Study of Intertidal Fauna of Thane Creek

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Mr. Goldin I. Quadros
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STATEMENT BY THE CANDIDATE

As required by the University ordinances 770 and 771, I wish to state that the work embodied in this thesis titled " Study of Intertidal Fauna of Thane creek." forms my own contribution to the research work carried out under the guidance of Dr. R.P. Athalye at the B. N. Bandodkar College of Science, Thane. This work has not been submitted for any other degree of this University or any other University. Whenever reference have been made to previous work of others, it has been clearly indicated as such and included in the Bibliography.

Date :
Place :

Mr.Quadros Goldin Ignatious.
(Signature of the candidate)

The above statement made by the candidate is correct.

Date :
Place :

Dr. R.P. Athalye
(Signature of the Guide.)

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Contents

Introduction

The earth is called a ‘Watery planet’ because about three-quarters of its surface is covered by water; 97 % of which is sea water, 2 % is ice, located mainly in the polar regions and the remaining 1 % is fresh and brackish inland waters (Boojh, 1989). The brackish waters comprise of estuaries and creeks that are tidally influenced ecological systems where rivers meet the sea and freshwater mixes with the salt water. These ecosystems, according to Nigam (1988), act as filters between land and the oceans and they influence various processes on the adjoining continental shelf, thus creating a microenvironment near their mouths. Further, the extent of the areas covered under these microenvironments depends upon the amount of freshwater discharge from the estuaries. The estuaries and creeks also influence the fauna. They act as nursing and breeding grounds for many organisms including commercially important fishes and crustaceans.

In the tropical and subtropical coastlines between latitudes 30° N and 30° S, mangroves form the main vegetation type in the protected intertidal areas; are dominant in the marine to freshwater ecotones (Tomlinson, 1986) and grow at the upper intertidal level (Harbison, 1986). According to Ellison & Stoddort (1991), mangroves are taxonomically diverse group of mainly arboreal angiosperms that grow in the sheltered shores of the tropics and show special physiological and morphological adaptations like prop and stilt roots which apart from helping the plant to survive, gradually trap the fine suspended particles in water, leading to accumulation of sediment and formation of mudflats. The tidal flats occupy large and significant areas of estuarine and sheltered coastal ecosystems (Widdows *et al.*, 2000). These ecosystems are regularly inundated by tides and can be divided into three zones, namely the upper intertidal zone (where the mangroves grow) which is submerged mostly during peak tides, the lower subtidal zone that is always submerged under water and the middle intertidal mudflat zone that gets submerged during high tide.

According to Parulekar (1981), the intertidal region is a zone of interaction between the sea, land and air, and is one of the most interesting regions of the marine biota. The inhabitants of this region, due to their diel changes in submergence, exposure and desiccation are known to be hardy and diverse. These inhabitants, according to Heip *et al.* (1995), can play an important role in the metabolic processes and material fluxes within the estuary. The plant litter, mainly leaves, represent about one-third of primary production in mangrove forests and up to half this quantity can be exported via creeks to adjacent waters (Robertson *et al.*, 1992; Dittmar & Lara, 2001). Further, Jiunn (1995) is of the view that apart from mangroves, the mudflats also receive nutrients from other sources, such as terrestrial runoff and estuary outflows, depending on the geomorphology of the basin and tidal amplitude; all of which have a recognisable effect on the food web. According to Qasim (1972), the organisms that form the intertidal life forms can be divided into 3 main groups 1) Plankton – countless minute organisms with no or limited capacity of movement. They drift about in the water and are transported by winds and currents. The unicellular floating plants are called phytoplankton and the drifting swarms of small animals and younger stages of larger animals are termed as zooplankton. 2) Benthos – which include creeping and sedentary animals of the bottom and also the benthic algae and 3) Nekton – that comprise of the actively swimming animals which are brought in by the tidal waters. Among the 3 groups, the benthos is the resident fauna and because of its sedentary or less mobile nature has a lot of significance in assessment of the ecosystem (Pearson & Rosenberg, 1978).

According to Varshney (1982), primary production can provide an immediate index of pollution, while benthic organisms are more or less sessile and reflect not only the conditions at the time of sampling but also the conditions that prevailed earlier. Further Bilyard (1987) stated that analysis of benthic fauna is a key element of many marine and estuarine monitoring programmes. They provide the fundamental data as they are sedentary and respond to pollution stress. Their response to sediment contamination helps to define the quantity and quality of pollution impact. They have the potential to mediate the transfer of toxic substances to higher trophic levels and thereby initiate pathological response in predators. Besides, the benthic infauna are also important mediators of nutrient recycling from the sediments into the water column. Mann (1982) states that in coastal waters, the nutrients regenerated from benthic sediments are a major factor influencing primary productivity. He also suggests that meiofauna and macrofauna are responsible for about 20 % of regenerated nutrients. Over the years, considerable evidence has demonstrated the importance of macro and meiofauna in the estuarine benthos. According to Middelburg *et al.* (2000), macrofauna and meiofauna are well documented for feeding on the benthic algae i.e. microphytobenthos. The microphytobenthos contribute significantly to the total primary production of estuarine and other shallow water ecosystems (MacIntyre *et al.*, 1996; Underwood & Kromkamp, 1999). These benthic algae are an important carbon source for benthic heterotrophs (Herman *et al.*, 1999) and can significantly affect the exchange of oxygen and nutrients across the sediment – water interface (Risgaard-Petersen *et al.*, 1994). According to Parulekar *et al.* (1982), estimates of the benthic abundance are necessary for the assessment of demersal fishery resources as they form an important source of food for the demersal fishes.

In addition to benthos, plankton according to Lodh (1990), form a major link in the energy transfer at primary and secondary level and play a significant role in the production potential of marine environment. To a certain extent the success and failure of fishery, particularly that of pelagic fishery, is dependent on the availability of plankton. Hence the knowledge of plankton is imperative to obtain a comprehensive account of the fishery potential. Lodh (1990) further stated that the pollution monitoring surveys also consider plankton production and diversity as indices to evaluate the biological sensitivity of the area. Further according to Kuo *et al.* (1999), many species found in mangrove habitats are linked directly or indirectly to existing commercial fisheries. Nevertheless, large-scale destruction and modification of mangrove ecosystems has been increasingly reported worldwide, and these disturbances are the cause of great concern.

In marine ecosystem, foodweb is a functionary system which is very sensitive and highly dependant on what happens in the ecosystem (Dybern, 1973). The natural system is often upset due to various reasons of which pollution is a major factor. The ever-increasing human activities result in a steady deterioration of environment. The estuaries, creeks and coastal waters according to Varshney (1982) have been considered as the ideal dumping grounds for the wastes generated from industrial and domestic sectors. Release of the wastes to these water bodies in quantities exceeding their waste assimilation capacity results in pollution. This often completely imbalances the ecosystem by imposing additional stress on the marine life.

In nearly 75 % of the world's tropical and subtropical coastlines, mangrove forests form the common intertidal ecosystems, but they are now disappearing at rates exceeding 1 % per year in many developing countries (Alongi *et al.*, 1998). Further, these intertidal forests, characterized by high rates of net primary production, in most regions are being converted into housing and industrial estates, fields, plantations, aquaculture ponds, and are also used for bottom trawling, extraction of sand and various recreational activities (Jonge *et al.*, 1993; Wulff, 1997; Alongi *et al*., 1998). Ansari *et al*. (1994) observed that the anthropogenic influence alters the ecosystem and the impact is severe in estuaries and creeks adjacent to major cities. The information on the loss of tidal wetlands is important as they are a vital link in the marine energy flow through transfer of solar energy into forms which are readily usable (Odum, 1961), and are responsible for maintaining fisheries not only by way of catch, but as feeding, spawning and nursery grounds. Ninety percent of the world’s marine fish catch (measured by weight) reproduces in these areas (FAO, 1991). Thus according to Nayak (1995), degradation of coastal wetlands can have long term consequences for fish populations. The mangrove forest also serve as buffer for the mainland against ocean storms and protect the coast from erosion. The knowledge about the areal extent, condition and destructive uses of wetlands is vital for coastal management programmes.

Degradation of natural resources is a major environmental issue the world is currently facing (Twilley *et al.*, 1998), and hence to detect the extent of deterioration of these ecosystems constant monitoring is recommended. Among the different aspects studied while monitoring an ecosystem, the study of hydrological parameters has its own importance. It provides first hand information about the short term metabolic events and the chemical interactions taking place in an ecosystem (Quadros, 1995). Hence these studies can be less reliable in the tidally driven dynamic ecosystems like estuaries and creeks. Therefore, it is felt that the study of intertidal fauna along with its associated components would form a better tool in monitoring both short and long term effects of pollution. The benthic fauna is part of all marine ecosystems, and the analysis of its structure is an important tool to describe changes in space (with applications on point source pollution monitoring) and time (with applications on the description of changes in the state of the marine system) (Heip, 1992). Many workers have voiced this view and the ecological studies covering all the aspects of the food web have been frequently monitored from many water bodies around the world. Some of which are Chesapeake bay, Florida bay & estuary, Shark river estuary, Thames river estuary, North Carolina estuaries, Mangrove creeks of Taiwan, Gazi bay, Grevelingen estuary, Biscayne bay, Froth estuary, Delaware bay, Maine estuary, Robin Hood’s bay, New England estuary, Ao Nam Bor mangroves, Marennes-Oleron bay, Hudson estuary, Loire river estuary, Guanabara bay, Buzzards bay, Narragansett bay, Bahia Blanca estuary, Jiulong river estuary, Changjiang estuary, Saldahana bay, Potomac river estuary, Malayasian mangrove estuary, Liffey estuary, Mississippi estuary, Amazon estuary, Zaire estuary, etc.

According to Muniz & Pires (2000), tropical and subtropical coastal systems, comprising more than one third of the world shelf area, are less understood than temperate and high latitude ones, despite their significance. Wiebe (1987), observed that the tropical marine systems have been inadequately studied and in most cases were sampled at rather few sites by short term expeditions. Corroborating with the above, most of the Indian estuaries are infrequently investigated. Along the east coast of India the water bodies that are regularly studied for the entire food chain include Hooghly estuary, Mahanadi estuary, Rushikulya estuary, Gopalpur estuary, Kollidam estuary, Kali estuary, Bahuda estuary, Cuddalore –Uppanar backwaters, Gautami-Godavari estuary, Swarnamukhi river estuary. While on the west coast Cochin backwaters, Visakhapatnam harbour, Nethravati-Gurupur estuary, Mandovi estuary, Zuari estuary, Narmada estuary, Ambica river estuary and Asthamudi Lake estuary are the most frequently studied ecosystems.

The present dissertation deals with the Thane creek that lies on the central west coast of India. The literature surveyed reveals that the creek has been extensively studied by various organizations like BARC, CPHERI, NIO, NEERI, etc. The aspects that were frequently analysed include hydrology, phytoplankton, zooplankton, fishery, subtidal benthos, mangroves and associated saltpans. However, the studies on the intertidal mudflats are meager, mainly due to difficult access to the mudflats. Athalye (1988), Mukherjee (1993), Gokhale & Athalye (1995), Kotibhaskar (1998) and Venkatachalam (1999) have reported the intertidal benthos from the 5 km stretch near Thane city. Hence, the lack of data on the intertidal benthic fauna of the entire stretch of the creek and the realization of the importance of its study in association with the ecological aspects emphasized the need for the present study.

Thane creek (Long. 72°.55’ to 73°.00’ E and Lat. 19°.00’ to 19°.15’ N) is 26 km long. It is connected to the Mumbai harbour on its south and joins by a minor connection with the Ulhas river on its north near Thane city (Plate 1). Geologically, the Mumbai – Thane region is part of the deccan trap that was formed by volcanic effusions at the end of the cretaceous period (Blasco, 1975; Tandale, 1993). Primarily, both the south and north connections of Thane creek isolate the Mumbai (Bombay) island from the mainland. The creek is narrow & shallow at the riverine end due to the presence of the geomorphic head and broader & deeper towards the sea.

Thane creek being tropical in location (Lat. 19° N), winter is not severe, and 3 seasons can be distinguished viz., monsoon (June to September), post monsoon (October to February) and pre monsoon (March to May). The creek is tidally influenced with dominance of neritic waters and negligible freshwater flow except during the monsoon. The substratum of the creek in the mid stream is made up of consolidated and unconsolidated boulders intermingled with loose rocks and rarely with sand and gravel. Extensive mudflats are formed along the banks of the creek which are characterized by the growth of mangroves.

Total of 10 mangrove species were recorded along the creek including, *Avicennia marina, Avicennia officinalis, Avicennia alba, Ceriops tagal, Bruguiera cylindrica, Bruguiera gymnorhiza, Aegiceras corniculatum, Sonneratia apetala, Sonneratia caseolaris & Excoecaria agalocha*. While the mangrove associate species included *Acanthus illicifolius, Aeluropus lagopoides, Sesuvium protulacastrum, Salvadora persica Derris trifoliata, Ipomea spp., Typha spp., Clerodendron spp. ,etc. Avicennia marina and Acanthus illicifolius* were the dominant species through out the creek, while *Sonneratia apetala* was more prominent at the riverine end. The presence of mangroves along both the banks has made Thane creek a highly productive ecosystem.

According to the local fishermen a few decades ago, Thane creek provided excellent catch of commercial fish and crustaceans, which in the recent years has dwindled to a bear minimum. This decline in fishery was mainly attributed to heavy industrialization and urbanization that has taken place along both the banks of the creek. On the east bank exist Asia's largest industrialized zone namely Thane –Belapur industrialized area along with the Navi-Mumbai Urban area. While the west bank has the highly urbanized Mumbai & Thane regions along with a good number of industries. According to TMC – ES report (2000), there are about 2000 industries along the creek of which 51 are large, 250 medium and 1221 small industries. Among the industries, 10 % are chemical industries, 63 % engineering, 4 % textile & pharmaceutical and others 23 %. Moreover the human population in Thane city alone has doubled in the past 10 years. Such an extensive industrialization and urbanization along the creek has adversely affected it. Gajbhiye *et al.*(1981) reported Thane creek to receive 27 mld. of industrial waste water and 6 mld. of sewage waste, which increased to 180mld. and 350 mld. respectively (Annie Mathew, 1989). While the TMC – ES report (2000) quotes 294. mld and 145 to 260 mld industrial waste and domestic sewage waste release respectively in the creek within the Thane city limits. Not only the domestic and industrial effluents are released in the creek but since 1995 the creek is also being indiscriminately used as a dumping ground for huge quantity of solid wastes. These alarming statistics indicate the detrimental state of the creek. For such ecosystem which is under significant stress of anthropogenic activities, careful and continuous monitoring of different ecological aspects is necessary so as to assess the status and impact of pollution. Such studies will help in deciding the preventive & remedial measures and also the effectiveness of implemented measures in due course of time. The present investigation aims at studying the impact of pollution and assessing the present productivity of the creek by analyzing the intertidal fauna of the creek.

Materials & Methods

The study was conducted for one year, from May 1999 to April 2000 during the neap tide phase. 12 stations (Plate1) along the 26 km stretch of Thane creek were selected (5 on the east bank and 7 on the west bank). According to Miller and Ambrose (2000) species are rarely dispersed uniformly in nature, hence the ecological field studies should be designed accordingly. In the present study while selecting the stations due care was taken so as to depict and represent the creek in totality. The profile of the sampling stations is as follows.

Station 1 – (Near Dadalani village) This station is situated at the extreme northern end of Thane creek at the junction of the creek and the Ulhas river and is on the west bank. It was characterized by dominance of mangrove *Sonneratia apetala* followed by *Avicennia marina* and a thick growth of *Acanthus illicifolius* as back mangrove. *Sonneratia apetala* and *Avicennia marina* had a maximum height of around 3 m., while *Acanthus illicifolius* reached a height of 2 m. The mangroves were mostly covered by the climber plant *Derris trifoliata.* The mudflats in this region were narrow (maximum width from the midstream upto 10 m.) The mud was sticky, brown in colour, moderately hard, non sinking type. This station receives maximum amount of freshwater from the Ulhas river estuary and the water depth during high tide was approximately 3.5 m.

Station 2 – (Near Kharegaon village) This station is on the east bank & is situated about 1.5 km downstream of station 1, with similar mangroves as station 1 growing up to a height of 5 m. The mudflats of this station were about 15 m wide from the midstream, black in colour, soft and sinking type. The distance between the opposite banks during the peak high tide was barely 100 m. And the water depth about 3 m. This station faced a large amount of anthropogenic pressure in terms of human interference, sewage and solid waste disposal.

Station 3 – (Near Thane railway bridge) This station is located on the west bank of the eastern mainstream of the creek and is about 2 km downstream of station 2. This station is in the viscinity of a municipal hospital and is a recipient of large amount of domestic waste. The mudflats at this station were barely 5 – 7 m in width with a rocky substratum and the mangroves at this station were mostly stunted with a maximum height of 2 m. The maximum water depth during high tide was 2.5 m.

Station 4 – (Near Vitawa village) This station is located 2 km downstream from station 3 on the east bank. The mudflats of this region were gradually sloping, soft and sinking type with a maximum width of 30 m. The soil colour varied from green-black to brown to green-brown. *Avicennia marina* was the dominant mangrove about 3 – 4 meters in height. The maximum water depth during high tide was about 5 m. The station is also influenced by anthropogenic activities and domestic sewage.

Station 5 – (Near Thane saltpans) This station is on the west bank about 2 km downstream of the 4^{th} station and in close proximity to a prominant sewage out let. The mudflats of this region were soft, sinking type, black in colour and always gave a foul odour due to decomposing organic matter, the width of the mudflat was around 30 – 35 m. *Avicennia marina* was the dominant mangrove species, with a maximum height of about 2 m. The maximum water depth during high tide was around 6 m.

Station 6 – (Near Airoli village) This station is located on the east bank about 2 km downstream of station 5. This station was characterized by dominance of *Avicennia marina* reaching a maximum height of about 4 m. and very few stands of *Sonneratia apetala* which were short in height. The mudflats were soft & sinking, brown in colour, gradually sloping type with a width from the midstream of around 75 m. This station receives effluents from the residential and industrial areas of Airoli region.

Station 7 – (Near Bhandup saltpans) The station is 3 km down stream of station 6 and is located on the west bank. There are 2 sewage outlets in close proximity of this station. It was characterized by the dominance of *Avicennia marina* that had a height of 3 m. The mudflats were about 75 – 80 m in breadth, black-brown in colour and with very soft sinking type of mud. The maximum water depth during high tide was around 9 –10 m.

Station 8 – (Near Ghansoli village) This east bank station is about 2 km downstream of station 7. The mudflats were large and wide extending about 150 m from the low level water mark to the high level water mark and had a gradual slope. At high level water mark there were tall trees (av. height 5 m.) of *Avicennia marina* & *Sonneratia spp*. whereas on the outer side of them there was thick growth of *Acanthus illicifolius*. The mud was sticky & hard due to many dead molluscan shells and non sinking type. The water depth during high tide was around 6 – 7 m. There is no effluent source in the near by viscinity of the station.

