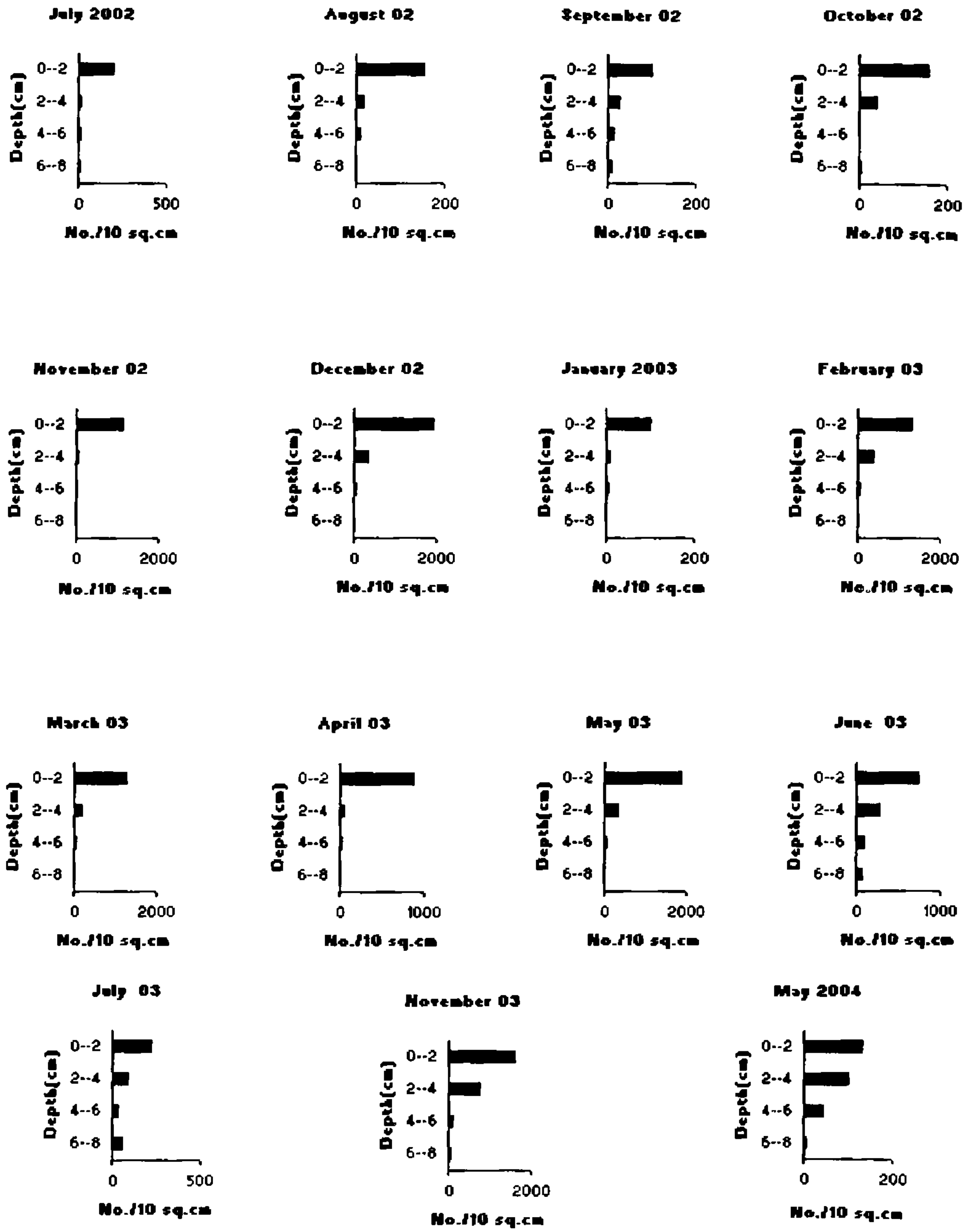
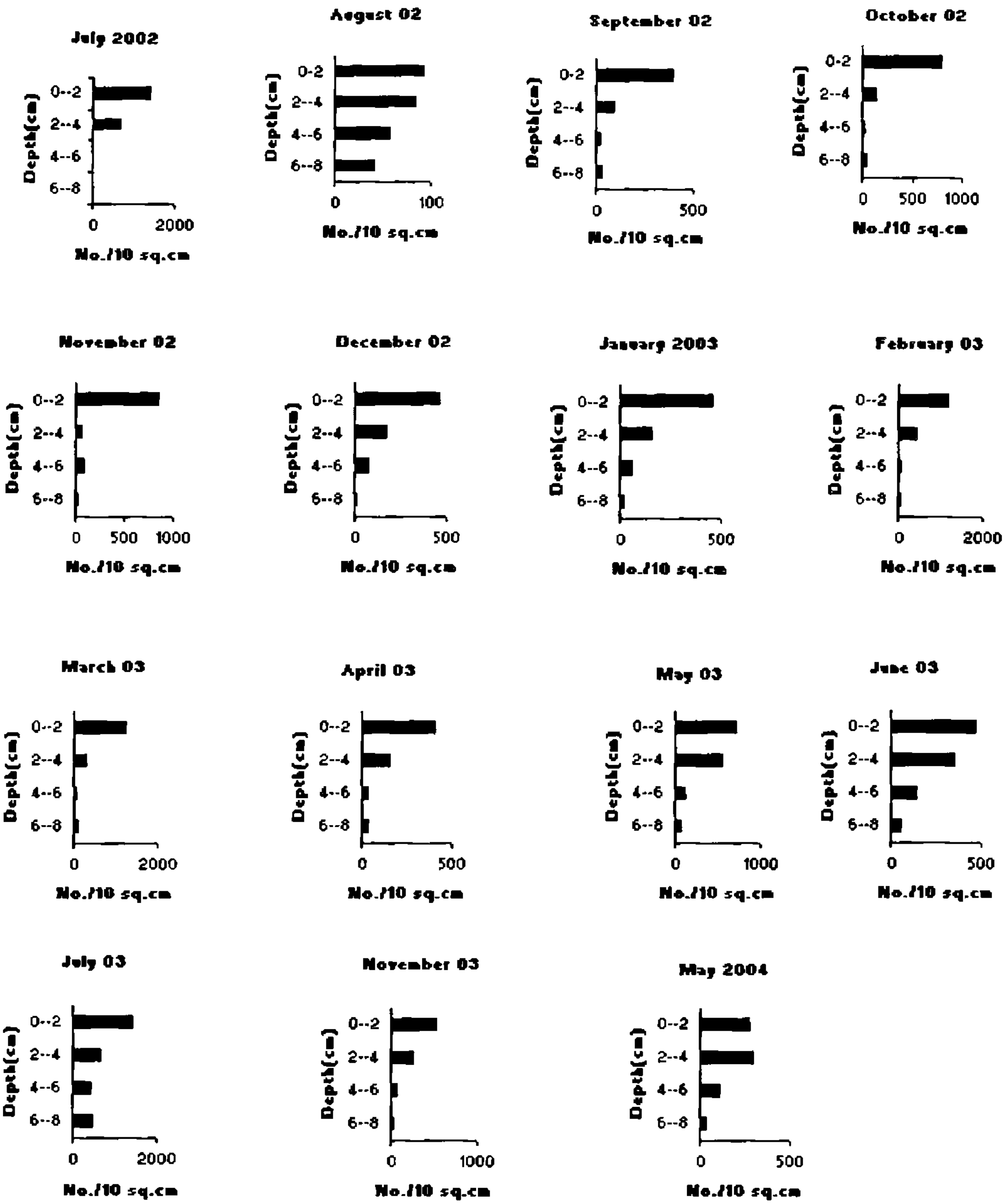