Station 9 – (Vikhroli – Godrej area) This is 2 km downstream of station 8 and is on the west bank. The mud flats at this station were broad (125 m) with a steep slope, probably due to faster currents. The mud was sticky, soft & sinking type. At high level water mark *Avicennia marina* was the dominant species with an average height of about 3 meters. Water depth was approximately up to 10 m. There are effluent outlets from Bhandup & Vikhroli in the viscinity. At high level water mark deposition of oily matter on the tree stems could be observed.

Station 10 – (Near Koparkhairne village) This station is on the east bank and approximately 2 km downstream of station 9. The water column height at high tide was about 5 m. The station is influenced by the sewage / effluent outlets from Belapur & Navi- Mumbai region. At this station the mudflats were broad (250 m), shallow with a gradual slope. *Avicennia marina* was the dominant species with a maximum height of 5 m.

Station 11 – (Near Ghatkopar-Mankhurd region) This is located on the west bank of the creek & is 2 Km downstream of station 10. The mudflats had a gradual slope with a breadth of around 125 m. At high tide level mark *Avicennia marina* of about 3 – 5 m height were observed. The mudflats were soft and dangerously sinking type. The water depth at high tide was 10 meters. Deonar sewage nallah opens in this region.

Station 12 – (Trombay region) The last station on the southern end of the creek on its west bank, located near to the Mumbai harbour. This station has high human interference as it is also the landing site for fishery collected from the Thane creek and Mumbai Harbour. The mudflats were soft, sinking type, with a breadth of around 100 m. The mangroves were about 3 – 5 m in height with dominance of *Avicennia marina*. The maximum water depth during high tide was 15 m.

During the present investigation the different aspects studied of Thane creek include water, sediment, phytoplankton, zooplankton, microphytobenthos, meiobenthos, macrobenthos, gut contents of different organisms, birds, and fishes of the intertidal region. International Standard methods as suggested by Holme (1964); APHA, AWWA, WPCF (1981); Trivedi & Goel (1984) and Rumohr (1999) were used during the study. The parameters and methodology employed is listed below.

a) **Water / Hydrological studies** : Surface water samples were collected monthly, using clean plastic buckets during neap high tide and neap low tide and the following parameters were analysed.

Parameters	***Method***
Temperature °C	0 to 110° C alcohol thermometer
Light penetration cms.	20 cm diameter Secchi disc.
Suspended solids gm/l	Evaporating known volume of filtered and unfiltered samples at 70° C till constant weight.
pH	Bielectrode 'Systronics' pH meter.
Salinity ppt.	Argentometric method
Dissolved oxygen mg/l	Wrinkler's method
Inorganic Phosphorus mg/l	Ammonium molybdate method
Nitrate-Nitrogen mg/l	Phenol disulphonic acid method.
Silicate-Silicon mg/l	Molybdo-silicic acid method.

b) **Sediment** : Monthly soil samples were collected from the 12 stations using a metal scoop of 0.01 m^2 (10cm x 10cm) dimension. The samples were oven dried at 70° C and analysed for the following.

Parameter		***Method***
pH	1 : 5 soil solution	bielectrode 'Systronics' pH meter.
Redoxpotential Eh		bielectrode 'Systronics' pH meter
Chlorides %		Argentometric method
Organic carbon %		Walkley and Black method
Available phosphorus %		Ammonium molybdate method
Total Phosphorus %		Ammonium molybdate method
Total Nitrogen %		Kjeldhal distillation method
Soil texture %		Buchanan's pipette method
Moisture content %		Oven drying 100 gm soil sample at 70° C.

c) **Phytoplankton** : samples for phytoplankton analysis were collected from all the 12 stations during neap high tide and neap low tide. A sample volume of 500 ml was collected using a wide mouth container from a depth 1 foot from the surface.

For immediate fixation, Lugol's iodine solution was used in the field and later 4 % formaldehyde was used for long term preservation.

The phytoplankton were concentrated, identified using standard keys (Caljon, 1983; Bellinger, 1992 and Tomas, 1997).and counted for different genera using the haemocytometer method and calculated using the following formulae.

$$\text{Phytoplankton, units / ml} = \frac{\text{Number of phytoplankton in central chamber} \times 10^4}{\text{Concentration factor.}}$$

$$\text{Concentration factor} = \frac{\text{Total volume of the water concentrated}}{\text{Final volume made after concentration.}}$$

d) **Zooplankton** : The sample collection for the quantitative study of zooplankton was done by using a 30 number plankton net (41μm mesh size). The net was towed for a fixed time of 5 minutes during the neap high tide. As the current meter was not available, a float was devised and current speed was recorded in meters per second. Total water filtered was computed with the help of the current speed and the volume of the sampling net. The filtered zooplankton samples were collected and preserved in 10 % formaldehyde solution prepared in filtered creek water.

The entire sample was observed for rare and common groups. The zooplankton count was done for abundance by observing subsamples under compound microscope, and the number / ml was calculated. Standard keys were used in identifying the zooplankton groups (Wimpenny, 1966; Krishnapillai, 1986; Battish 1992 and Santhanam & Srinivasan, 1994).

Due to practical difficulties the zooplankton samples were not collected from all the stations, instead the creek was divided into 5 zones for zooplankton analysis viz Zone 1- stn. 1 to stn 3; Zone 2- stn. 3 to stn 6; Zone 3 – stn 6 to stn.9 Zone 4 – stn 9 to Stn 11 and Zone 5 – stn.11 to stn 12..

e) **Microphytobenthos** The sampling was done from all the stations during neap low tide using a spatula. 5 random soil surface samples measuring 1 cm^2 were collected. The samples were fixed in Lugol's iodine in the field and later in 4 % formaldehyde solution. The microphytobenthos were observed under the compound microscope by taking subsamples and cells/ cm^2 were later calculated (Wulff, 1999).

f) **Meiobenthos** : Soil samples were collected during the neap low tide up to a depth of 10 cm using a core of 2.5 cm diameter. The samples were collected and fixed in 1 : 500 rose bengal formalin (Tiegtan, 1969) and preserved in a plastic container (McIntyre & Holme, 1971). In the laboratory the samples were passed through 2 seives, first through 0.5 mm followed by 62 μm sieve to separate the macrobenthos and collect the meiobenthos. The sieved meiobenthos were observed under microscope and separated into broad categories such as nematoda, oligochaeta, polychaeta, foraminifera, etc. The abundance and biomass of each category was expressed in number per meter square (no/m^2) and gram per meter square wet weight (gm/ m^2 wet wt.) respectively.

g) Macrobenthos : According to Bourget & Missier (1983) and Sunita Rao(2000) the benthic diversity and abundance is maximum in the low tide to the mid tide zone due to the presence of optimum environmental conditions. Hence the soil samples in the present study were collected from the low tide mark (Low level water mark) to a little over the mid tide mark (Mid level water mark) from all the stations. The collection was done from 10 cm depth surface soil with the help of 10 cm x 10 cm metal scoop (Kiceniuk & Williams, 1987). 5 scoops were randomly collected and pooled together. 10 % $MgCl_2$ was used to narcotize the macrofauna in the soil samples to prevent its fragmentation. The sediment was then drained through a sieve of mesh size 0.425 mm (Bachelet, 1990). The fauna collected on the sieve was preserved in 10 % formalin prepared in creek water. The preserved samples were later separated, identified, counted and biomass was recorded for individual organisms. The results are expressed in number / meter square and gram (wet weight) / meter square for abundance & biomass respectively. For mollusca, shell free wet weight was estimated for biomass. For this purpose, the shells were dissolved using dilute (1 %) HCl.

The following personnel helped by identifying of the macrofauna up to species level.

Mollusc – Mr. S.C. Mitra (ZSI- Calcutta) and Mr. Deepak Apte (BNHS- Mumbai)

Sea anemones – Dr.Daphne Fautin, Adorian Ardelean & Dr. Meg Daly (University of Kansas , U.S.A.)
Polychaetes - Dr. R.P. Athalye (B.N.Bandodkar College of Science, Thane).

h) **Fish** : The fish samples were collected seasonally from the local fishermen, from the riverine and seaward end. The fishes were identified using standard key (Day, 1874).

i) **Birds** : The birds from the entire 26 km stretch were observed using binoculars during field the visits. However for the dissertation, only those birds that settled on the intertidal mudflats, inhabited the intertidal waters or rested up to 1m on poles or dead branches lying in the intertidal region are reported.

j) **Gut contents** : The gut contents of the representatives of macrofauna, meiofauna, and fish collected during the present study were observed under the microscope. The methods suggested by Tandel *et al.* (1986) for fishes, were employed in the analysis of the gut contents.

Statistical & biological indices

Apart from the simple graphical comparisons, statistical methods were also used to interprete the data.

The mean (X), Standard deviation (S.D.) and simple correlation coefficient (r) were calculated using the computerized Excel statistical package. The simple correlation coefficients between different parameters were calculated for the entire data set (i.e. 144 paired observations) except for zooplankton where the monthly averages were used (i.e. 12 paired values). The significance of the correlation was tested at 5% level of significance.

Diversity indices : Correlations between the inhabitants of an ecosystem with the environmental parameters including pollution are crude ways of assessing a community (Athalye, 1988). Further in a vast data the various interpretations would lack brevity and precision. Hence it is necessary to use other analysis methods such as species diversity indices, etc to integrate all the aspects. For the present dissertation the diversity indices were calculated using PRIMER computer software package. The indices calculated are as follows.

1. N 0 – This is the simplest of all the indices and indicates the total number of species occurring at a location in a sample.
2. N 1 – is the number of abundant species in a sample and is calculated by the formula

   $N\,1 = e^{H'}$ where H' is the Shannons' index (discussed below).
3. N 2 – is the number of most abundant species in a sample calculated using the formula

   $N\,2 = 1/\lambda$ where λ is the Simpsons' index (defined below).

   All the above three i.e. N 0, N 1 & N 2 are also called as Hill's numbers.

4. Simpsons' index (λ) varies between 0 to 1, it gives the probability that two individuals drawn at random from a population belong to the same species. In simple words, if the probability is high that both individuals belong to the same species, then the diversity of the community sample is low.

   Simpsons' index is calculated by the following formula

$$\lambda = \sum_{i=1}^{S} \frac{n_i(n_i - 1)}{n(n-1)}.$$

   Where n = the total number of individuals,

   n_i = number of individuals of the i^{th} species,

   S = total number of species..

5. Shannons' index (H') measures the degree of uncertainty for S number of species and N number of individuals of the species. The index comes to zero when there is only one species in the community and it is maximum when all species are in equal number. This index is calculated as

$$H' = \sum (p_i \ln p_i) \ ;$$

Where,

$p_i = n_i / N.$

n_i = total number of individuals of a species.

N = Total number of individuals of all species.

6. Richness index is based on the relationship between the number of species 'S' and the total number of individuals 'n' where in 'S' increases with increasing sample size 'n'. The two well-known richness indices are as follows.

   Margalef richness index (1958)

$$R\,1 = \frac{S - 1}{\ln(n)}$$

7. Menhinick richness index (1964)

$$R\,2 = \frac{S}{\sqrt{n}}$$

The Margalef index (R 1) comes to zero when the community has only one species while Menhinick's index (R 2) gives some value in every case.

8. Evenness index : when all species in a sample are equally abundant, it seems intuitive that an evenness index should be maximum and decrease towards zero as the relative abundances of the species diverge away from evenness.

   An evenness index should be independent of number of species in the sample. Hence it is reasonable that regardless of the number of species present the evenness index should not change. Of the 5 evenness indices E 1, E 2 & E 3 are very sensitive to species richness & hence number of species present in a community should be known when computing them. The evenness index E 4 proposed by Hill (1973) is the ratio of N 2 to N 1, wherein as the diversity of a community decreases, E 4 converges towards the value of one. Alatalo (1981) modified Hill's ratio (E 5) and showed that it approaches zero as a single species becomes more and more abundant in a community (unlike E 4 which approaches one). This is clearly a desirable property for an evenness index & hence E 5 is preferred over the other evenness indices. In the present study also E 5 was calculated using the following formula.

$$E\,5 = \frac{1/\lambda - 1}{e^{H'} - 1} = \frac{N\,2 - 1}{N\,1 - 1}$$

(λ, H', N 1, N 2 in the formulae are discussed above.)

Biological indices : along with the statistical diversity indices the biological indices also help in correctly depicting the status of an ecosystem. In the present dissertation various biological indices are used which are as follows.

1. Palmer’s Algal genus index: Palmer (1969) has given a list of pollution tolerant genera and assigned a number to each of them depending on their relative tolerance. An algal geneus is said to be present when its 50 or more individuals are present in one ml of the sample. This way, the presence of pollution tolerant genera is decided and a total of their assigned number is calculated.
   A score of 20 or more for a sample is an indication of high organic pollution. A score between 15 – 19 is taken as probable evidence of high organic pollution. Lower figures indicate that the organic pollution is not high enough.

   This index has been employed for phytoplankton and microphytobenthos in the present study.

2. Nematode to copepod ratio : Rafaelli & Mason (1981) have proposed that the ratio of abundance of nematodes to copepods in marine sediments is a sensitive index to evaluate marine pollution. They showed that the overall ratio of nematodes / copepods increases with increasing degree of pollution due to the reduction of the denominator (copepods) with pollution. They generalized that a value over 100 would indicate organic pollution.
   This index has been used in the analysis of meiobenthos.

3. Lambshead *et al*. (1983) introduced into ecology an apparently easily applicable method to assess stress through pollution, the ‘K – dominance method’. This was later simplified by Warwick (1986) and renamed as ABC – method, indicating that it relates abundance to biomass in two comparative curves.
   For obtaining these curves the abundance and biomass of benthic organisms are arranged in an increasing order and ranked accordingly. The percentage is calculated and the cumulative percent is plotted on the log scale as per the rank. Depending on the curves obtained the ecosystem can be termed as unpolluted,

moderately polluted and grossly polluted. For easy understanding he further plotted the hypothetical curves as shown in the figure ahead.

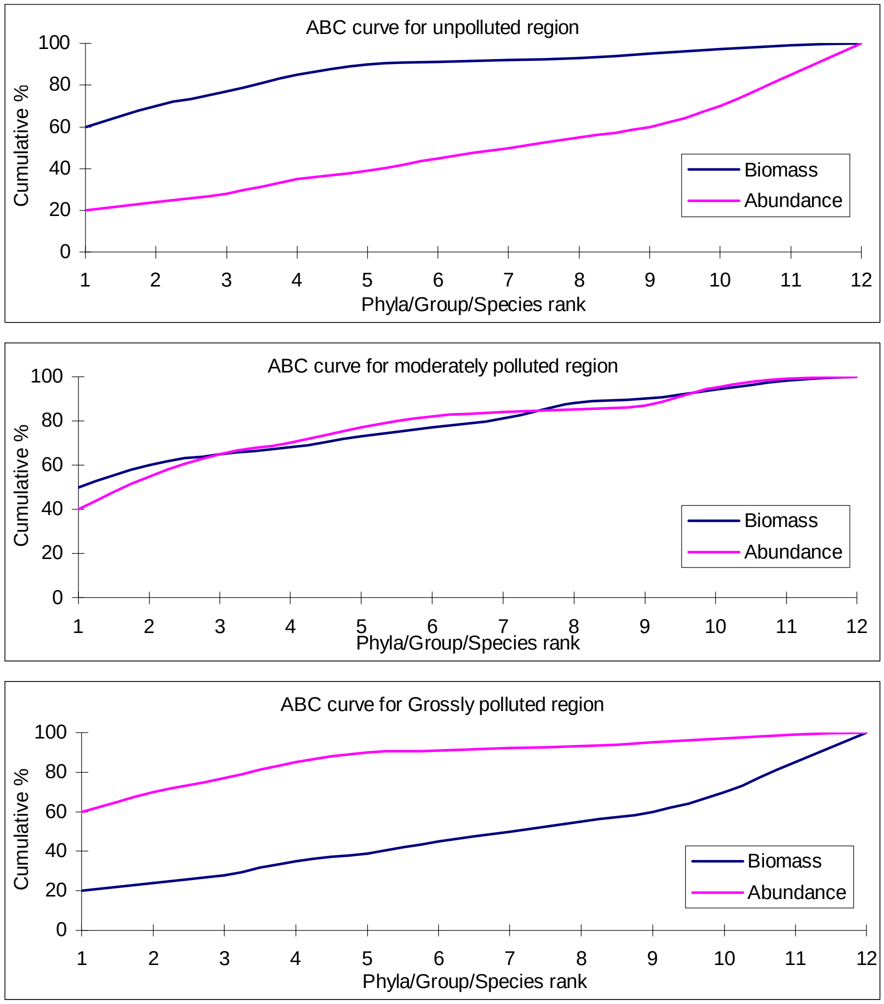


Fig. MM-1 : The hypothetical ABC curves as suggested by Warwick (1986).

In the present dissertation an attempt has been made to assess almost all the aspects of ecology. At the onset of the study it was felt that, if the number of sampling stations is large, it would not only represent the entire creek, but also the data generated would be statistically significant. This has resulted in a large data difficult to manage. Moreover, the aim of this study is to depict the present status of the creek, in terms of its productivity and pollution. Hence wherever absolutely necessary the data has been individually treated for various probabilities; Other wise in order to correctly arrive at a conclusion, the data is analyzed, interpreted and presented using the annual averages along with the monthly and seasonal average values, thereby reducing / eliminating any possible fluctuations.

Hydrology

Introduction

Water is the most vital resource necessary for all forms of life living in and around it. The basic requirement of water has located the world's population around the water bodies. However, indiscriminate use of the water resources has led to pollution, which has become a serious problem for the entire world. As a consequence of industrial revolution, it was only in the later half of the 19th century that the attention of the biologists was drawn to water pollution problem (Misra & Viswanathan, 1989). Presently significant awareness has been developed regarding the studies on management of coastal waters and associated mangrove ecosystems (Chandramohan and Sreenivas, 1998). The studies include analysis of physico-chemical properties of water & sediment and the study of aquatic life. The knowledge of physico-chemical parameters of water is extremely important for proper management of any water body because these parameters indicate the status of different metabolic processes in the water body and significantly influence the aquatic life. According to Zhi and Zhaoding (1984), as compared to the open sea, the chemical and the bio-chemical processes in the creeks and estuaries are much more complicated because of mixing of fresh and marine waters. These processes decide the hydrographic status of the estuaries and are influenced by many factors such as fresh water run off, influx of the seawater, geographical location & topography and seasonal variations. Due to free access to the sea, estuaries become unique environments that play an important role in the transfer of products of continental weathering to the ocean (Bijoy Nandan and Abdul Aziz, 1990). Apart from this, they harbour rich flora and fauna and provide feeding and breeding grounds to the migratory oceanic organisms. It is now well known that they play an important role in supporting the oceanic fishery. The distribution and abundance of the resident and visiting flora and fauna in estuaries however depend primarily on the water quality. Hence, Gouda and Panigrahy (1993), contented that it is worthwhile to acquire adequate knowledge on short term and long term variations of different hydrographic events in each and every estuary.

The long-term studies were thought to be more important in understanding estuarine processes (Stanley, 1993), because they can indicate deterioration or improvement of water quality and also help in understanding behavior & changes of nutrients over a long duration. But according to Randall and Day (1987), long term, low frequency sampling schemes miss short term variability that arises from daily tidal variations. There are several parameters that are influenced by the short-term occurrences, such as nutrients, chlorophyll a., temperature, salinity, dissolved oxygen, and pH, which vary over the short term and are interrelated. Understanding them according to Hubertz and Cahoon (1999), may be useful in identifying the sources of pollution and help effective management. It can be understood thus, that both the short term and long term studies of water parameters have their own significance.

The hydrological parameters are usually studied while assessing the ecological aspects of an aquatic ecosystem. They prove useful in understanding the correlation of different organisms with their environment. The most extensively studied estuaries in India are Vellar estuary (Ramamoorthi, 1954; Jacob & Rangarajan, 1959; Balasubramanyan, 1960; Vijayalakshmi and Venugopalan, 1973; Rajendran, 1974; Fernando *et al.*, 1988; Chandran & Ramamoorti, 1984; Chandran, 1987). Zuari and Mandovi estuaries of Goa. (Dehadri, 1970; Parulekar and Dwivedi, 1974; Cherian *et al.*, 1975; Parulekar, 1980; Ansari *et al.*, 1986a; Harkantra and Parulekar, 1986). Vashista - Godavari estuary (Srinivara Rao & Ramasarma, 1983; Sai Sastry & Chandramohan, 1990), Asthamudy estuary. (Divakaran *et al.*, 1980 & 1982) Rushikulya estuary (Gouda & Panigrahy, 1992, 1993 & 1996) Extensive work has also been carried out on the Cochin backwaters (Qasim & Gopinathan, 1969; Shyanamma and Balakrishnan, 1973; Sankaranarayanan & Punampunnayil, 1979; Sarala devi *et al.*, 1979; Remani *et al.*, 1983).

The Thane Creek ecosystem is one such water body that has been regularly monitored by various workers since 1970's (CPHERI, 1971, N10 1972, Govindan *et al.*, 1976; Metcalf and Eddy, 1979; Zingde *et al.*, 1979; Zingde & Desai, 1980 & 1981; Gajbhiye & Desai, 1981; Varshney, 1982; Ram *et al.*, 1984; Govindan & Desai, 1984; Gajbhiye *et al.*, 1984; Tandel, 1984 & 1986; Pejaver, 1984 & 1987; Sahoo & Khopkar, 1985; Zingde, 1985; Athalye, 1988; Borgaonkar, 1989; Annie Mathew, 1989; Neelam Lodh, 1990; Deshmukh, 1990; Mukherji, 1993; Gokhale & Athlaye, 1995; Quadros, 1995; Kotibhaskar, 1998; Venkatachalam, 1999). According to Nair *et al.* (1991), the various studies indicate the accumulating tendency of pollutants affecting the water quality and biological productivity of the creek. Most of the recent studies are confined to either upper shallow or lower deeper stretch of the creek, very few cover the entire creek. The present hydrological studies were carried out in the entire 26 km stretch of Thane Creek, while studying the intertidal fauna of the creek. The results are presented and discussed in this chapter. As mentioned in materials and methods the parameters were studied during neap high tide and low tide. However, as the difference between the high tide and low tide values was insignificant, their averages are used to know the monthly and station wise trend.

Temperature °C

Temperature is an important environmental parameter as it affects the rate of metabolism and the reproductive cycle of aquatic animals. In the present study the water temperature varied between 20.5 to 35.5 °C (Tables T-1 & T-2). According to Mishra *et al.*(1993), most of the Indian estuaries have a difference of 8 to 10 °C between the highest and the lowest water temperatures. Such annual variation has been reported from some of the Indian estuaries like Netravati – Gurupur estuary, Killai backwaters, Vembanad Lake, Mandovi & Zuari estuary, Asthamudi estuary, Karnafully estuary, Edaiyur – Sadras estuarine system, Akathumuri – Anchuthenga – Kadinamakulam backwaters (Quadros, 1995). Whereas the Uppanar backwaters showed temperature variation between 23 to 36 °C (i.e. 13°C Murugan & Ayyakkannu, 1991), which is comparable to the present study.

Table T-1 Monthly variations in water temperatures °C at different stations during high tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg
May-99	32	33.5	34	33	33.5	35	35	35	35	35	35.5	35	34.29
Jun	28	28	27	31	31	31	31	31	31	31	31	26	29.75
Jul	28	30	28	28.5	28.5	28.5	28	28.5	28	28	29	28	28.42
Aug	27	27	27.5	29.5	29.5	29.5	29.5	29	29.5	28.5	28	30.5	28.75
Sept	31	29	29	30	29.5	29.5	30	29.5	29.5	29.5	29.5	29	29.58
Oct	29	29	30	30.5	30.5	30	30.5	29.5	29	28.5	28	34.5	29.92
Nov	23	23	24	24	24	23.5	23.8	24	24	25	26	24	24.03
Dec	23	23	23	24	24.5	25	24.5	24	24	24	25	22	23.83
Jan-00	23.5	24.5	24.5	26	26	23.5	25	24.5	24	24	24	22	24.29
Feb	23	23	24	23	23	22.5	22.5	23	23	23	23	21.5	22.88
Mar	26	28	28	29	30	29	28.5	28	28	29	29	26	28.21
Apr	32	33	33	34.5	34.5	34.5	33	33	34	34	34	31	33.38
Stn.Avg→	27.13	27.58	27.67	28.58	28.71	28.46	28.44	28.25	28.25	28.29	28.50	27.46	**28.11**
Min	23.00	23.00	23.00	23.00	23.00	22.50	22.50	23.00	23.00	23.00	23.00	**21.50**	22.88
Max	32.00	33.50	34.00	34.50	34.50	35.00	35.00	35.00	35.00	35.00	**35.50**	35.00	34.29
SD	3.48	3.66	3.51	3.65	3.66	4.13	3.84	3.78	3.95	3.85	3.77	4.69	3.71

Table T-2 Monthly variations in water temperatures °C at different stations during Low tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	HT & LT avg.
May-99	32	33.5	34	33	33	32	33	32.5	34	33	34	34	33.17	33.73
Jun	27	27	27.5	30	30	29.5	29.5	29.5	29	29.5	30	26	28.71	29.23
Jul	28	28	28.5	27	27	27	27	27	27	28	28	29	27.63	28.00
Aug	30	30	30	27	28	27	28	26.5	27	27	29	29	28.21	28.48
Sept	29.5	27.5	28.5	29.5	29.5	29	29	29	29	29	29	31	29.13	29.35
Oct	26	26	28	27	27	27.5	27.5	27.5	27.5	27.5	28	31.5	27.58	28.75
Nov	24	24	24	23	24	23.5	24	24	25	25	25.5	24	24.17	24.10
Dec	22	22	23	20.5	21	21	21	22	22.5	22	24	22	21.92	22.88
Jan-00	22.5	24.5	24	21.5	22	21	21.5	21.5	22	21.5	22.5	21	22.13	23.21
Feb	21.5	22	24	21.5	21.5	21	21	21	21.5	21	22	21.5	21.63	22.25
Mar	25	26	30	27	28	27.5	28	28.5	29	28.5	29	26	27.71	27.96
Apr	31	33	35	31	31.5	31	31.5	32	33	32	33	32.5	32.21	32.79
Stn.Avg→	26.54	26.96	28.04	26.50	26.88	26.42	26.75	26.75	27.21	27.00	27.83	27.29	**27.01**	**27.56**
Min	21.5	22	23	**20.5**	21	21	21	21	21.5	21	22	21	21.63	22.25
Max	32	33.5	**35**	33	33	32	33	32.5	34	33	34	34	33.17	33.73
SD	3.62	3.76	3.89	4.08	3.97	3.91	4.04	3.91	4.00	3.93	3.77	4.52	3.84	3.76

The reason for the wide annual temperature variation in Thane creek could be the shallowness of the creek, due to which the water temperature varied according to the atmospheric temperature (Fig. T-1). The present author (Quadros, 1995), had observed similar wide range of temperature (17 – 35 °C) in the shallow region of Thane creek near Thane city during the period 1991 – 93.

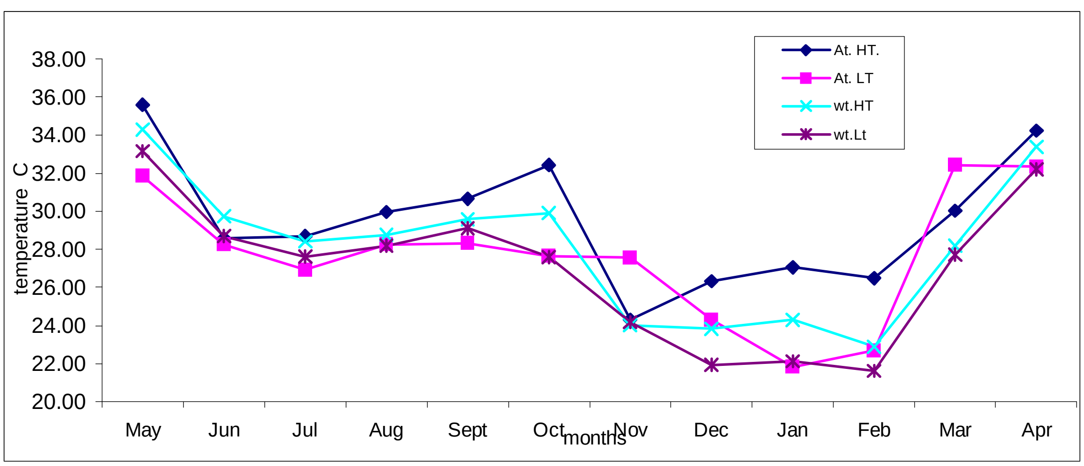


Fig T-1 : Monthly variations in the atmospheric temperature and the overall average water temperature (°C)

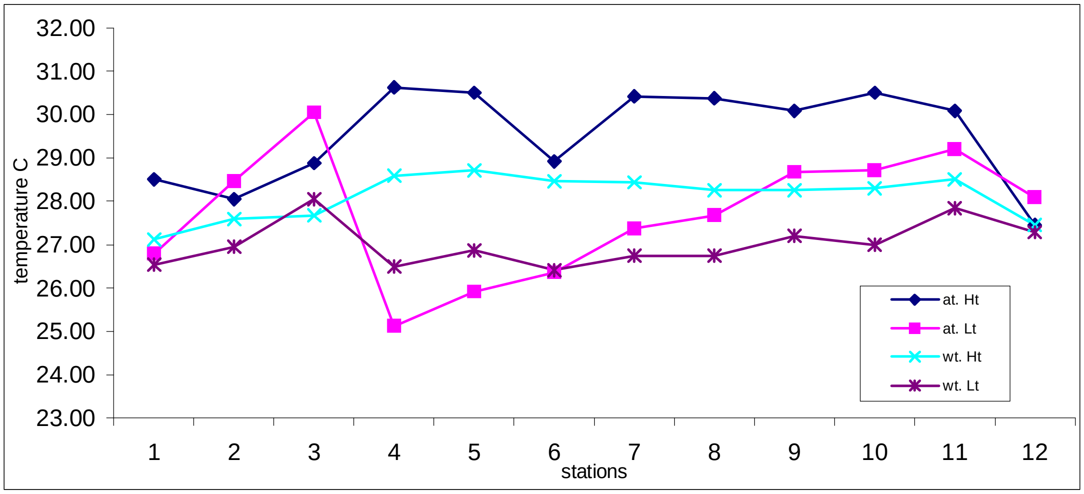


Fig T –2: Station wise variations in atmospheric and water temperature (°C) during High tide and Low tide.

A comparison between the overall monthly average temperatures (Fig. T-1) revealed cooler waters during winter months (Dec, Jan, Feb) and higher water temperature during the summer (April & May). The tidewise comparison revealed higher temperature during high tide compared to the low tide. A stationwise and tidewise comparison indicated greater difference between the high tide and low tide values in the middle to lower stretches of the creek as compared to the shallow upper stretches (Fig. T-2). This can be attributed to the release of warmer waters in the creek by the surrounding industries which use the creek water in cooling processes, as was reported by Sahoo and Khopkar (1985). They recorded temperature up to 41°C and attributed it to the disposal of warm waters from the industries.

A comparison of the present annual average temperature with the available annual average water temperature data of the past is shown in figure T-3. It is apparent that the fluctuations were insignificant. However when the overall temperature ranges of the past and the present data are compared (Table T-3) it becomes evident that the difference between the minimum and the maximum was 7°C in 1975, which has gradually increased to 15°C difference in the present study. This can be attributed to increased shallowness of the creek, due to which water temperature is significantly affected by air temperature.

Table T-3 : Comparison of water temperature (°C) ranges with the past data.

Study Period	1975	1985	1980	1999-2000
Range	23.3 – 30.5	25 - 35	21 - 32	20.5 – 35.5

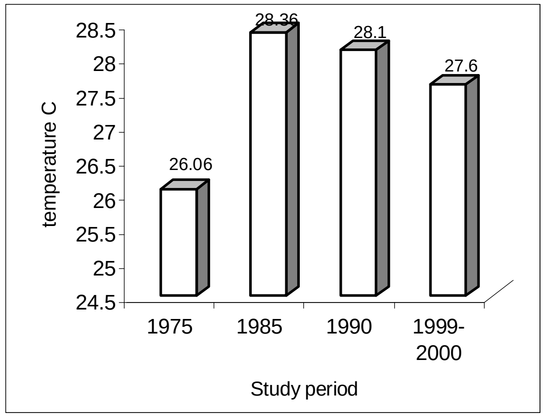


Fig T –3 : Comparison of the average water temperature data of Thane creek with that of the past.

In earlier studies on Thane creek Tandel (1986), Athalye (1988) & Goldin (1995) reported wide temperature difference between the minimum and the maximum values in the shallow upper stretches of the creek, whereas Gajhibye (1982) & Annie Mathew (1989) reported narrow temperature difference in the deeper downstream region of Thane creek. In the present study the range was wide for the entire creek. This suggests the shallowness is spreading in the downstream reaches of the creek. Siltation has been observed in the creek (discussed in chapter III), in the past 5 years making it shallow.

Light penetration (cms)

The transparency of water is generally affected by the sun's position in the sky, the angle of incident light, cloudiness, visibility, water surface conditions and abundance of phytoplankton and zooplankton. Apart from these, it is also influenced by turbulence and nature of suspended material (Ramana *et al.*, 1991).

In the present investigation the light penetration varied between 1 to 175 cms (Tables Lp-1 & Lp-2). The lowest reading was recorded during the monsoon due to high suspended silt and clay and the highest in winter. Similar range of light penetration has been recorded from many other Indian estuaries like Akathumuri – Anchuthenga – Kadinamakulam backwaters, Edaiyur & Sadras backwaters, Ashtamudi estuary, Karnafully river estuary, Uppanar backwaters, Malad creek, Rushikulya estuary and

Hooghly estuary (Quadros, 1995). Wide range of light penetration is a common feature of several Indian estuaries. (Mishra *et al.*, 1993).

Table Lp-1: Monthly variations in light penetration (cms) at different stations during high tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.
May-99	38	35	21	30	18	25	14	5	10	5	2	15	18.17
Jun	10	14	25	27	20	36	10	1	1	1	1	34.5	15.04
Jul	6	13	15	55	45	22	61	4	39	2	14	10	23.83
Aug	87	50	43	33	33	30	43	68.5	40	67	42.5	10	45.58
Sept	32	8	18	36	44	56	48	68	85	57	35	20	42.25
Oct	38	35	34	35	35	32	35	42	39	82	29	24	41.08
Nov	17	38	40	32	41	65	50	51	49	65	33	37	43.17
Dec	45	45	40	49	35	52	46	85	127	132	56	47	63.25
Jan-00	74	50	35	41	37	57	72	88	79	57	64	23	56.42
Feb	38	27	32	44	43	54	66	57	64	51	52	10	44.83
Mar	57	25	20	26	33	34	49	53	46	44	69	15	39.25
Apr	39	35	35	33	37	36	54	61	52	50	20	8	38.33
Stn.Avg→	40.08	31.25	29.83	36.75	35.08	41.58	45.67	48.63	52.58	51.08	34.79	21.13	**39.27**
Min	6.00	8.00	15.00	26.00	18.00	22.00	10.00	**1.00**	**1.00**	**1.00**	**1.00**	8.00	15.04
Max	87.00	50.00	43.00	55.00	45.00	65.00	72.00	88.00	127.00	**132.00**	69.00	47.00	63.25
SD	24.01	14.17	9.60	8.86	8.59	14.34	18.69	30.30	33.68	37.07	22.83	12.55	14.27

Table Lp-2: Monthly variations in light penetration (cms) at different stations during low tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	HT & LT avg.
May-99	18	23	18	25	15	35	33	8	10	3	1	10	16.58	17.38
Jun	14	2	15	46	33	39	34	2	6	1	1	34	18.92	16.98
Jul	12	5	13	23	20	30	29	25	26	31	16	20	20.83	22.33
Aug	48	25	45	57	62	62	57.5	122	57	92	32	7	55.54	50.56
Sept	50	10	30	60	46	30	34	57	57	113	32	10	44.08	43.17
Oct	35	35	45	36	33	30	28	39	42	45	20	18	33.83	37.46
Nov	18	30	49	69	57	53	75	108	44	150	33	30	59.67	51.42
Dec	65	18	48	67	48	55	67	91	49	175	57	25	63.75	63.50
Jan-00	85	35	48	59	51	51	64	82	68	100	53	20	59.67	58.04
Feb	25	38	41	54	50	52	60	69	59	126	49	20	53.58	49.21
Mar	45	15	30	39	38	35	58	90	59	65	55	22	45.92	42.58
Apr	28	23	42	46	39	26	47	64	36	50	39	27	38.92	38.63
Stn.Avg→	36.92	21.58	35.33	48.42	41.00	41.50	48.88	63.08	42.75	79.25	32.33	20.25	**42.61**	**40.94**
Min	12.00	2.00	13.00	23.00	15.00	26.00	28.00	2.00	6.00	**1.00**	**1.00**	7.00	16.58	16.98
Max	85.00	38.00	49.00	69.00	62.00	62.00	75.00	122.00	68.00	**175.00**	57.00	34.00	63.75	63.50
SD	22.46	11.93	13.62	15.28	14.17	12.30	16.65	38.40	19.91	56.07	19.67	8.24	16.88	15.29

The trends of stationwise and monthly averages (Fig Lp-2 & Lp-1) reveal in general higher light penetration during low tide as compared to high tide. According to Nair (1988), during high tide the suspended solids and other pollutants get accumulated in the creek affecting the transparency in the creek, so also the turbulence caused by tidal incursion increases suspended silt & clay particles in the water. Whereas during low tide the suspended solid load is flushed out to some extent, thus improving the light penetration. However, in the present case the difference between light penetration during the high tide and the low tide was not significant.