Fig: 6.2.2.Vertical distribution of meiofauna down to 8cm sediment depth at station 2



Fig; 6.2.3.Vertical distribution of meiofauna down to 8cm sediment depth at station 3

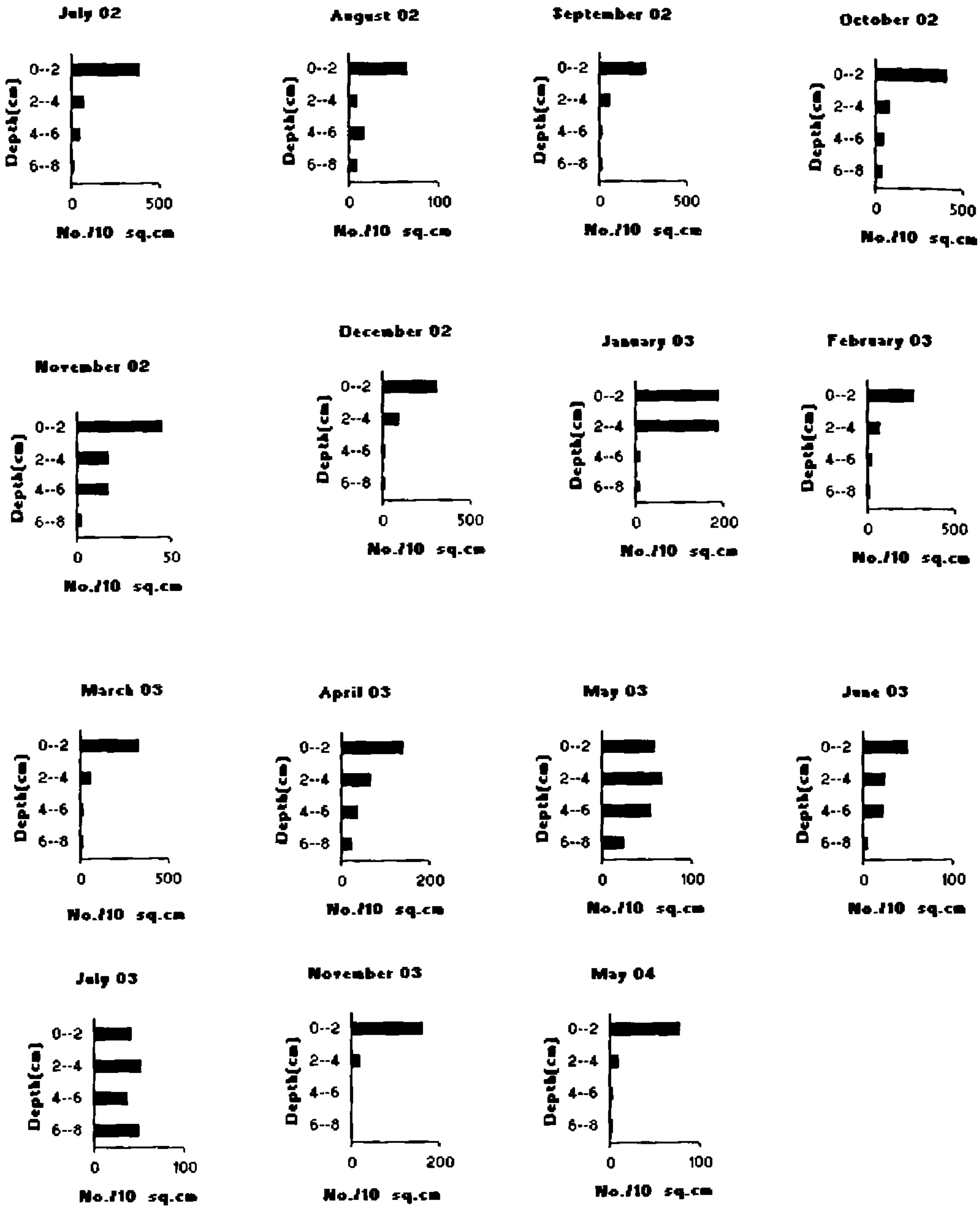


Fig: 6.2.4.Vertical distribution of meiofauna down to 8cm sediment depth at station 4

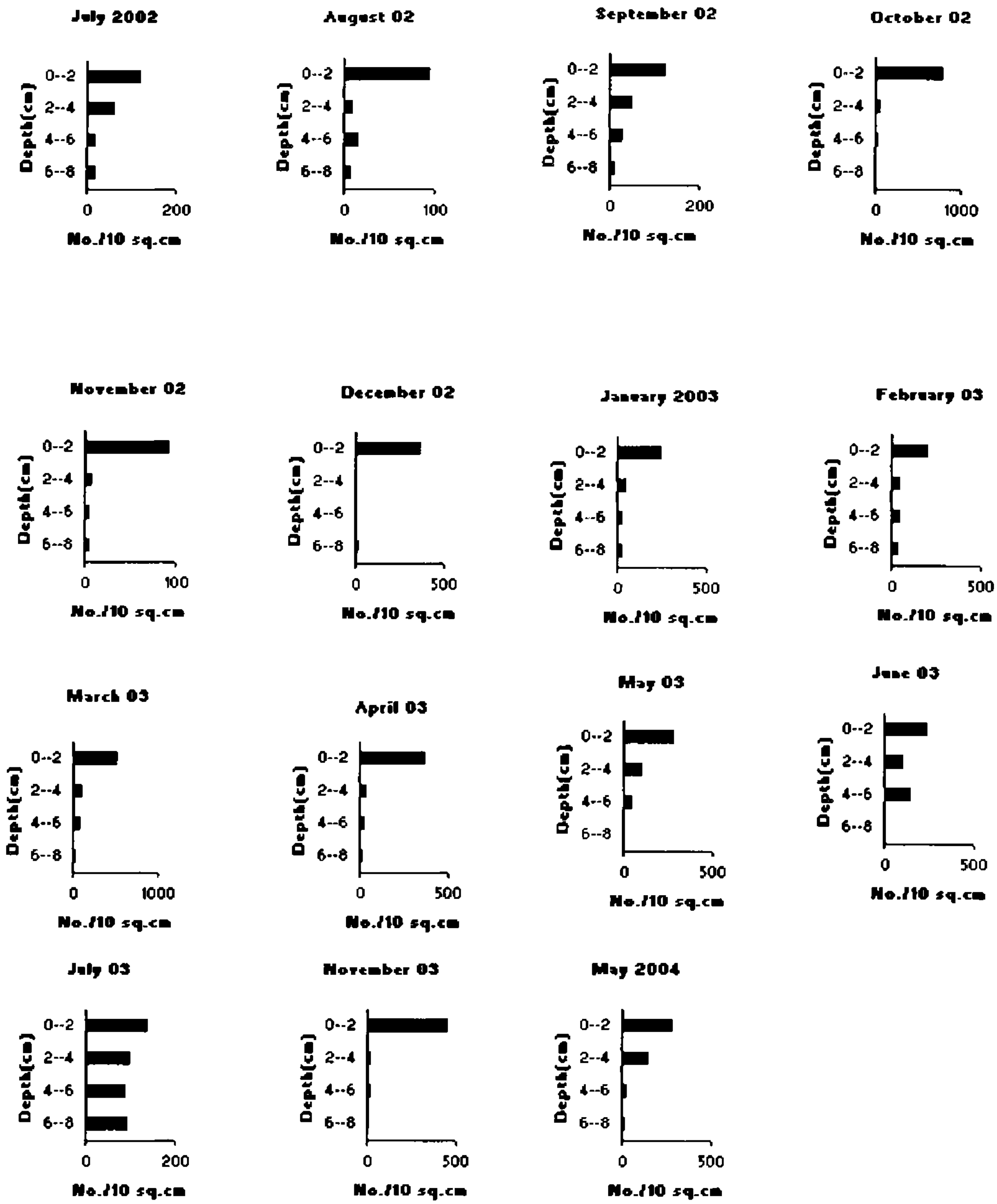


Fig: 6.2.5.Vertical distribution of meiofauna down to 8cm sediment depth at station 5