Monthly variations in light penetration showed slight drop in light penetration at the onset of monsoon (June) due to silt containing runoff water. This was followed by improvement up to August and decline in September and October. This decline could be due to increased production of phytoplankton and zooplankton. The lower production of plankton in winter probably caused improved light penetration in November – December whereas improved production from January to April reduced the light penetration (Fig. Lp-1).

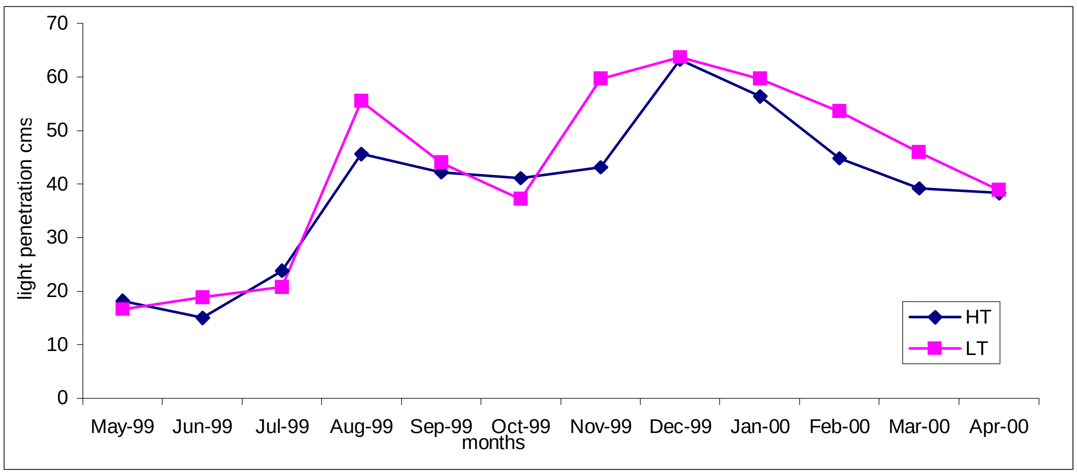


Fig. Lp-1 : Monthly variations in the average light penetration (cms) during high tide and low tide.

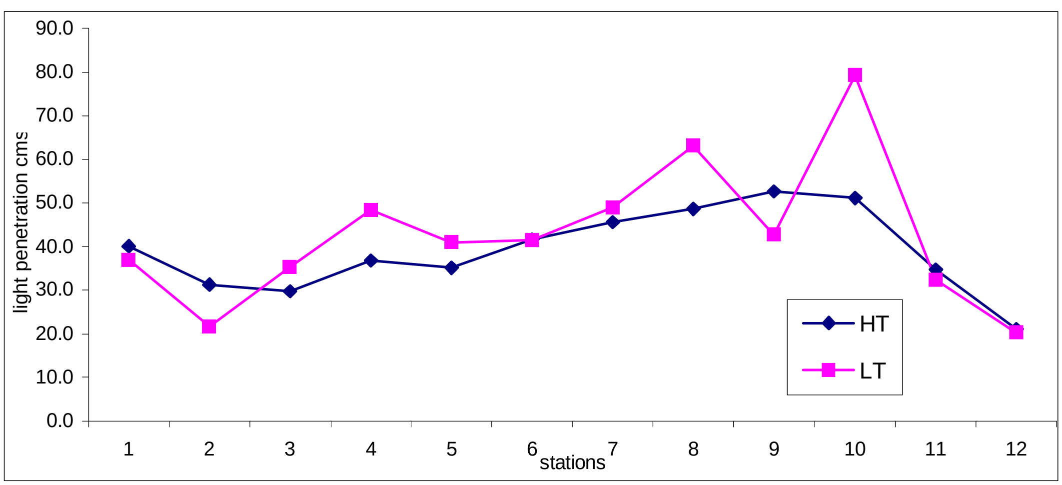


Fig. Lp-2 : Stationwise variations in the average light penetration (cms) during high tide and low tide.

Stationwise pattern of light penetration (Fig. Lp-2) showed overall low light penetration at the stations of upstream stretches (1 to 5) probably due to high pollution load in the region. Stations 6 to 10 showed increasing light penetration. Whereas station 11 & 12 characterised by proximity with sewage reach and high water turbulence & anthropogenic activity respectively, showed lower light penetration.

Suspended solids (gm/l)

Suspended solids are of different types such as suspended silt and clay particles, debris from agricultural fields, inorganic and organic matter in the domestic sewage & industrial effluents etc. Apart from these, the particulate matter generated by biological productivity which includes phytoplankton and zooplankton are also important components of suspended solids (Biggs, 1970), They make the water turbid and turbidity according to Behera *et al*. (1996), poses threat to aquatic life.

The study of distribution of suspended solids according to Nair *et al*. (1987), is recogonised to be a natural tracer that can reveal the concentration and dispersion of a pollutant and also its impact on the ecosystem. According to O'Sullivan (1971), the suspended solids have two important effects on an aquatic environment. (1) They cause smothering of benthic animals including filter feeders and detritus feeders. (2) They absorb light, causing reduced photosynthesis. The suspended solids also adsorb different materials and transport them from the land to the sea via estuary. In some instances they adsorb metals and other toxicants and settle, thereby reducing the toxins from water. However, these settled toxicants may be ingested and concentrated by sediment dwelling and filter feeding animals forming a part of the food chain leading to fish and man.

In the present study the suspended solids ranged from 0.200 to 59.200 gm/l (Table SS-1 & SS-2) with an annual average of 6.12 gm/l. The maxima of 59.2 gm/l was an exceptionally high value observed in December 1999 at station 9. However, suspended solid values between 20 to 50 gm/l were not very uncommon. In most of the studies suspended solid values are expressed in mg/l. In the present case, they are given in gm/l units, as they are exceptionally high when compared with the suspended solids of other Indian estuaries reported by Nair *et al.* (1987) and Reddy *et al.* (1994).

Table SS-1: Monthly variations in suspended solids (gm/l) at different stations during high tide

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.
May-99	4.00	2.60	9.60	10.00	16.80	6.80	8.60	2.80	12.00	8.60	13.00	4.00	8.23
Jun	0.60	0.40	19.60	0.80	0.20	0.20	0.80	7.40	30.40	1.20	3.60	0.60	5.48
Jul	3.60	2.40	0.80	1.40	2.00	0.20	2.00	1.80	1.20	1.20	2.00	1.40	1.67
Aug	0.40	0.60	1.40	0.80	1.80	6.80	2.00	7.20	2.20	11.60	2.80	0.80	3.20
Sept	1.20	1.40	0.40	1.20	2.80	1.60	1.40	1.00	6.80	4.60	5.80	2.00	2.52
Oct	0.20	0.20	0.20	1.20	1.20	10.40	7.40	0.40	2.00	0.80	19.00	8.00	4.25
Nov	4.00	1.40	15.40	0.20	38.40	6.20	1.00	1.00	0.80	14.00	2.60	17.80	8.57
Dec	4.00	1.60	3.60	51.80	5.00	8.40	1.40	2.00	11.40	2.60	1.20	1.40	7.87
Jan-00	1.20	1.60	16.00	1.80	3.20	0.60	2.00	5.00	2.60	3.20	9.80	22.40	5.78
Feb	3.00	33.20	1.40	1.40	39.80	1.80	1.20	1.40	0.40	3.00	1.00	0.20	7.32
Mar	13.00	0.60	10.20	4.00	9.40	6.20	17.20	2.20	1.40	2.20	3.40	0.80	5.88
Apr	1.80	2.60	1.80	2.60	1.00	3.00	1.60	14.60	3.60	0.20	1.80	2.60	3.10
Stn.Avg→	3.08	4.05	6.70	6.43	10.13	4.35	3.88	3.90	6.23	4.43	5.50	5.17	**5.32**
Min	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	0.80	0.40	0.40	**0.20**	1.00	**0.20**	1.67
Max	13.00	33.20	19.60	**51.80**	39.80	10.40	17.20	14.60	30.40	14.00	19.00	22.40	8.57
SD	3.46	9.22	7.11	14.52	14.30	3.52	4.91	4.12	8.59	4.51	5.60	7.35	2.37

Table SS-2: Monthly variations in suspended solids (gm/l) at different stations during low tide

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	HT & LT avg.
May-99	5.20	10.00	9.00	15.00	16.40	7.40	13.00	8.80	13.20	15.80	22.40	7.00	11.93	10.08
Jun	35.20	44.00	1.20	0.80	0.20	0.40	0.20	0.80	1.40	1.20	3.60	0.20	7.43	6.46
Jul	1.20	2.00	1.80	0.80	2.20	0.20	1.20	1.60	0.20	0.40	2.80	1.20	1.30	1.48
Aug	0.20	1.00	0.20	2.20	2.60	0.80	2.20	2.20	1.00	1.20	0.80	1.80	1.35	2.28
Sept	1.00	1.20	0.60	17.00	17.20	18.80	4.00	8.20	14.40	10.60	15.20	4.40	9.38	5.95
Oct	1.20	0.20	0.40	10.40	1.00	20.20	0.20	0.20	0.40	3.80	1.00	10.80	4.15	4.20
Nov	39.60	1.00	0.60	11.00	37.60	2.00	12.40	1.80	1.00	20.80	0.20	46.80	14.57	11.57
Dec	0.60	2.00	2.60	0.20	3.80	36.00	2.60	39.20	59.20	3.60	3.00	2.20	12.92	10.39
Jan-00	0.20	2.60	4.00	1.20	2.40	2.60	3.20	2.00	19.00	1.80	2.20	5.60	3.90	4.84
Feb	2.00	3.00	1.00	1.20	0.20	0.80	1.00	5.40	2.40	2.00	1.20	1.80	1.83	4.58
Mar	1.40	1.60	1.00	0.40	18.60	5.20	10.60	3.40	5.40	2.00	8.00	1.20	4.90	5.39
Apr	1.80	0.40	0.40	22.40	19.80	3.60	0.80	40.60	1.00	17.80	3.80	0.80	9.43	6.27
Stn.Avg →	7.47	5.75	1.90	6.88	10.17	8.17	4.28	9.52	9.88	6.75	5.35	6.98	**6.93**	**6.12**
Min	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	0.40	**0.20**	**0.20**	1.30	1.48
Max	39.60	44.00	9.00	22.40	37.60	36.00	13.00	40.60	**59.20**	20.80	22.40	46.80	14.57	11.57
SD	14.07	12.32	2.49	7.89	11.71	11.14	4.82	14.46	16.83	7.42	6.78	12.92	4.69	3.14

Monthly variations in the average suspended solids (Fig. SS-1) showed lowering of suspended solids in monsoon months. During this season light penetration was poor due to highly turbid water, but the turbidity was in the form of lightweight silt and clay particles, hence the suspended solids were low. The suspended solids increased from

September to November, then declined up to winter months December, January and further up to April (except March, April for low tide). These changes however cannot be attributed to the biotic components phytoplankton and zooplankton due to very high and fluctuating suspended solid load in the creek. They could be mainly due to changing load of pollutants swinging in the creek with the tides. Quadros (1995) reported similar observation during 1991-93 in the upper stretch of Thane creek.

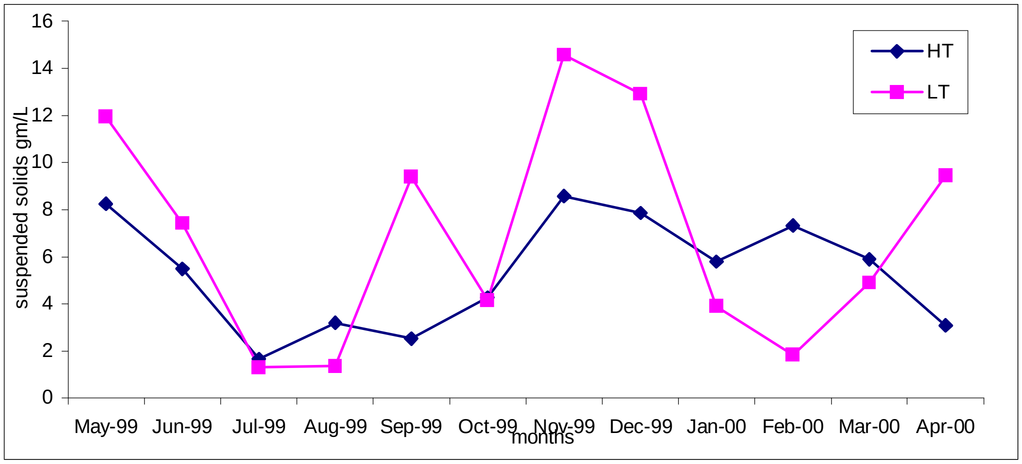


Fig SS-1 : Monthly variations in the average suspended solids (gm/l) during high tide and low tide.

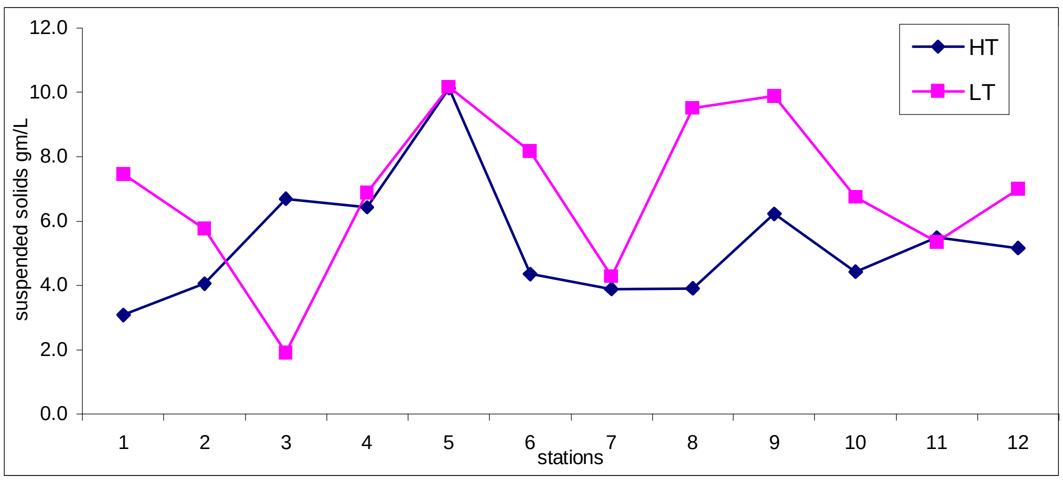


Fig SS-2 : Stationwise variations in the average suspended solids (gm/l) during high tide and low tide.

Tidally driven resuspension is presumed to be a primary mechanism governing the variability of suspended particulate matter in estuaries. According to Ong *et al.* (1991), with each tide a varying amount of dissolved and suspended matter is transported from the mangrove mudflats into the estuary and then into the sea; they also observed increased flushing during ebb tide. Corroborating with the observation, in the present study higher load of suspended solids was recorded during the low tide than the high tide. This can be attributed to the release of effluents during low tide and subsequent dilution during high tide abating the concentration of suspended matter.

A stationwise comparison (Fig. SS-2) of suspended solids revealed the maximum concentration at station 5, which can be attributed to the proximity of a Thane municipal corporation's effluent drain. Ramanathan *et al.* (1996) observed the total suspended matter to show an increasing trend with fluctuations towards the marine environment in Cauvery estuary. However in the present study the fluctuations were recorded in the entire length of the creek and were not restricted to the marine end.

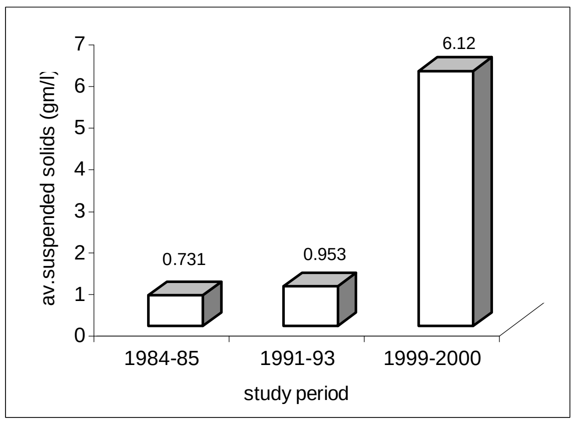


Fig. SS-3: Comparison of suspended solids of the past and present data from the comparable shallow region of Thane creek.

A comparison of the available upstream data of Thane creek of 1984-85 (reported by Tandel, 1986; Pejaver, 1987 & Athalye, 1988) and 1991-93 (Quadros, 1995) with the present overall average of suspended solids in the same region indicates significant increase in the average suspended solid load (Fig. SS-3). This can be attributed to impaired flushing caused by reclamation and construction activities leading to obstruction of tidal flow, oscillatory movement of sewage & industrial effluents and due to significant increase in human population and industries in this region (TMC-ES Report, 2000). Similar comparison of the suspended solids in the lower stretches of the creek was not possible due to inavailability of past data.

pH

In aquatic ecosystems the pH is a function of the dissolved carbondioxide content (Odum, 1971). In freshwaters the dissolved carbondioxide makes the pH slightly acidic, whereas in marine water, along with dissolved carbondioxide there are other weakly ionizing chemicals and salts, which make the pH slightly alkaline around 8 (Levinton, 1982). The salts in the marine water have a buffering effect, even then, when carbon dioxide increases in great quantities due to decomposition or respiration, may decrease the pH to 7.5; as against this, photosynthesis can raise the pH to 9. The estimation of pH, can thus illustrate the status of decomposition, respiration and photosynthesis in water. Moreover, pH changes cause reshuffling of ionic properties of suspended particles and metals, leading sometimes to their precipitation; they also govern leaching of nutrients and other chemicals from the sediments.