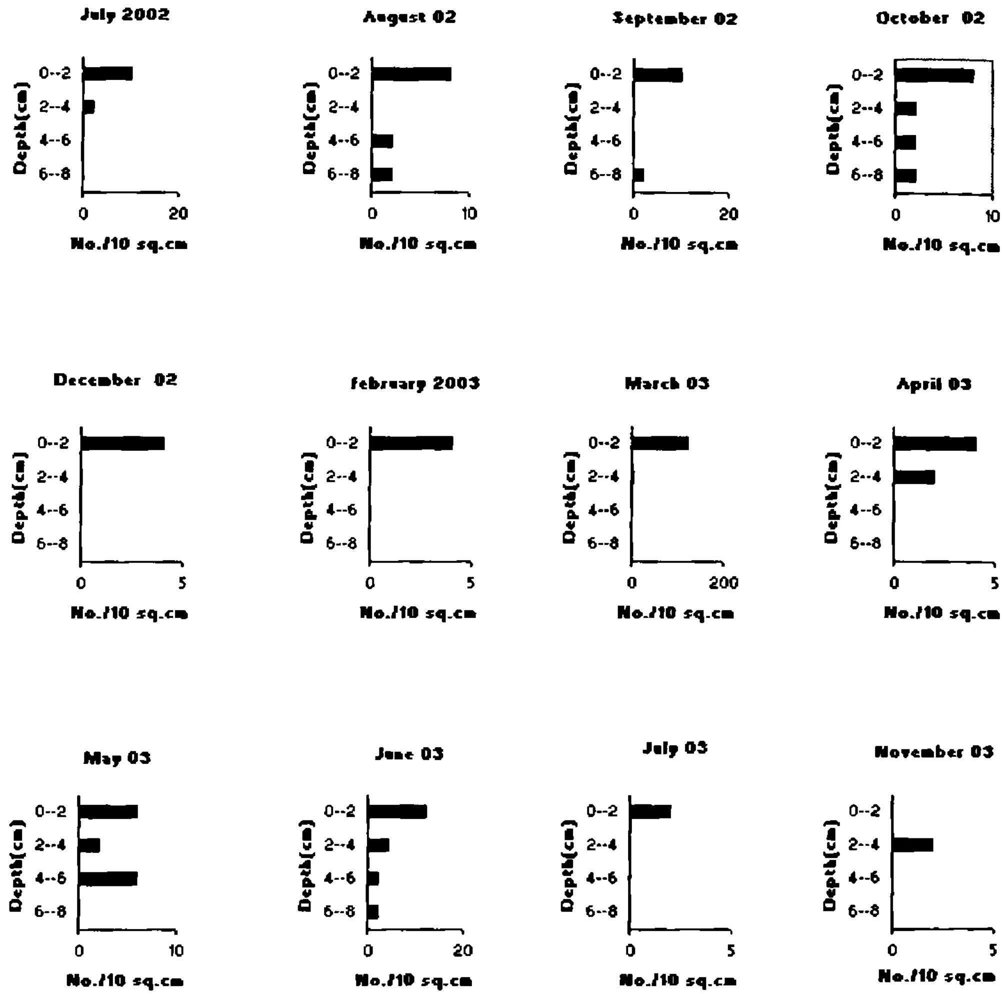


Fig: 6.2.6.Vertical distribution of meiofauna down to 8cm sediment depth at station 6*

*November 2002, January 2003 &May 2004 was characterized by complete absence of meiofauna

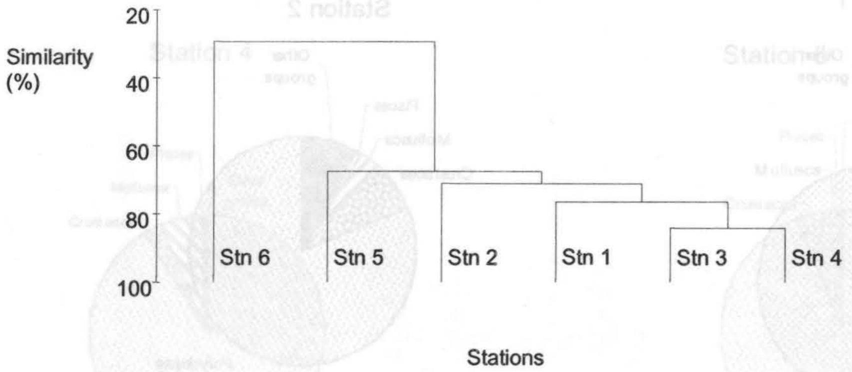


Fig: 7.1 Dendrogram for stations 1 to 6 based on the abundance of nematodes

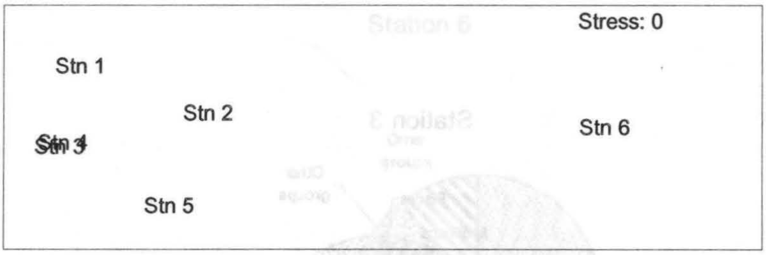


Fig: 7.2 MDS ordination for stations 1 to 6 based on the abundance of nematodes.