Table pH- 1: Monthly variations in pH at different stations during high tide

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.
May-99	7.52	7.35	7.4	7.52	7.93	7.85	7.7	7.55	7.32	7.2	7.5	7.35	7.52
Jun	6.95	7.05	7.08	7.39	7.31	7.19	7.11	7	7.17	7.17	7.15	7.36	7.16
Jul	7.48	7.55	7.44	7.39	7.4	7.5	7.62	7.74	7.72	7.67	7.64	7.8	7.58
Aug	7.52	7.49	7.91	7.82	7.83	7.99	7.75	8.42	8.46	8.55	7.96	8.7	8.03
Sept	7.43	7.35	7.4	7.53	7.61	7.6	7.7	7.7	7.74	7.67	7.62	7.71	7.59
Oct	7.8	7.8	8.18	8.57	7.93	9.15	8.77	8.86	9.22	8.49	8.83	8.25	8.49
Nov	7.45	7.9	8.5	7.89	7.84	7.81	7.81	7.87	7.88	7.87	8.07	7.94	7.90
Dec	6.99	7.01	7.21	7.39	7.63	7.8	7.87	7.52	7.37	7.34	7.36	7.37	7.41
Jan-00	7.45	7.54	7.57	7.69	7.61	7.59	7.62	7.63	7.59	7.59	7.74	7.4	7.59
Feb	7.18	7.2	7.3	7.34	7.32	7.35	7.3	7.31	7.37	7.45	7.34	7.25	7.31
Mar	6.41	6.41	6.78	7.25	7.45	7.18	6.94	6.9	6.85	6.89	7.02	6.83	6.91
Apr	8.3	8.22	8.7	8.92	9.05	9.04	8.7	8.73	9.03	9.06	8.81	8.44	8.75
Stn.Avg→	7.37	7.41	7.62	7.73	7.74	7.84	7.74	7.77	7.81	7.75	7.75	7.70	**7.69**
Min	**6.41**	**6.41**	6.78	7.25	7.31	7.18	6.94	6.90	6.85	6.89	7.02	6.83	6.91
Max	8.30	8.22	8.70	8.92	9.05	9.15	8.77	8.86	**9.22**	9.06	8.83	8.70	8.75
SD	0.47	0.47	0.58	0.52	0.47	0.64	0.54	0.62	0.73	0.65	0.58	0.55	0.53

In the present study pH ranged from 6.36 to 9.45 with an annual average of 7.71 (Tables pH-1 & pH-2). Low values of pH were recorded mostly during the monsoon due to fresh water run off. Low values of pH were also recorded during March which can be attributed to the decomposition of phytoplankton resulting from increased temperatures. Similar low values have been recorded by Zingde *et al.* (1987) for Purna river estuary.

Sarla Devi *et al.* (1979), while studying the Cochin back waters observed pH as low as 5.5, whereas Gouda & Panigrahy (1993), reported pH upto 9.1 in the Rushikulya estuary.

Table pH- 2: Monthly variations in pH at different stations during low tide

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	HT & LT avg.
May-99	7.96	7.78	7.55	7.69	7.89	7.58	7.62	7.65	7.88	7.75	7.7	7.55	7.72	7.62
Jun	6.91	6.98	6.95	6.95	7.2	7.1	7.16	6.97	7.18	7.06	7.06	7.2	7.06	7.11
Jul	7.36	7.46	7.3	7.75	7.32	7.92	7.82	7.83	7.63	7.45	7.56	7.75	7.60	7.59
Aug	7.42	7.81	7.55	8.55	8.53	8.34	8.31	8.03	8.05	8.64	8.4	8.85	8.21	8.12
Sept	7.52	7.48	7.64	8.03	7.8	7.94	8.04	7.68	7.77	7.75	7.67	7.76	7.76	7.67
Oct	7.96	7.76	7.74	8.2	8.14	8.21	8.45	8.64	8.9	8.83	8.23	8.54	8.30	8.39
Nov	8.86	7.78	9.14	8.6	8.02	8.82	7.95	7.88	7.97	7.95	8.14	7.97	8.26	8.08
Dec	7.45	7.44	7.35	7.07	6.99	7.15	7.39	7.19	7.4	7.23	7.32	7.35	7.28	7.34
Jan-00	7.63	7.45	7.75	7.43	7.65	7.71	7.7	7.53	7.57	7.5	7.43	7.14	7.54	7.56
Feb	7.21	7.33	7.57	7.69	7.55	7.37	7.63	7.23	7.4	7.27	6.96	7.17	7.37	7.34
Mar	6.36	6.63	6.48	7.57	6.91	7.06	7.02	6.84	6.9	6.92	6.9	6.81	6.87	6.89
Apr	8.51	8.42	8.71	9.26	8.49	9.36	9.45	9.1	9.1	8.87	9.1	8.35	8.89	8.82
Stn.Avg →	7.60	7.53	7.64	7.90	7.71	7.88	7.88	7.71	7.81	7.77	7.71	7.70	**7.74**	**7.71**
Min	**6.36**	6.63	6.48	6.95	6.91	7.06	7.02	6.84	6.90	6.92	6.90	6.81	6.87	6.89
Max	8.86	8.42	9.14	9.26	8.53	9.36	**9.45**	9.10	9.10	8.87	9.10	8.85	8.89	8.82
SD	0.67	0.45	0.70	0.67	0.54	0.71	0.65	0.66	0.65	0.68	0.66	0.63	0.59	0.55

The Monthly average pH values (Fig. pH-1) in the present study were higher than 7.6 in the months May, July to November and April, where as they were lower in June & December to March. It is probable that in the earlier period photosynthetic activity was higher and in the later period it was lower.

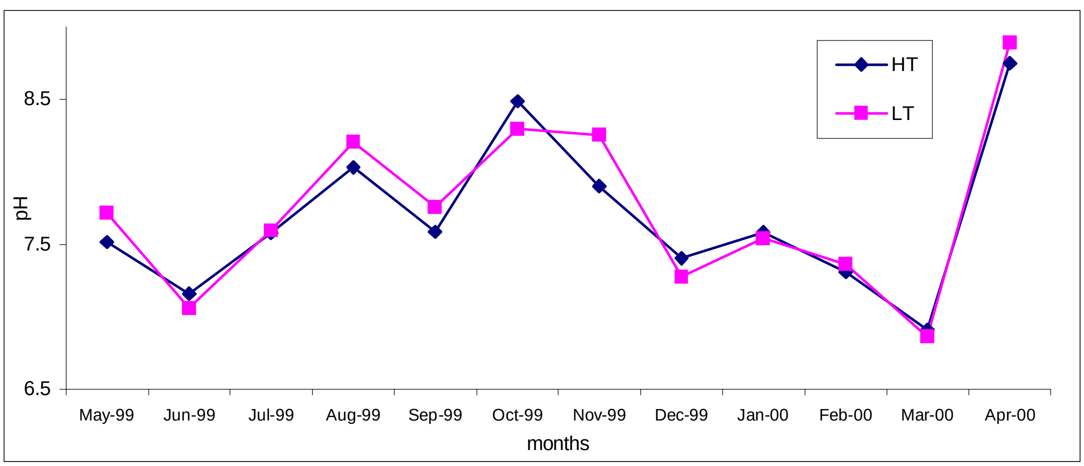


Fig. pH-1 : Monthly variations in the average pH during high tide and low tide.

In estuaries and creeks tidal influx has significant effect on pH. Usually low tides are associated with dominance of fresh water, hence low pH. While high tides have higher pH due to salt water incursion. In the present study, the average pH values during low and high tide were more than 7.5 suggesting dominance of marine water. The insignificant difference in the low tide and high tide averages of pH confirms the same. Moreover, Thane creek has a geomorphic head near Thane city and in the past 10 years the creek has become shallow due to reclamation activities. Due to these reasons the freshwater flow from the Ulhas river has got reduced significantly.

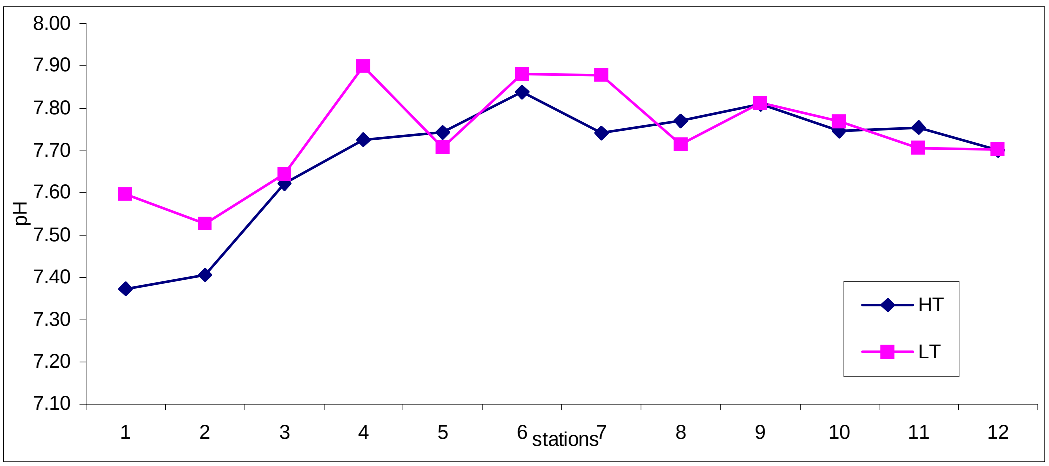


Fig pH-2 : Stationwise variations in the average pH during high tide and low tide.

A station wise (Fig. pH-2) picture depticted higher pH at the sea ward stations than the riverine end, corroborating with the earlier observation by Quadros 1995 for shallow region of Thane creek. Nair *et al.* (1983), have observed decrease in pH from marine to fresh water zone in the Ashtamudi estuary.

A comparison with the previous study (Tandel, 1986; Pejaver, 1987; Athalye 1988 & Annie Mathew,1989) has been shown in Fig. pH-3. It indicates significantly lowered pH during the study of 1991-93 (Gokhale & Athalye, 1995), which has improved to some extent. However the present average pH is slightly acidic than that in 1984-85. This can be attributed to the increased effluent load in the creek. Lowering of pH due to pollutant load has been reported by Verlencar & D'silva (1977), Sarma *et al.* (1982), Hussain *et al.* (1988), Gouda & Panigrahy (1993) while studying the Velsas & Colva beaches of Goa, Visakhapatnam harbour, Karnafully river estuary & Rushikulya estuary respectively.

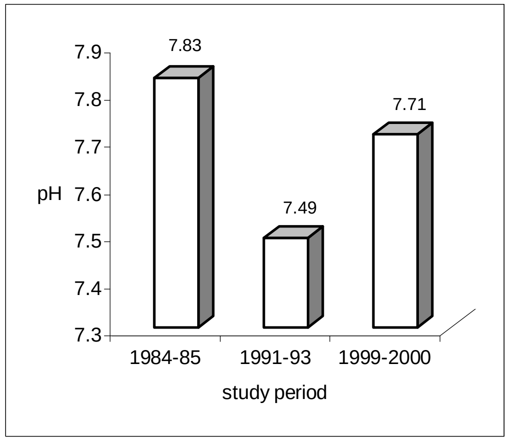


Fig. pH-3: Comparison of annual average pH with the past comparable data of Thane creek.

Salinity (ppt.)

Salinity is the most important water parameter in estuaries and creeks. It is largely influenced by influx of freshwater and intrusion of seawater (Anirudhan & Nambissan 1990). Depending on the magnitudes of these a salinity gradient is formed from the riverine end to the seaward end of an estuary, thus providing a variety of environments for different types of organisms. In a particular nitche also, the salinity changes with the flood and the ebb tides. These changes in salinity present significant physiological challenges to the organisms affecting their occurance and distribution (Levinton,1982). Salinity also affects various phenomena in the water such as adsorption, leaching and precipitation of nutrients, toxic metals and suspended solids in the effluents etc. In general, it significantly affects the abiotic and biotic components.

The salinity during the present study varied between o.1 to 44.5ppt. with an annual average of 19.23 ppt. (Tables Sl-1 & Sl-2) The wide range in salinity as above is a common feature of Indian estuaries (Quadros, 1995). The minimum salinity was recorded during monsoon at the riverine end of the creek, while the maximum was obtained during the premonsoon at the seaward end.

Table Sl-1: Monthly variations in salinity (ppt.) at different stations during high tide

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.
May-99	25.15	31.61	32.33	35.20	26.94	31.61	36.63	38.78	38.78	38.07	36.63	43.09	34.57
Jun	0.64	0.71	0.53	10.44	11.51	13.67	16.90	20.12	25.87	20.48	20.84	17.25	13.25
Jul	0.10	0.24	0.18	0.46	0.53	0.80	1.29	1.68	1.72	2.29	3.55	5.77	1.55
Aug	3.62	3.98	11.51	2.54	3.26	7.92	10.80	12.95	14.74	12.95	20.12	19.77	10.35
Sept	0.75	1.11	3.26	1.11	1.43	1.75	1.97	2.15	2.15	2.08	2.18	17.97	3.16
Oct	0.14	3.08	13.02	5.77	6.49	12.23	15.82	17.97	18.69	19.77	16.54	27.84	13.11
Nov	9.00	12.59	28.74	17.97	19.05	23.00	24.79	28.38	28.02	32.33	35.20	33.40	24.37
Dec	14.38	18.33	20.84	23.35	21.20	30.53	33.76	32.33	25.51	25.87	26.94	27.66	25.06
Jan-00	17.61	20.84	29.45	20.84	26.22	29.45	24.07	28.38	30.17	29.45	31.25	44.53	27.69
Feb	19.41	17.61	25.51	25.51	28.38	27.66	33.40	32.68	35.91	36.27	32.33	35.20	29.16
Mar	20.12	24.07	32.33	14.74	19.77	23.35	25.15	26.22	25.15	27.66	28.02	34.12	25.06
Apr	20.84	14.02	33.76	36.63	25.15	30.17	35.91	37.35	34.12	33.40	32.33	36.63	30.86
Stn.Avg →	10.98	12.35	19.29	16.21	15.83	19.35	21.71	23.25	23.40	23.38	23.83	28.60	**19.85**
Min	**0.10**	0.24	0.18	0.46	0.53	0.80	1.29	1.68	1.72	2.08	2.18	5.77	1.55
Max	25.15	31.61	33.76	36.63	28.38	31.61	36.63	38.78	38.78	38.07	36.63	**44.53**	34.57
SD	9.60	10.49	12.99	12.60	10.60	11.52	12.49	12.53	12.09	12.26	11.58	11.55	11.09

Table Sl-2: Monthly variations in salinity (ppt.) at different stations during low tide

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	HT & LT avg.
May-99	23.35	30.53	26.94	33.40	25.87	30.89	34.12	33.04	34.12	33.40	32.68	36.63	31.25	32.91
Jun	0.32	0.64	0.57	12.23	11.51	7.92	16.54	19.77	17.61	20.48	20.48	16.18	12.02	12.63
Jul	0.13	0.19	0.19	2.18	0.75	1.11	1.47	2.15	2.00	0.64	3.47	5.66	1.66	1.61
Aug	2.18	2.90	3.26	7.21	6.13	7.92	11.15	11.51	15.82	14.02	14.74	19.05	9.66	10.00
Sept	0.39	0.57	1.00	1.57	1.43	1.39	1.68	1.75	1.93	1.97	2.29	18.33	2.86	3.01
Oct	0.16	0.68	1.43	6.13	6.85	11.15	13.31	14.74	16.18	18.69	17.61	27.12	11.17	12.14
Nov	15.10	12.23	19.05	25.15	27.30	24.07	29.45	28.02	28.74	31.61	33.04	33.40	25.60	24.98
Dec	17.25	18.69	16.18	26.58	27.30	33.04	34.12	33.04	25.51	15.82	21.20	29.81	24.88	24.97
Jan-00	21.56	17.97	23.71	28.74	26.94	30.17	28.74	29.45	30.89	27.30	29.81	40.94	28.02	27.85
Feb	21.56	22.28	24.79	33.04	31.25	27.66	33.04	28.74	29.10	31.25	27.66	33.04	28.62	28.89
Mar	24.07	24.43	17.61	16.18	15.10	16.18	19.41	20.84	22.28	20.84	23.00	33.04	21.08	23.07
Apr	23.00	19.77	20.48	21.56	18.33	21.92	26.22	28.74	30.17	34.48	31.61	42.73	26.58	28.72
Stn.Avg →	12.42	12.57	12.93	17.83	16.56	17.79	20.77	20.98	21.20	20.88	21.47	28.00	**18.62**	**19.23**
Min	**0.13**	0.19	0.19	1.57	0.75	1.11	1.47	1.75	1.93	0.64	2.29	5.66	1.66	1.61
Max	24.07	30.53	26.94	33.40	31.25	33.04	34.12	33.04	34.12	34.48	33.04	**42.73**	31.25	32.91
SD	10.71	11.08	10.72	11.79	11.09	11.68	11.99	11.23	10.82	11.48	10.56	11.10	10.53	10.78

The monthly averages indicated minimum salinity during monsoon, which can be attributed to the dilution by fresh water runoff. While the maxima during postmonsoon or summer can be ascribed to lack of freshwater flow, evaporation due to high solar radiation and neretic water dominance (Murugan and Ayyakkannu, 1991). After monsoon, only October showed intermediate salinity followed by rise up to 25 ppt. in November. Salinities more than 35ppt. or even 40 ppt. were also evidenced sporadically. According to Cyrus (1986) it is not unusual for some creeks and estuarine systems to reach salinity levels above that of the sea. However, the monthly average salinities in the present-study did not exceed 35 ppt. The post monsoon salinities were in range 25 to 32.9 ppt (Fig. Sl-1) indicating moderate dilution of the incoming seawater which could be due to 145 –260 mld sewage effluents and 15-20 mld industrial effluents from Thane city (TMC-ES report, 2000) and additional from Mumbai suburbs and New Mumbai area along with minor riverine fresh water flow.

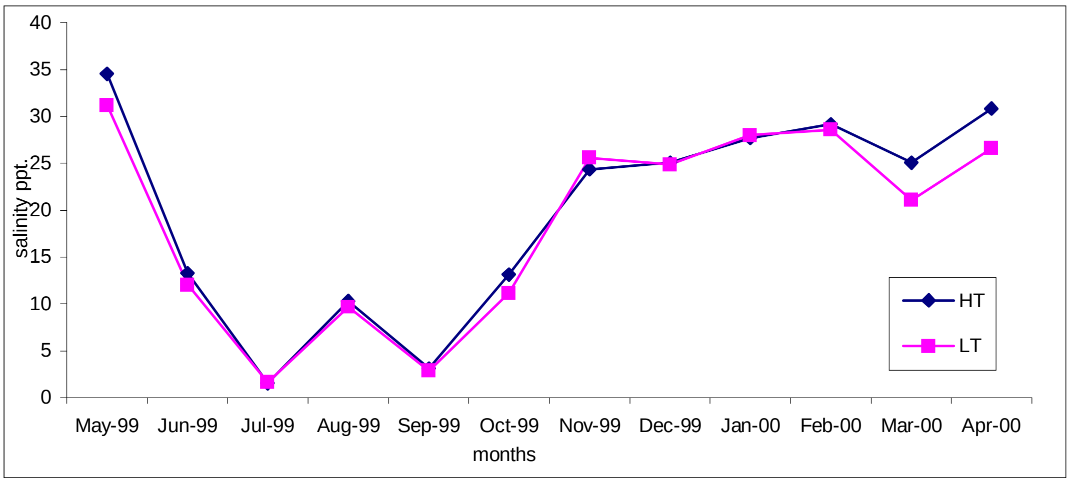


Fig Sl-1 : Monthly variations in the average salinity (ppt.) during high tide and low tide.