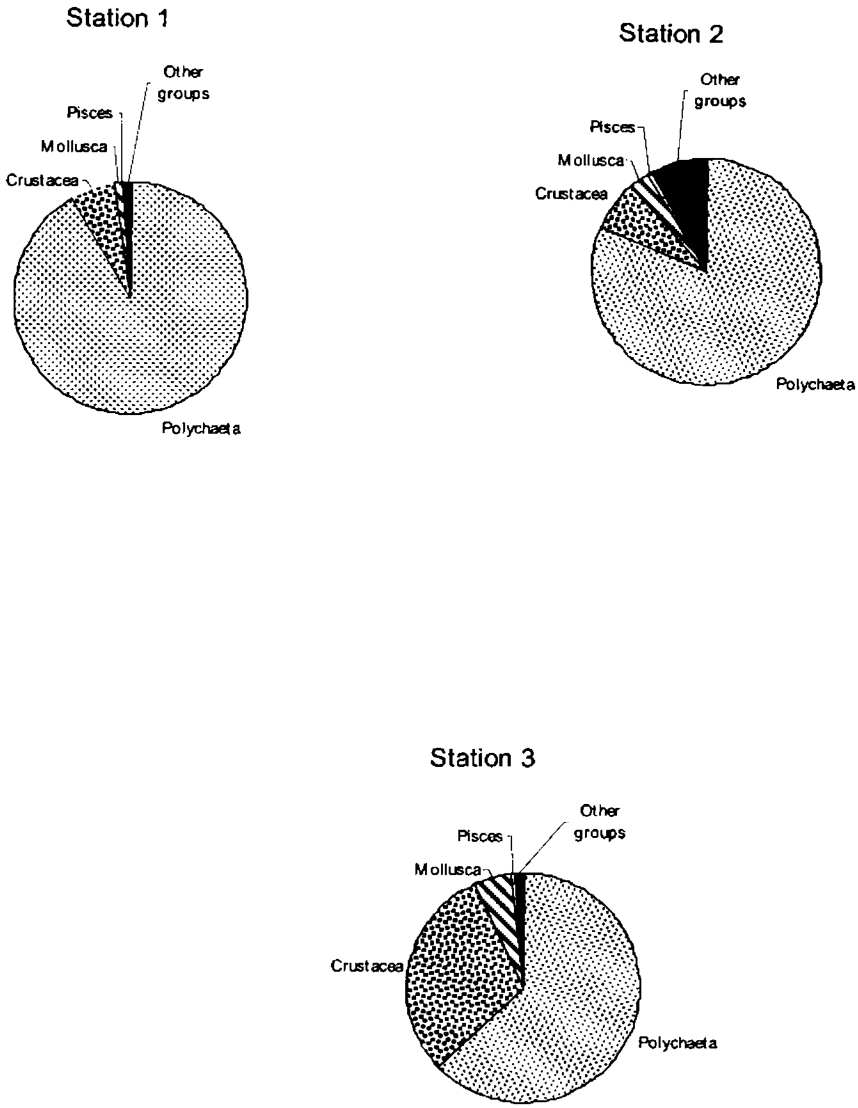


Fig: 8.1.1. Percentage composition of macrofauna at stations 1 to 3

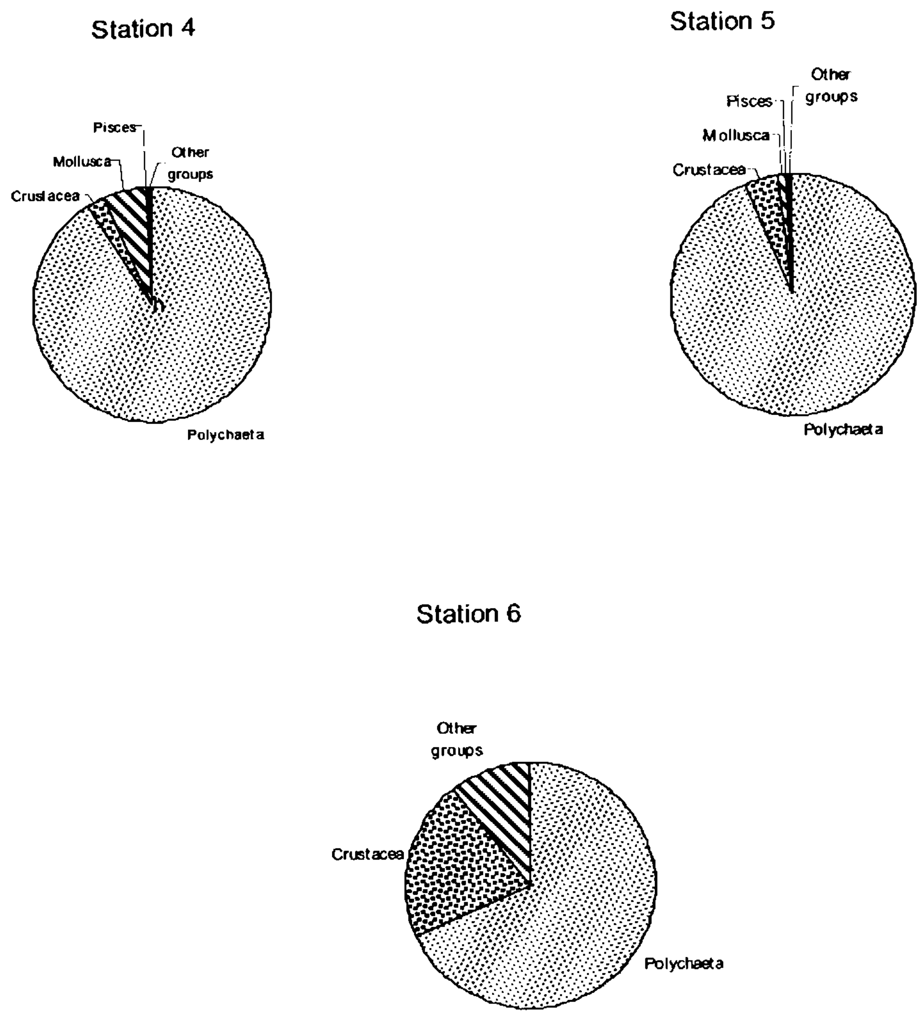


Fig: 8.1.2. Percentage composition of macrofauna at stations 4 to 6.

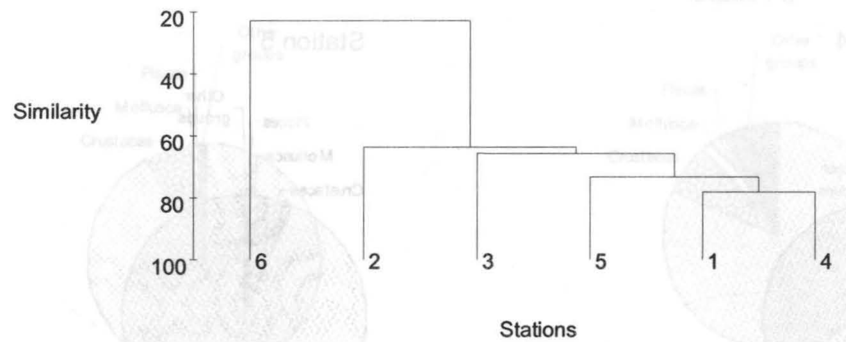


Fig: 8.2. Dendrogram for stations 1 to 6 based on the abundance of macrobenthos

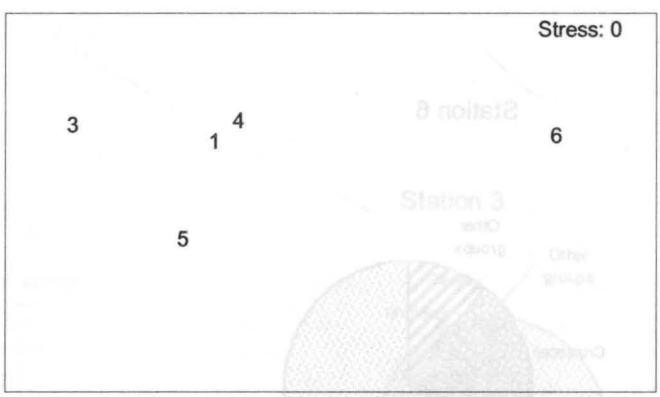


Fig: 8.3 MDS ordination for stations 1 to 6 based on the abundance of macrobenthos

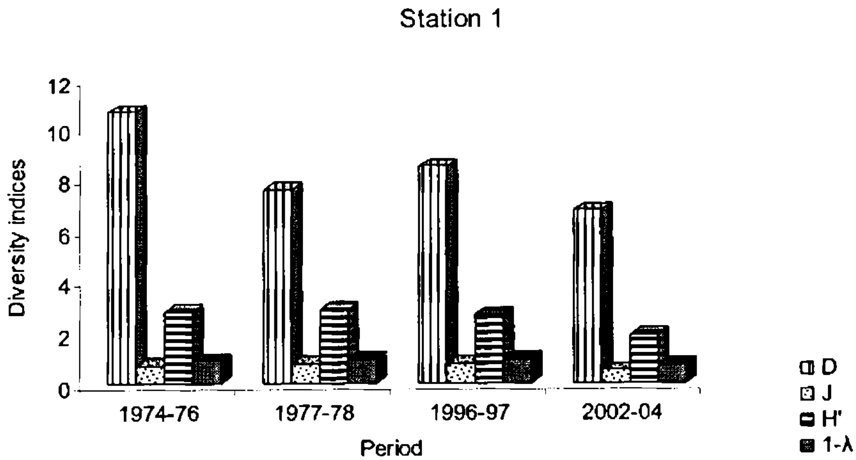


Fig: 10.1.1.

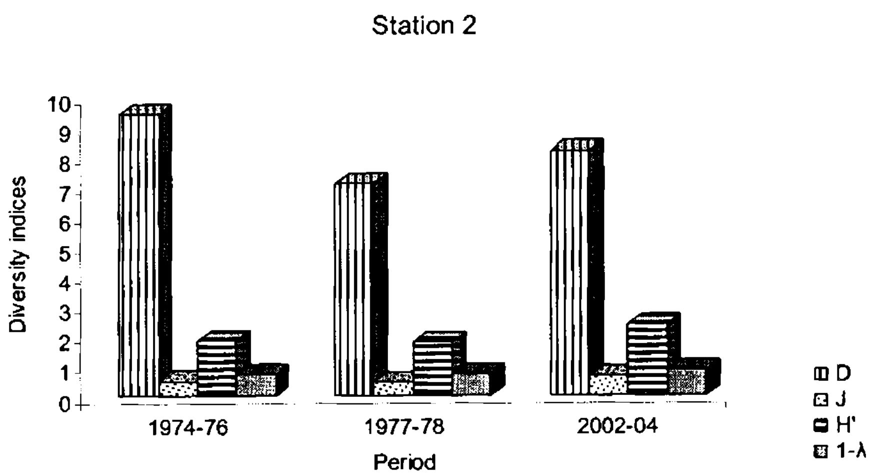


Fig: 10.1.2.