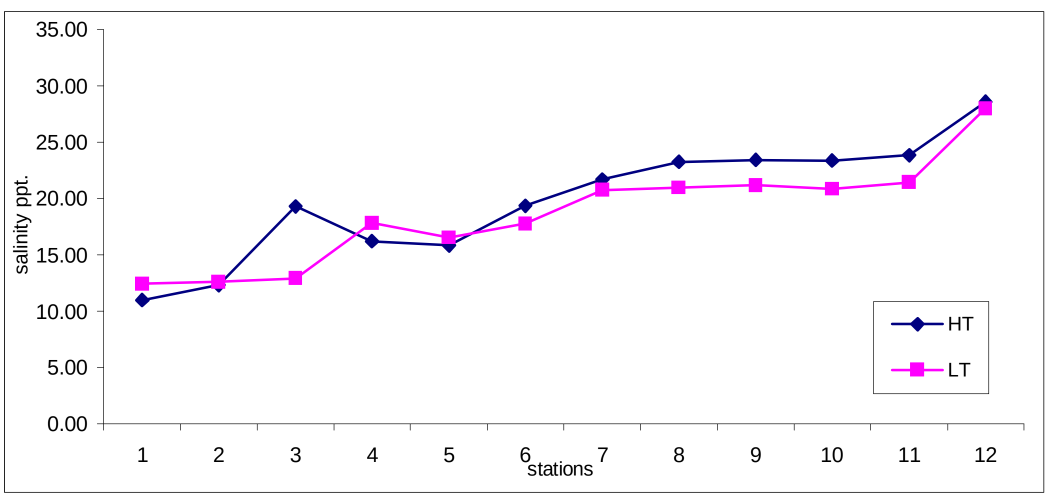


Fig Sl-2 : Stationwise variations in the average salinity (ppt.) during high tide and low tide.

In most estuaries and creeks ebb tides experience lower salinities than flood tides. In the present study the difference between average high tide and low tide salinity was insignificant due to dominance of marine water and homogenous mixing. Low salinities on the riverine end is a common feature of estuaries. Nair & Abdul Aziz (1987), observed that the salinities progressively decreased from the mouth to the riverine end in Asthamudi estuary. Similar observations were made by Alam (1992) and Athalye (1988) in the Malad creek and Thane creek respectively. In the present investigation also similar trend was observed (Fig. Sl-2). Average salinity at stn 1. on the riverine side was 11 ppt. which steadily increased to 28 ppt. at stn 12. on the seaward side.

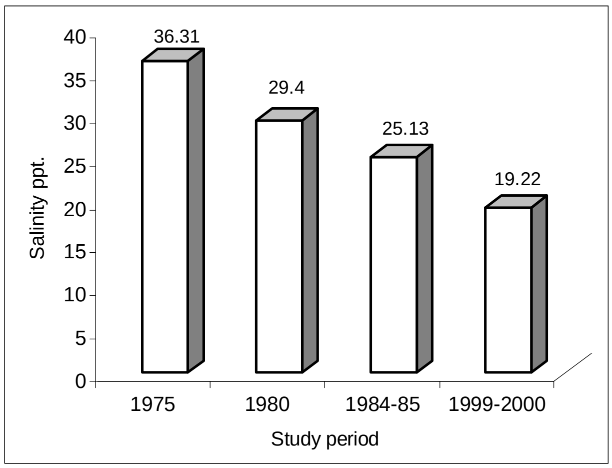


Fig Sl-3: Comparison of the average annual salinity with the past comparable data.

A comparison of the present average with the comparable past data (reported by Govindan ***et al*** 1976; Nair ***et al.***, 1980; Athalye, 1988; Annie Mathew, 1989) as shown in figure Sl-3, indicates a significant gradual lowering of average salinity in past 25 years. As increase in riverine freshwater flow does not seem possible, the change can be attributed to (1) the increased effluent load containing fresh water and (2) reduced flow of tidal marine water due to hinderances created by human activities, especially reclamation, construction of bridges, solid waste dumping etc.

Dissolved oxygen (mg/l)

Dissolved oxygen is most essential element for survival of aquatic flora and fauna. Their respiratory processes which release energy by oxidation of food, consume the dissolved oxygen, whereas photosynthetic processes add oxygen to water. Hence, dissolved oxygen level in water reveals much about the metabolism of water and is used as an index of water quality, primary productivity and pollution. The sources of dissolved oxygen are, from the atmosphere and the photosynthetic processes of the green plants. Active photosynthesis and respiration of planktonic organisms in surface waters can significantly change the oxygen concentration over short periods of time. Moreover, decomposing bacteria, can rapidly remove oxygen from the waters (Levinton, 1982). According to Adeney (1908), bacterial decomposition can many times lead to anoxic conditions in the aquatic ecosystems.

Table D-1: Monthly variations in dissolved oxygen (mg/l) at different stations during high tide

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.
May-99	3.00	0.60	1.00	2.00	2.40	3.00	3.30	2.00	3.50	3.00	3.60	3.50	2.58
Jun	4.40	2.90	1.40	2.80	0.88	2.90	4.60	0.00	5.00	4.40	4.80	4.70	3.23
Jul	6.40	2.70	4.70	2.00	1.70	3.00	3.90	5.90	5.90	5.00	5.20	4.10	4.21
Aug	2.60	0.00	4.40	1.50	1.56	1.84	1.02	2.10	1.98	1.74	1.08	2.16	1.83
Sept	1.06	0.60	0.50	2.90	2.40	2.50	4.60	4.40	4.20	2.80	3.80	4.70	2.87
Oct	3.80	0.36	0.76	2.06	1.48	4.84	3.30	2.42	3.82	1.88	2.58	3.80	2.59
Nov	2.20	0.50	0.50	0.78	3.70	0.90	0.92	1.04	0.90	1.00	1.54	2.80	1.40
Dec	2.10	0.30	0.62	0.74	2.60	4.08	1.36	1.50	1.42	1.44	1.50	2.54	1.68
Jan-00	2.20	0.94	0.52	2.00	1.28	3.20	1.34	1.22	1.20	2.08	3.60	2.50	1.84
Feb	1.36	1.80	0.60	0.86	0.94	3.50	3.30	2.50	3.60	1.20	2.40	1.40	1.96
Mar	2.30	2.20	1.20	4.04	3.58	2.50	1.40	1.02	0.92	0.90	1.56	2.90	2.04
Apr	1.36	0.60	1.46	2.36	3.38	3.54	1.24	2.36	2.30	2.08	1.28	2.20	2.01
Stn.Avg→	2.73	1.13	1.47	2.00	2.16	2.98	2.52	2.21	2.90	2.29	2.75	3.11	**2.35**
Min	1.06	**0.00**	0.50	0.74	0.88	0.90	0.92	**0.00**	0.90	0.90	1.08	1.40	1.40
Max	**6.40**	2.90	4.70	4.04	3.70	4.84	4.60	5.90	5.90	5.00	5.20	4.70	4.21
SD	1.51	1.00	1.48	0.97	1.01	1.02	1.44	1.59	1.68	1.30	1.42	1.05	0.79

As the dissolved oxygen is of paramount importance to maintain the aerobic metabolism in marine organisms, reduced DO values become critical in determining quality of tropical marine waters and their ability to sustain biologically diverse habitats (Laponite & Clark,1992) Federal water pollution control administration of USA has recommended

4mg/l DO as optimum for coastal and estuarine waters (Metcalf & Eddy,1979). In the present study DO ranged between 0 to 7mg/l with an annual average of 2.4 mg/l (Tables D-1 & D-2). The minimum and the maximum values were recorded at the riverine end during monsoon. Dissolved oxygen deficiency as an index of deteriorated water quality, has been widely used in estuarine and coastal waters (Park *et al.*,1996). In Chesapeake bay anoxia was a common feature (Canuel & Zimmerman,1999) and was documented in 1930's (Newcombe & Horne, 1938). In Indian waters anoxia was reported from Ashtamudi estuary, Kadinamakulam Kayal and Malad creek by Nair & Abdul Aziz (1997), Nadan & Abdul Aziz (1990) and Alam (1992) respectively. In the present study also anoxia, was sporadic in its occurance, but hypoxia was prevalent. There is no widely accepted quantitative definition for hypoxia, however, the Common Wealth of Virginia has adopted water quality standard of 5mg/l average daily with no observations below 4mg/l (Park et al, 1996). Taylor and Eggleston (2000), considered DO below 3mg/l as hypoxic, Zimmerman & Canuel (2000) reported DO below 2mg/l as hypoxic, where as Laponite and Clark (1992) considered DO < 2.5 mg/ l as hypoxic in nutrient enriched aquatic system. Thane creek being highly nutrient rich (description ahead), DO values below 2.5 mg/l were considered to be hypoxic (Quadros, 1995). In the present investigation (Fig. D-1), baring a few high DO values of monsoon, the dissolved oxygen was perpetually below 2.5 mg/l.

Table D-2: Monthly variations in dissolved oxygen (mg/l) at different stations during low tide

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	HT & LT avg.
May-99	2.90	2.50	1.50	0.80	0.40	1.00	1.40	2.10	2.80	2.00	1.50	3.30	1.85	2.21
Jun	5.90	4.40	2.20	1.80	1.40	3.50	2.40	5.20	3.00	4.60	2.40	3.90	3.39	3.31
Jul	7.00	4.80	4.00	1.60	0.80	5.30	2.80	6.80	4.80	6.90	3.70	4.50	4.42	4.31
Aug	4.20	1.40	3.20	0.60	1.00	2.30	2.50	3.50	0.86	1.50	1.56	2.34	2.08	1.96
Sept	5.40	2.50	1.00	0.60	0.40	0.70	1.60	2.40	2.20	2.70	2.50	5.50	2.29	2.58
Oct	3.00	0.56	1.80	0.80	1.30	3.40	4.00	6.50	1.26	3.80	2.90	2.50	2.65	2.62
Nov	5.80	0.90	1.90	5.40	5.50	0.74	0.90	3.40	2.20	2.50	1.54	3.10	2.82	2.11
Dec	2.20	0.82	0.72	3.90	1.80	2.50	2.40	2.10	1.42	4.40	1.18	2.34	2.15	1.92
Jan-00	2.40	3.30	2.48	0.80	0.80	1.00	1.60	2.10	2.70	1.90	1.60	2.80	1.96	1.90
Feb	4.00	1.04	2.04	0.70	0.50	1.00	1.30	2.40	1.70	1.60	0.40	1.50	1.52	1.74
Mar	2.00	1.04	0.60	6.70	2.40	1.44	0.90	3.40	1.06	1.20	2.80	3.10	2.22	2.13
Apr	3.40	1.16	1.10	0.90	0.00	2.20	3.30	3.50	1.20	2.20	2.00	2.50	1.96	1.98
Stn.Avg →	4.02	2.04	1.88	2.05	1.36	2.09	2.09	3.62	2.10	2.94	2.01	3.12	**2.44**	**2.40**
Min	2.00	0.56	0.60	0.60	**0.00**	0.70	0.90	2.10	0.86	1.20	0.40	1.50	1.52	1.74
Max	**7.00**	4.80	4.00	6.70	5.50	5.30	4.00	6.80	4.80	6.90	3.70	5.50	4.42	4.31
SD	1.66	1.46	1.01	2.10	1.47	1.41	0.97	1.68	1.12	1.68	0.89	1.08	0.80	0.74

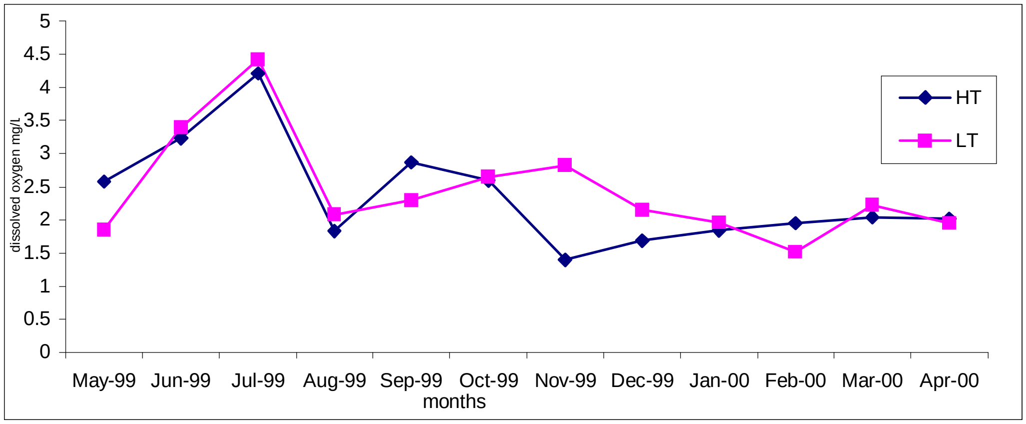


Fig. D-1: Monthly variations in the average dissolved oxygen (mg/l) during high tide and low tide.

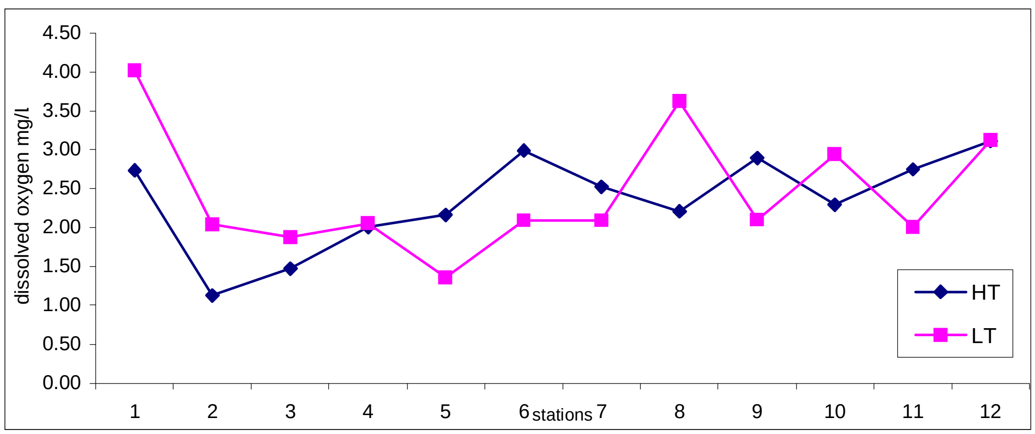


Fig. D-2: Stationwise variations in the average dissolved oxygen (mg/l) during high tide and low tide.

Comparison between the high tide and the low tide averages revealed marginally higher DO during the low tide. Similar observations were also recorded by Qasim & Sengupta (1981), in the Mandovi and Zuari estuaries. The higher values during low tide can be attributed to lower salinity allowing more dissolution of oxygen. Alam (1992) reported high dissolved oxygen in Malad creek at the seaward end compared to the riverine end and attributed it to the difference in the sewage load. In the present study stationwise comparison indicated an increasing trend of DO concentration from the riverine to the seaward end (Fig.D-2). The lower dissolved oxygen at the riverine end can be attributed to accumulation of the pollutants, as this part is narrow, shallow and much away from the mouth, so the pollutants are not properly flushed out.

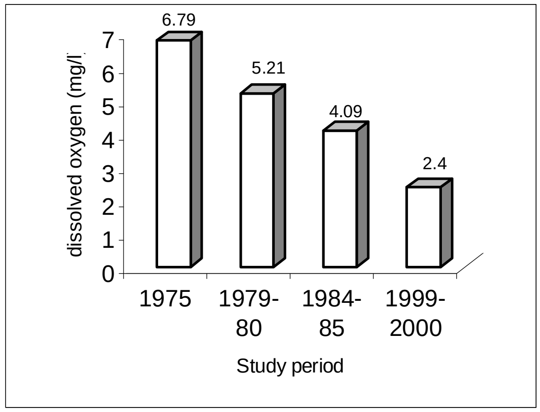


Fig. D-3: Comparison of the annual average dissolved oxygen with the past comparable data of Thane creek.

According to Zimmerman and Caunel (2000), cultural eutrophication (i.e. anthropogenically induced) results in anoxic or hypoxic conditions and is cited as the most important environmental problems. Urbanization and industrialization around Thane creek has severely affected the water quality of the creek. It is indicated from the comparison of the present average dissolved oxygen with the past available data for the entire creek (reported by Govindan *et al.* 1976; Varshney, 1982; Athalye, 1988 and Annie Mathew, 1989) (Fig D-3). The gradual decline from healthy to hypoxic conditions can be attributed to the growing exploitation of the creek ecosystem to release domestic sewage, industrial effluents, and other pollutants and dumping of solid wastes.

Phosphate-Phosphorus ($P0_4$-P)

The study of phosphorus according to Ketchum (1967), helps in determining the state of primary production in water bodies. In aquatic ecosystem phosphorus mainly occurs as dissolved inorganic phosphorus, dissolved organic phosphorus and particulate phosphorus. The primary producers and other biological processes in the water transform the inorganic phosphorus into dissolved and particulate organic phosphorus (Lemasson and Pages,1981). Further, according to Fisher *et al.*(1988), the industrialization of land and coastal waterways has led to a wide spread increase in the phosphorus concentration in estuaries. The urbanization and agricultural advancement have added to this and increased the phosphorus level of many estuaries. Recent studies have indicated that some estuarine systems function as conduits for phosphorus transport to coastal waters (Norvick & Oviatt, 1990).

Table P-1: Monthly variations in Phosphate-Phosphorus (mg/l) at different stations during high tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.
May-99	0.250	0.632	0.452	0.436	0.430	0.366	0.422	0.179	0.250	0.296	0.296	0.125	0.345
Jun	0.109	0.242	0.273	0.281	0.242	0.257	0.234	0.140	0.211	0.203	0.187	0.109	0.207
Jul	0.078	0.203	0.195	0.378	0.429	0.460	0.172	0.211	0.289	0.148	0.121	0.109	0.233
Aug	0.121	0.460	0.312	0.429	0.499	0.359	0.062	0.109	0.101	0.062	0.101	0.090	0.226
Sept	0.039	0.351	0.230	0.218	0.328	0.187	0.211	0.218	0.126	0.179	0.187	0.078	0.196
Oct	0.067	0.257	0.195	0.203	0.413	0.172	0.056	0.034	0.019	0.016	0.020	0.020	0.123
Nov	0.250	0.374	0.312	0.462	0.437	0.336	0.339	0.328	0.211	0.078	0.269	0.053	0.287
Dec	0.257	0.530	0.394	0.491	0.441	0.367	0.297	0.257	0.179	0.180	0.367	0.098	0.322
Jan-00	0.320	0.421	0.460	0.390	0.413	0.281	0.421	0.335	0.242	0.300	0.250	0.145	0.332
Feb	0.203	0.632	0.452	0.437	0.398	0.406	0.343	0.320	0.335	0.281	0.320	0.129	0.355
Mar	0.218	0.663	0.464	0.632	0.319	0.468	0.179	0.179	0.222	0.063	0.078	0.125	0.301
Apr	0.242	0.632	0.503	0.437	0.421	0.425	0.328	0.238	0.257	0.257	0.328	0.119	0.349
Stn.Avg→	0.180	0.450	0.354	0.400	0.398	0.340	0.255	0.213	0.204	0.172	0.210	0.100	**0.273**
Min	0.039	0.203	0.195	0.203	0.242	0.172	0.056	0.034	0.019	**0.016**	0.020	0.020	0.123
Max	0.320	**0.663**	0.503	0.632	0.499	0.468	0.422	0.335	0.335	0.300	0.367	0.145	0.355
SD	0.092	0.168	0.114	0.120	0.069	0.098	0.124	0.092	0.087	0.100	0.112	0.035	0.074

Table P-2: Monthly variations in Phosphate-Phosphorus (mg/l) at different stations during low tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	HT & LT avg.
May-99	0.274	0.496	0.422	0.358	0.452	0.430	0.504	0.328	0.282	0.336	0.328	0.172	0.365	0.35
Jun	0.051	0.101	0.250	0.234	0.234	0.133	0.117	0.109	0.211	0.203	0.203	0.086	0.161	0.18
Jul	0.062	0.078	0.101	0.250	0.328	0.140	0.191	0.191	0.121	0.265	0.070	0.039	0.153	0.19
Aug	0.133	0.449	0.296	0.250	0.296	0.328	0.211	0.211	0.082	0.062	0.070	0.101	0.207	0.22
Sept	0.018	0.018	0.088	0.250	0.242	0.133	0.300	0.187	0.218	0.230	0.179	0.059	0.160	0.18
Oct	0.195	0.234	0.199	0.117	0.101	0.211	0.230	0.105	0.086	0.059	0.112	0.052	0.142	0.13
Nov	0.139	0.367	0.261	0.273	0.343	0.335	0.710	0.250	0.289	0.187	0.128	0.103	0.282	0.28
Dec	0.218	0.273	0.421	0.296	0.367	0.296	0.281	0.281	0.280	0.273	0.320	0.105	0.284	0.30
Jan-00	0.273	0.530	0.378	0.359	0.351	0.335	0.304	0.203	0.312	0.265	0.367	0.172	0.321	0.33
Feb	0.234	0.328	0.452	0.351	0.374	0.378	0.339	0.308	0.398	0.335	0.441	0.139	0.340	0.35
Mar	0.277	0.495	0.745	0.355	0.183	0.406	0.234	0.328	0.339	0.006	0.003	0.144	0.293	0.30
Apr	0.273	0.402	0.425	0.363	0.601	0.406	0.273	0.359	0.324	0.250	0.296	0.108	0.340	0.34
Stn.Avg→	0.179	0.314	0.337	0.288	0.323	0.294	0.308	0.238	0.245	0.206	0.210	0.107	**0.254**	**0.26**
Min	0.018	0.018	0.088	0.117	0.101	0.133	0.117	0.105	0.082	0.006	**0.003**	0.039	0.142	0.13
Max	0.277	0.530	**0.745**	0.363	0.601	0.430	0.710	0.359	0.398	0.336	0.441	0.172	0.365	0.35
SD	0.096	0.175	0.180	0.074	0.129	0.112	0.158	0.085	0.103	0.109	0.138	0.044	0.084	0.08

In the present investigation $P0_4$-P ranged between 0.003 to 0.745mg/l with an annual average of 0.26 mg/l (Tables P-1 & P-2). The minimum and the maximum concentrations were recorded in March 2000 at the seaward and riverine ends respectively. This range and the average are intermediate compared to the other Indian estuaries (Quadros, 1995). The estuaries like Changjiang (Tian *et al.*, 1993); Edaiyur & Sadras estuarine system

(Nair & Ganapati, 1983); Creek & Coastal waters of Gopalpur (Choudhary & Panigrahy, 1991); Hooghly esturary (Vaithiyanathan *et al.*, 1993; De *et al.*, 1994); Kollidam estuary (Edward & Ayyakkannu,1991); Mahanadi estuary (Sengupta & Upadhyay, 1987); Mandovi – Zuari estuary (Qasim & Sengupta,1981); Uppanar backwaters (Murugan & Ayyakkannu, 1991) etc. have shown much lower $P0_4$-P than Thane creek, while Asthamudi estuary (Nair & Abdul Aziz, 1987) Cochin backwaters (Lakshaman *et al.*,1987); Malad creek (Alam,1992) & Ollipuramkadavu Backwaters (Ramkrishna *et al.*,1987) had much higher $P0_4$-P.

A tide wise comparison revealed marginally higher averages of $P0_4$-P during high tide than low tide. However, the difference was not significant. Similar observation has been recorded by Qasim & Gopinathan (1969), in Cochin backwaters and Singbal (1973) in Zuari estuary. In contrast higher P04-P values during low tide have been recorded by Alam (1992), in Malad creek; Dehadri (1970), for Zuari & Mandovi estuaries; Vijayalakshmi & Venugopalan (!973), for Zuari estuary and Quadros (1995) for the upstream stretches of Thane creek.

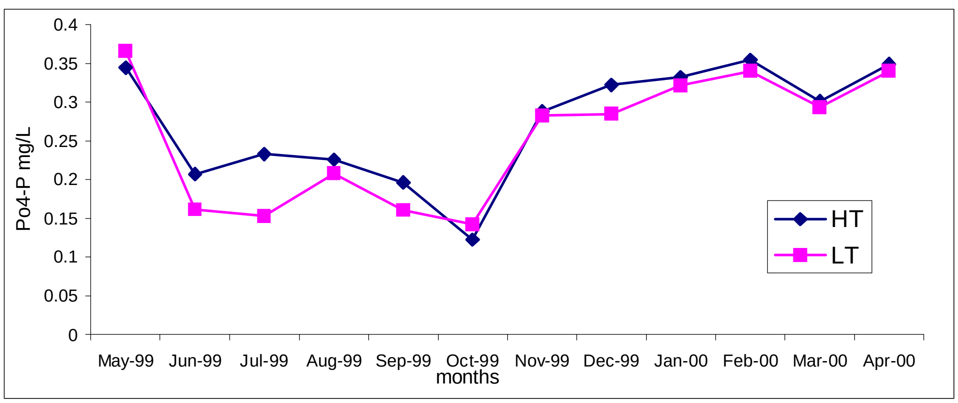


Fig. P-1: Monthly variations in the average Phosphate Phosphorus (mg/l) during high tide and low tide.

The seasonal variations (Fig P-1) indicated lower $P0_4$-P during the monsoon season followed by an increasing trend from October to May. Lowering of $P0_4$-P during monsoon has been recorded in some estuaries like Mahanadi, Hooghly estuary, Periyar estuary & Netravati estuary by Upadhyay (1988), Vaithiyananthan *et al.* (1993), Sarala Devi *et al.* (1991) & Nagarajaiah & Gupta (1983) respectively. The low monsoon phosphate was attributed to high sediment load during the rainy season favoring adsorption and removal of phosphates. Ramaraju *et al.* (1987), have reported station to station fluctuations in phosphate in Visakhapatnam harbour. In the present investigation also stationwise fluctuations were evident. The concentration was high on the riverine end which declined towards the seaward end (Fig. P-2). This can be attributed to sewage pollution in the creek. Due to more water mass at the downstream station the sewage got more diluted leading to a decreasing trend towards the sea.

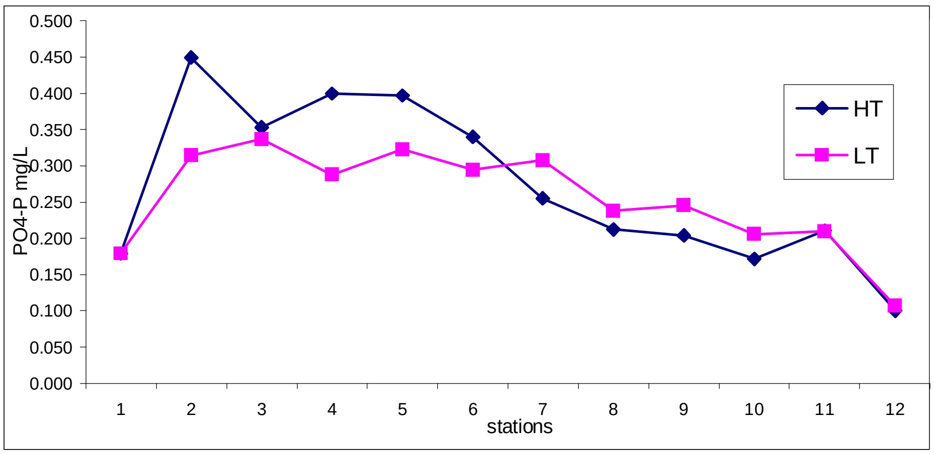


Fig. P-2: Stationwise variations in the average Phosphate –Phosphorus (mg/l) during high tide and low tide.

According to Lebo & Sharp (1992), the phosphorus cycle in estuaries is complicated due to its rapid biological and geochemical reactivity. In addition to physical mixing, the dissolved inorganic phosphate is removed geochemically and biologically, released from seston & from bottom sediments and regenerated biologically. The estuarine sediments also have a significant influence on the phosphorus concentration of the overlying water column by virtue of their capacity to release phosphorus under changing environmental conditions (Vaithiyananthan *et al.*, 1993). In the Thane creek the concentration of $P0_4$-P in general was much high as compared to 0.09 mg/l, the limit of unpolluted waters as given by Yentsch & Ryther (1957). According to Hubertz & Cahoon (1999), nutrient loading is one form of anthropogenic stress to estuarine ecosystems, and in shallow systems the responses are more rapid and distinct than deeper waters.

Comparison between the average PO4-P concentration of the present study with the previous comparable available data is shown in the Fig.P-3. It can be seen that in the past

20 years there is a gradual but significant rise in the PO4-P concentration indicating the growing pollution in the creek

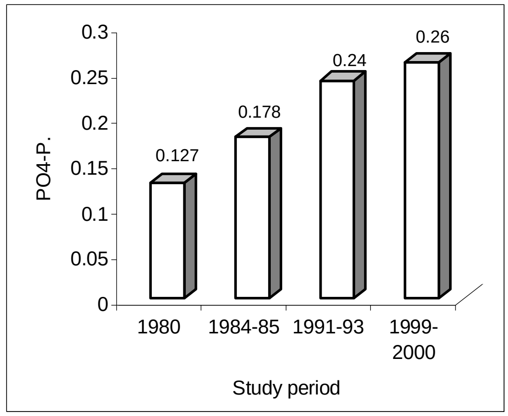


Fig. P-3: Comparison of the annual average PO4-P (mg/l) with the past comparable data.

Nitrate nitrogen ($N0_3$-N).

Nitrogen is a parameter that significantly affects phytoplankton growth in natural waters. In an aquatic biotope inorganic nitrogen is present as oxidized nitrite ($N0_2$) and nitrate ($N0_3$) and as reduced ammonia (NH_4) the most abundant form being nitrate (Nair *et al.*, 1983; Athalye 1988). According to Strickland (1965), shortage of nitrogen is responsible for even stopping the growth of phytoplankton. On the contrary enhanced anthropogenic nitrogen inputs to estuaries and coastal seas may affect nitrogen cycle in these ecosystems and disturb their functioning (Middleburg and Nieuwenhuize, 2000). The disturbances include eutrophication, changes in phytoplankton community structure, enhanced production and release of nitrous oxide (Jickells,1998).

In the present investigation $N0_3$-N varied between 0.126 to 3.168 mg/l with an average of 0.96 mg/l. Similar and exceptionally higher values were recorded in the earlier studies on Thane creek by Goldin (1995) and were attributed to pollution load. In the present study low NO3-N values were recorded during the monsoon season and high values were observed during the post monsoon (Fig. N-1) Usually in unpolluted estuaries, fresh water runoff in the monsoon season brings a fresh pulse of nutrients to increase them significantly. These nutrients then decline in the post monsoon due to utilization by the producers and other organisms. In polluted estuaries however, the initial nutrient level is so high that even the nutrient rich fresh water has a diluting effect. Thus the above seasonal trend observed in Thane creek could be due to the pollution in the creek.

According to Raman & Ganapati (1986), NO3-N levels 0.014 mg/l and 1.26 mg/l indicate unpolluted and semihealthy environments respectively. In the present study NO3-N values indicating unpolluted conditions were not recorded and the average (0.96 mg/l) indicated semihealthy condition.

Table N-1: Monthly variations in Nitrate-Nitrogen (mg/l) at different stations during high tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.
May-99	1.006	1.509	1.257	1.509	1.509	1.509	1.257	1.257	1.006	1.006	1.257	0.754	1.236
Jun	0.754	0.503	0.754	0.503	0.503	0.503	0.503	0.754	0.754	0.754	0.754	0.503	0.629
Jul	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.503	0.251	0.503	0.293
Aug	0.503	0.126	0.503	0.754	0.754	1.257	1.257	1.257	1.509	1.257	1.006	1.006	0.932
Sept	0.251	0.754	0.754	0.251	0.251	0.503	0.503	0.251	0.251	0.503	0.503	0.503	0.440
Oct	1.257	1.006	1.257	2.263	0.754	1.257	1.257	0.503	1.006	1.257	1.257	0.503	1.131
Nov	1.458	0.603	0.930	0.729	3.168	1.207	1.257	1.559	1.383	1.333	2.816	0.855	1.442
Dec	1.081	0.528	0.654	0.704	0.578	0.679	0.754	0.779	0.729	1.584	1.408	1.106	0.882
Jan-00	0.855	0.805	1.282	1.182	0.905	1.433	2.112	1.257	1.282	1.131	1.006	1.056	1.192
Feb	1.031	0.629	1.056	0.855	0.629	1.936	0.729	0.629	0.880	0.729	0.679	1.106	0.907
Mar	2.414	1.685	1.509	1.433	1.282	1.131	1.358	1.131	1.106	1.081	1.358	1.257	1.395
Apr	0.981	2.313	1.131	1.207	1.131	1.207	1.106	0.729	1.106	1.131	1.006	0.880	1.161
Stn.Avg→	0.987	0.893	0.945	0.970	0.976	1.073	1.029	0.863	0.939	1.022	1.108	0.836	**0.970**
Min	0.251	**0.126**	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.503	0.251	0.503	0.293
Max	2.414	2.313	1.509	2.263	**3.168**	1.936	2.112	1.559	1.509	1.584	2.816	1.257	1.442
SD	0.582	0.640	0.370	0.581	0.790	0.491	0.506	0.426	0.397	0.337	0.643	0.279	0.364

Table N-2: Monthly variations in Nitrate-Nitrogen (mg/l)at different stations during low tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	Ht & Lt Avg.
May	1.257	1.509	1.257	1.006	1.257	1.760	1.257	1.509	1.509	1.257	1.006	1.006	1.299	1.27
Jun	0.503	0.754	0.503	1.006	0.754	0.754	0.754	0.754	1.006	0.754	1.006	0.754	0.775	0.70
Jul	0.251	0.251	0.251	0.503	0.251	0.251	0.251	0.503	0.251	0.251	0.126	0.754	0.325	0.31
Aug	0.251	0.754	0.503	1.006	0.754	1.006	0.251	0.754	0.503	0.251	0.251	0.503	0.566	0.75
Sept	0.503	0.503	0.754	0.251	0.251	0.251	0.503	0.251	0.503	0.251	0.251	1.006	0.440	0.44
Oct	0.251	1.257	0.251	0.754	0.503	0.251	1.509	1.006	0.503	1.006	0.754	0.251	0.691	0.91
Nov	2.062	1.358	1.408	2.766	1.031	2.841	1.131	1.735	1.659	1.358	2.615	2.162	1.844	1.64
Dec	1.031	0.779	1.659	0.679	0.603	0.981	0.629	1.584	1.961	0.679	0.805	1.282	1.056	0.97
Jan	0.603	0.905	1.282	1.509	1.081	1.433	1.131	1.534	0.905	0.955	0.981	1.609	1.161	1.18
Feb	1.785	0.855	1.282	0.704	0.603	0.779	0.629	0.629	0.578	1.257	0.603	0.981	0.890	0.90
Mar	0.779	0.754	0.654	1.483	1.358	1.031	1.333	1.509	1.458	1.534	1.458	1.509	1.238	1.32
Apr	1.106	1.182	1.257	2.539	0.955	0.603	0.981	0.779	0.126	0.981	1.157	1.408	1.090	1.13
Stn.Avg→	0.865	0.905	0.922	1.184	0.784	0.995	0.863	1.046	0.914	0.878	0.918	1.102	**0.948**	**0.96**
Min	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.126	0.251	**0.126**	0.251	0.325	0.31
Max	2.062	1.509	1.659	2.766	1.358	**2.841**	1.509	1.735	1.961	1.534	2.615	2.162	1.844	1.64
SD	0.602	0.362	0.488	0.777	0.362	0.745	0.421	0.502	0.602	0.449	0.668	0.525	0.424	0.38

Stationwise variation has been shown in Fig. N-2. In general NO3-N values were lower during low tide except at stations 4, 8 & 12. This can be attributed to the proximity of these stations with sewage or effluent source on the upstream direction. High NO3-N during high tide could be due to upstream transport of pollutant load. The average NO3-N of high tide & Low tide did not differ significantly.

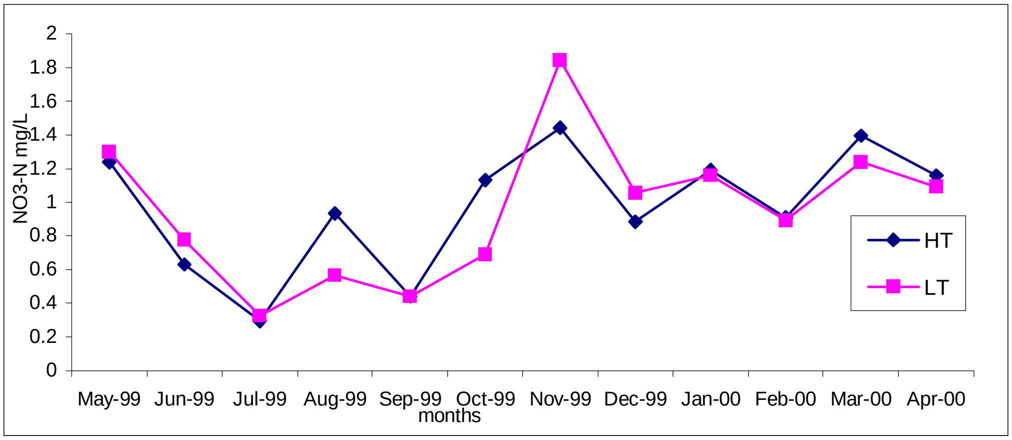


Fig.N-1: Monthly variations in the average Nitrate-Nitrogen (mg/l) during high tide and low tide.