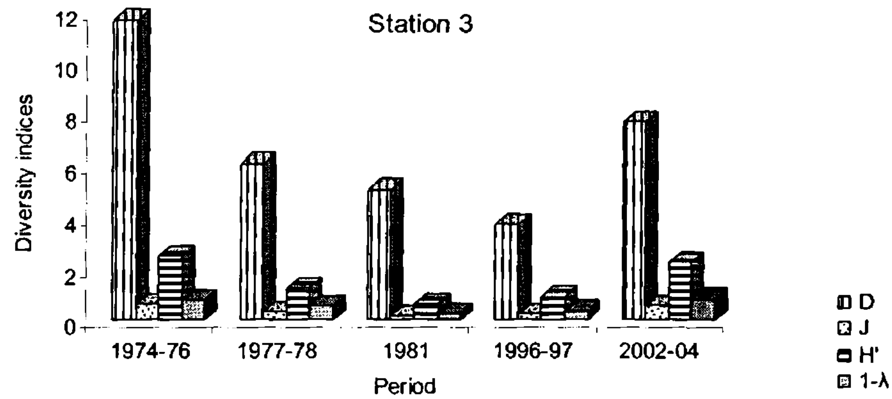


Fig: 10.1.3.

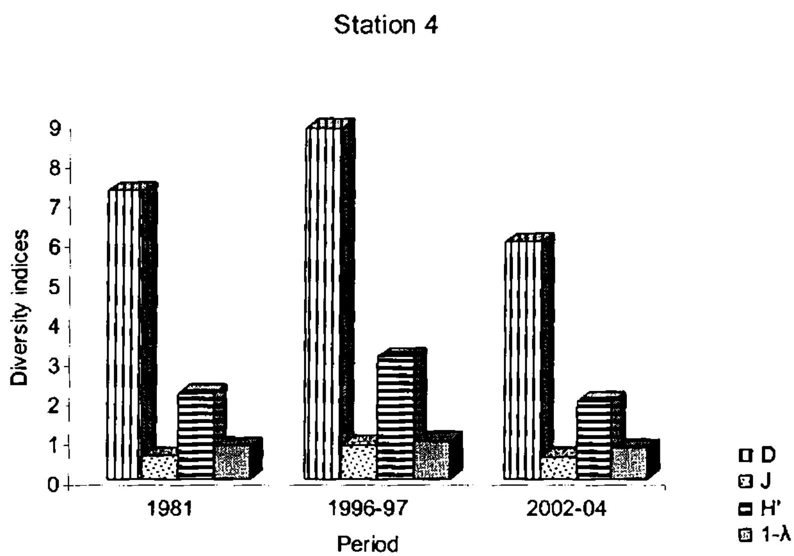


Fig: 10.1.4.

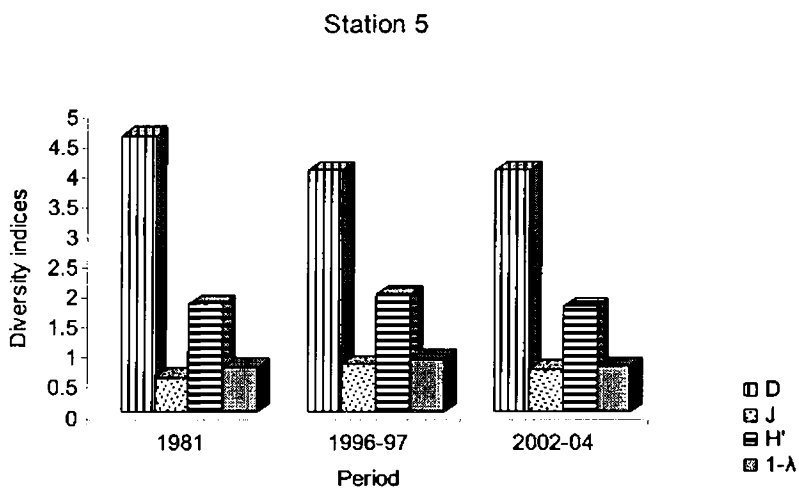


Fig: 10.1.5.

Fig:10.1.1-10.1.5.Diversity indices for macrobenthos during the period 1974 to 2004.

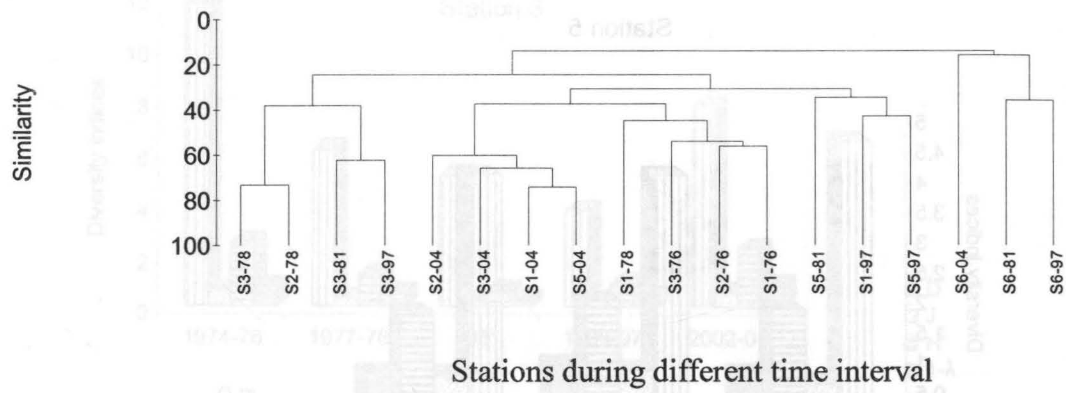


Fig:10.2 Dendrogram of Cochin backwaters during the period 1976-2004

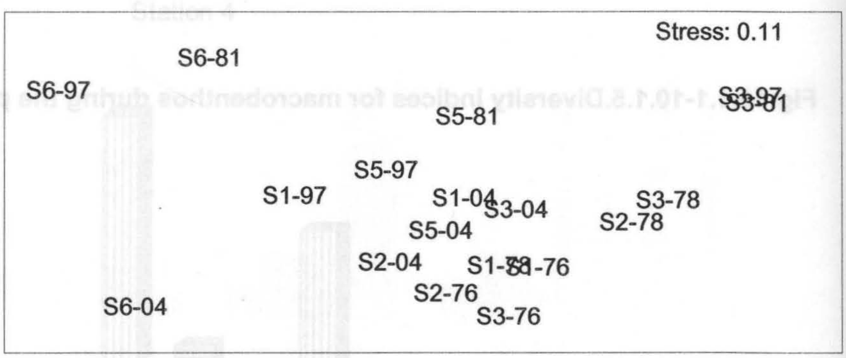
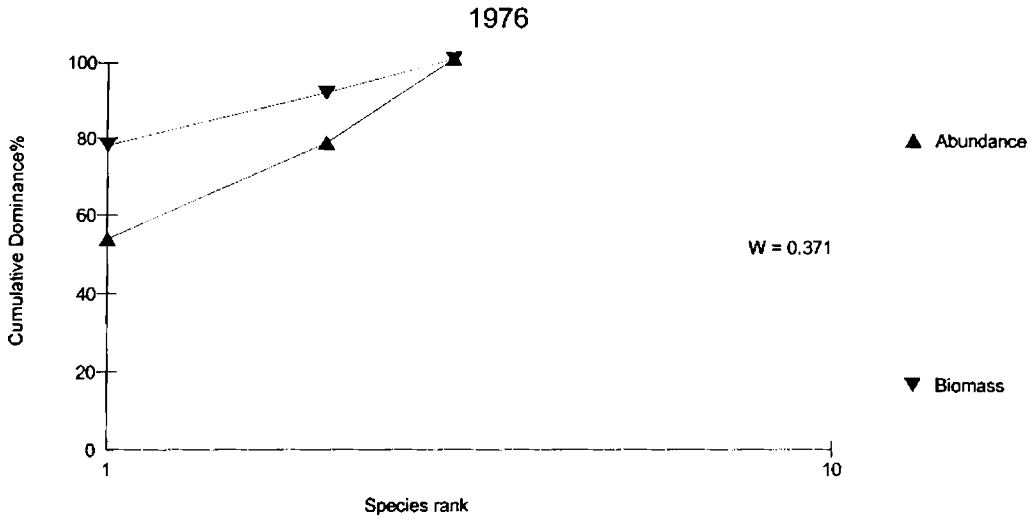


Fig: 10.3 MDS ordination of Cochin backwaters during the period 1976-2004



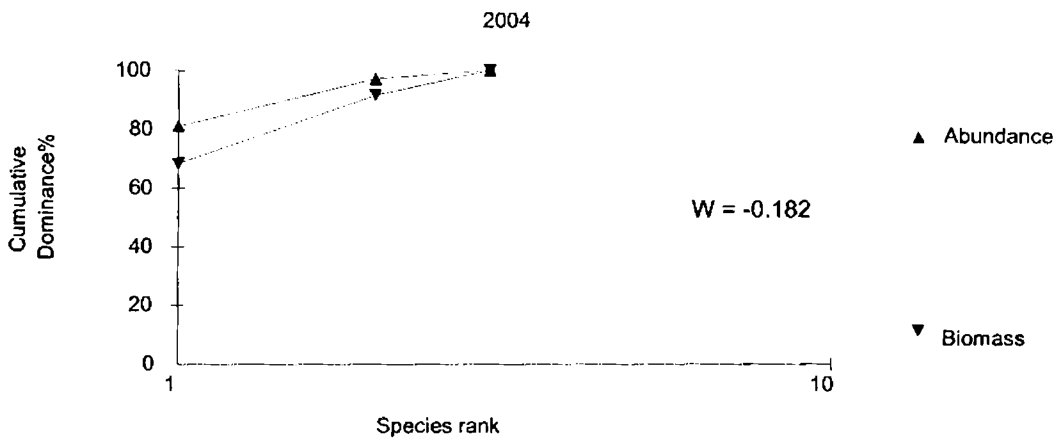


Fig:10.4 ABC PLOT for macrobenthos in Cochin backwaters during the period 1976 and 2004

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