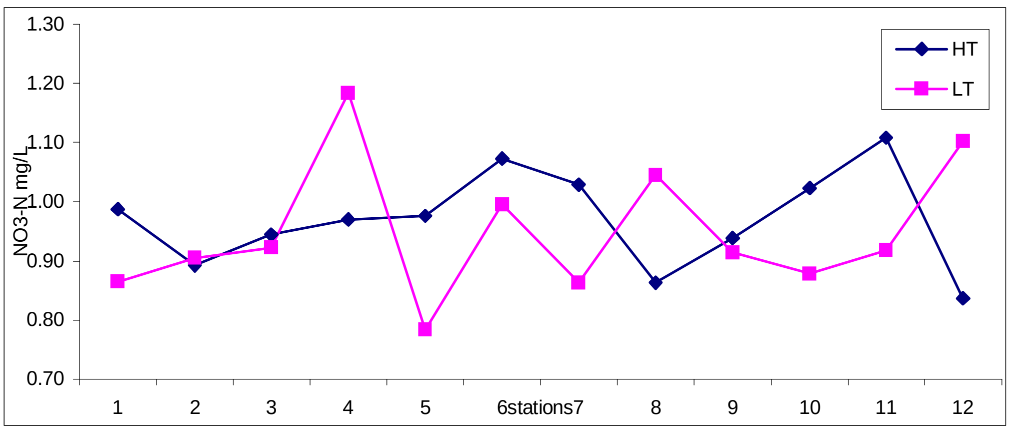


Fig.N-2: Stationwise variations in the average Nitrate-Nitrogen (mg/l) during high tide and low tide.

Goldin (1995), in his studies on upstream region of Thane creek during period 1991-93 observed wide fluctuations in NO3-N and also reported exceptionally high nitrates. Similar observations were also reported by Varshney (1987) who attributed them to release of some nitrate rich effluent in the creek. Sarala Devi *et al.* (1991) also observed high NO3-N in Periyar river estuary due to effluent discharge & non point sources in the system itself. Fig.N-3 shows comparable averages of NO3-N (in the upstream region of

Thane creek) during 1984-85 (Tandel.1986, Pejaver, 1987 & Athalye, 1988), 1991-93 (Goldin, 1995)and 1999-2000 (present study)highlighting very high NO3-N during period 1991 –93. However, if we look at the comparison of the data in Fig N-4. It becomes apparent that the NO3-N has significantly increased after 1985 in the down stream stretches of Thane creek.

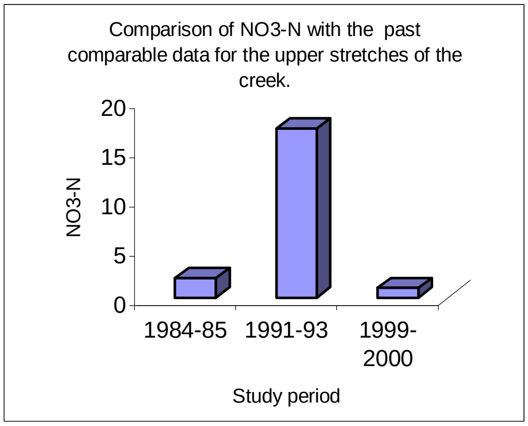


Fig. N-3: Comparison of the annual average NO3-N data with the past comparable data for the upper stretches of Thane creek.

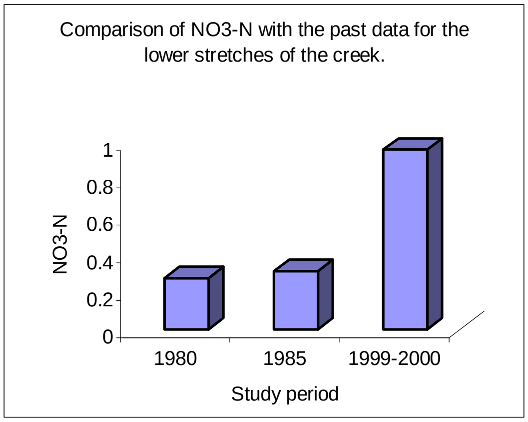


Fig.N-4: Comparison of the annual average NO3-N data with the past comparable data for the downstream stretches of Thane creek

Silicate Silicon (Si0$_3$-Si)

Silicon is the most abundant element in the earths' crust, it is known to be an important plant nutrient (Balls, 1992). According to Alam (1992), silica is an essential element for the growth of certain organisms like diatoms and radiolarions which secrete intricate shells made of silica. Further, Egge & Aksenes (1992) contented that the availability of dissolved silicates is one of the most important factors that can regulate the species composition of phytoplankton assemblage. When dissolved silicates are abundant, diatom phytoplankton become dominant, whereas, when silicates become low, the non-diatom phytoplankton can dominate the algal community and decrease the relative importance of diatoms.

In the present study the Si0$_3$-Si ranged from 1.65 - 66.7 mg/l with an annual average of 15.3 mg/l. As compared to other Indian estuaries like Bahuda estuary (Mishra *et al.*, 1993); Mahanadi estuary (Sengupta & Upadhyay, 1987); Nethravati estuary (Nagarajiah and Gupta,1983); Malad creek (Alam,1992); Uppanar backwaters (Anirudhan *et al.*, 1987), the range of Si0$_3$-Si in the present case is very wide and the average is very high. The minimum values were observed during the monsoon and the high values during nonmonsoon. According to Biggs & Cronin (1981) in Indian estuaries silicates show a strong pulse during monsoon & the high concentration persist through the post monsoon period. In Thane creek the low monsoon values can be attributed to dilution caused by fresh water influx.

Table Si-1: Monthly variations in Silicate-Silicon (mg/l) at different stations during high tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.
May-99	8.25	34.80	13.20	9.90	9.90	16.30	9.90	3.30	12.50	9.41	8.25	7.43	11.93
Jun	9.90	6.60	8.25	4.95	8.25	6.60	9.90	4.95	3.30	3.30	9.90	3.30	6.60
Jul	14.85	13.20	6.60	3.30	3.30	4.95	4.95	1.65	1.65	3.30	3.30	1.65	5.23
Aug	6.60	8.25	3.30	8.25	13.20	8.25	4.95	6.60	4.95	4.95	3.30	4.95	6.46
Sept	13.20	9.90	13.20	9.90	6.60	9.90	1.65	6.60	3.30	6.60	6.60	6.60	7.84
Oct	38.78	40.92	31.02	17.33	49.34	13.37	22.94	7.10	8.75	9.90	12.71	22.11	22.85
Nov	29.21	34.82	6.60	23.93	18.32	13.37	15.84	9.57	5.78	3.80	6.60	2.97	14.23
Dec	28.38	45.21	31.35	33.33	15.35	29.21	19.47	15.02	24.92	16.67	23.10	7.43	24.12
Jan-00	22.77	22.44	32.51	20.96	26.90	14.19	23.10	8.58	12.54	11.39	9.74	15.68	18.40
Feb	15.02	66.66	44.88	35.31	27.56	24.26	25.25	21.12	20.79	19.14	18.15	5.78	26.99
Mar	10.23	39.93	25.58	25.58	24.42	16.34	24.75	16.67	16.17	9.41	8.58	10.23	18.99
Apr	6.27	53.13	26.57	16.50	11.88	21.62	12.38	4.13	10.56	12.38	9.74	11.88	16.42
Stn.Avg→	16.95	31.32	20.25	17.44	17.92	14.86	14.59	8.77	10.43	9.19	10.00	8.33	15.00
Min	6.27	6.60	3.30	3.30	3.30	4.95	1.65	1.65	1.65	3.30	3.30	1.65	5.23
Max	38.78	**66.6**6	44.88	35.31	49.34	29.21	25.25	21.12	24.92	19.14	23.10	22.11	26.99
SD	10.47	19.35	13.37	10.65	12.68	7.28	8.46	5.90	7.34	5.17	5.75	5.89	7.50

Table Si-1: Monthly variations in Silicate-Silicon (mg/l) at different stations during Low tide.

Months ↓	Stn-1	Stn-2	Stn-3	Stn-4	Stn-5	Stn-6	Stn-7	Stn-8	Stn-9	Stn-10	Stn-11	Stn-12	Avg.	Ht & Lt Avg.
May-99	14.90	39.90	13.20	17.30	31.70	17.30	8.25	4.13	15.20	11.90	13.20	14.50	16.79	14.36
Jun	6.60	4.95	6.60	6.60	4.95	8.25	4.95	4.95	6.60	6.60	3.30	3.30	5.64	6.12
Jul	11.55	9.90	4.95	6.60	6.60	4.95	3.30	3.30	3.30	3.30	3.30	3.30	5.36	5.29
Aug	13.20	1.65	1.65	3.30	3.30	8.25	4.95	4.95	4.95	1.65	6.60	8.25	5.23	5.84
Sept	9.90	14.85	13.20	8.25	9.90	8.25	9.90	4.95	3.30	6.60	3.30	4.95	8.11	7.98
Oct	41.75	37.46	45.21	35.97	31.68	17.33	19.97	12.38	10.23	11.88	12.71	14.52	24.26	23.55
Nov	18.98	39.93	20.96	29.04	14.03	12.05	5.61	10.23	14.85	6.27	5.78	2.15	14.99	14.61
Dec	25.74	21.12	32.01	19.14	29.37	19.80	14.52	14.03	12.87	10.56	11.22	8.75	18.26	21.19
Ja-00n	29.54	20.79	18.32	17.99	20.63	11.88	15.02	16.67	15.18	13.20	20.46	13.37	17.75	18.07
Feb	18.98	38.61	51.32	23.76	29.54	34.49	24.09	28.38	22.77	25.25	34.82	9.41	28.45	27.72
Mar	15.35	22.28	37.79	19.31	31.35	23.60	18.15	21.62	14.69	11.72	9.90	11.39	19.76	19.37
Apr	24.26	26.90	35.48	19.47	40.43	24.59	17.00	21.29	10.73	18.65	15.18	17.33	22.61	19.51
Stn.Avg→	19.23	23.19	23.39	17.23	21.12	15.89	12.14	12.24	11.22	10.63	11.65	9.27	**15.60**	**15.30**
Min	6.60	**1.65**	**1.65**	3.30	3.30	4.95	3.30	3.30	3.30	**1.65**	3.30	2.15	5.23	5.29
Max	**41.75**	39.93	51.32	35.97	40.43	34.49	24.09	28.38	22.77	25.25	34.82	17.33	28.45	27.72
SD	9.80	13.71	16.56	9.76	12.81	8.66	6.89	8.32	5.88	6.57	9.06	5.07	7.91	7.56

In earlier studies on the Thane creek near Thane city Goldin (1995) observed maximum $Si0_3$-Si to be 34.82 mg/l. It has been consistently observed in past studies since 1980 that the maxima of $Si0_3$-Si and the averages showed an increasing trend indicating build up of $Si0_3$-Si (Fig. Si-1). This could be due to reason that the rocks and the earth crust of Thane region is said to be derived from volcanic rocks (Tandale,1993) which are rich in silica. The other reason could be, the sand dredging activity in Ulhas river which is connected to Thane creek. But the increase since 1993 is very high and if we try to trace the reason, it becomes apparent that in past 7 years there has been a tremendous increase in the human activities such as the construction of bridges & roads, solid waste disposal along the mangrove swamps and other reclamation activities. Because of these activities siltation in the creek has significantly increased (discussed in the next chapter). However, to decide the exact reason a detailed study of this nutrient is needed.

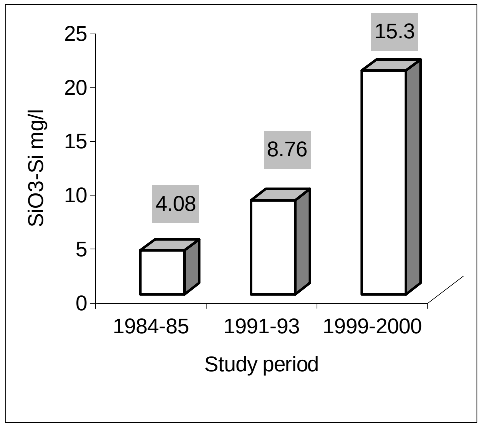


Fig.Si-1: Comparison of SiO_3-Si with the past comparable data.

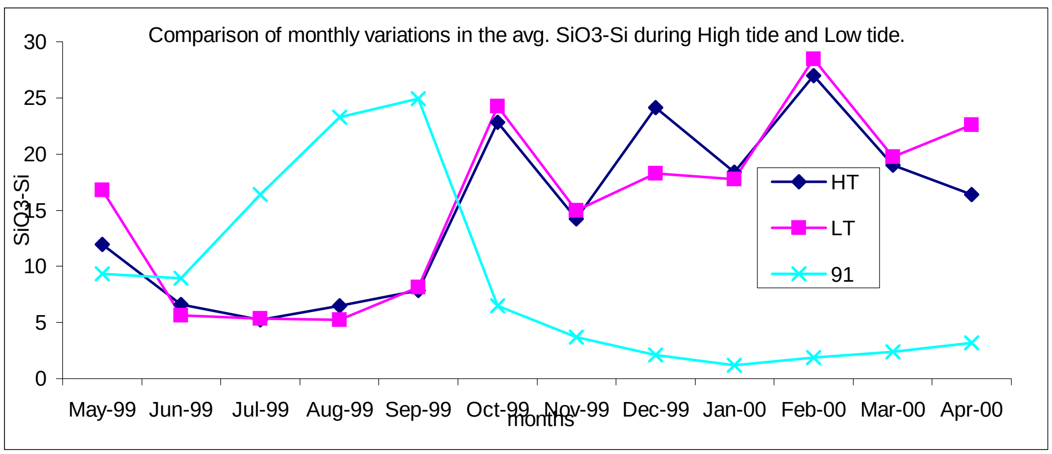


Fig. Si-2: Monthly variations in the average Silicate-Silicon (mg/l) during high tide and low tide.

It is interesting to note another change in the behaviour of $Si0_3$-Si. Previously, Athalye (1988) and Goldin (1995) observed increase in $Si0_3$-Si during monsoon due to input from runoff and then its decline in post monsoon due to utilization by diatom bloom (Fig Si – 2). This trend is characteristic of most Indian estuaries (Alam 1992). In the present investigation the $Si0_3$-Si showed reduction in monsoon due to dilution and increase in the post monsoon (Fig. Si-2). Is this change also due to the increased construction activities and siltation in the creek, remains a question.

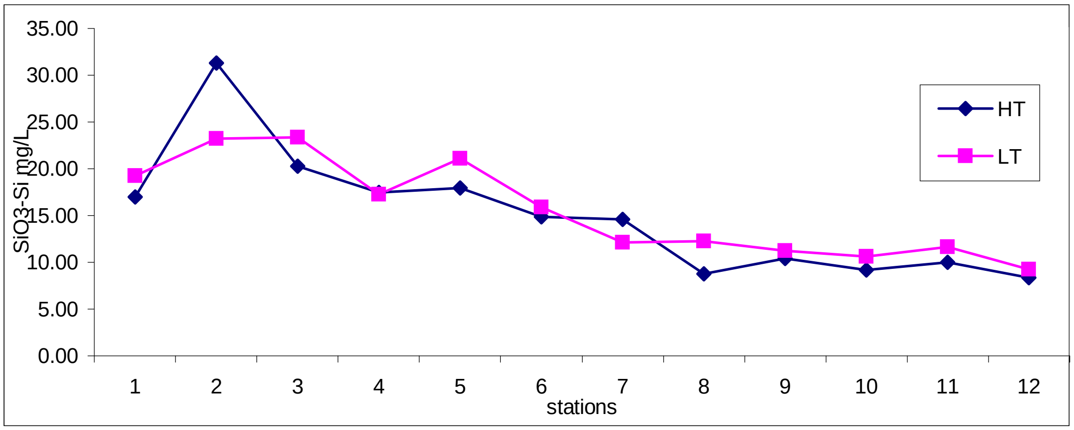


Fig. Si-3: Stationwise variations in the average Silicate-Silicon (mg/l) during high tide & low tide.

The station wise comparison (Fig. Si-3) revealed high concentration of $Si0_3$-Si at the riverine end which gradually decreased towards the seaward end. Though high $Si0_3$-Si on the riverine side is attributed to fresh water influence and low $Si0_3$-Si on seaward end to high salinity& fascilitated adsorption of $Si0_3$-Si on particulate matter and its precipitation (D'Souza, 1999); in present case it could be due to the higher construction and reclamation activities in the narrow & shallow riverine end near Thane city as compared to the seaward end. This caused more pollution of the upstream regions and the pollutants were not diluted due to the less amount of tidal water in this region which is away from the mouth.

Hence, it can be said that the behaviour of $Si0_3$-Si and the reason for its build up in the creek need to be investigated by careful and specific studies.

Summary

In conclusion, following hydrological characteristics of Thane creek are important to note.

1. Wide fluctuation in temperature and its wide range due to shallowness of the creek.
2. Very high suspended solids and reduced light penetration due to them.
3. General lowering of average pH as compared to the past data.
4. Change in salinity profile suggesting increased effluent load and reduced neritic flow.
5. Dissolved oxygen levels around hypoxic conditions.
6. Build up of nutrients.

All these indicate detrimental state of the creek.

Sedimentology

Introduction

In aquatic systems, the sediment act as the reservoirs of nutrients in water. They replenish these nutrients in times of need and also remove them from water which helps the biological cycle of the system. The sediments of mangrove forests receive mangrove derived litter which acts as a major food source for many organisms. In addition, according to Alongi (1991), the mangrove mudflats also receive nutrients from other sources, such as terrestrial runoff and estuarine outflows. Thus, nutrient rich sediments make the mangrove ecosystem a highly productive ecosystem, which is used as a feeding and breeding ground by large number of commercial species (Cheng, 1995). According to Johnston (1991), the mangrove and other wetland mudflats can store very high amount of nutrients, whereas Banus *et al*. (1975) are of the opinion that the soils of coastal marshes act as sink for heavy metals. Due to these reasons, recently these wetlands are universally used as biological systems for effluent purification and are attractive to the industries as they provide an alternative low cost, low maintainance and simple method for domestic and industrial sewage treatment (Conley *et al.,* 1991). The entire wetland soil-plant water system, which provides both aerobic and anerobic conditions, is important in the reduction of nutrients, heavy metals and even organic pollutants from waste water (Tam & Wong, 1995).

The mechanisms involved in the immobilization of pollutants in the soil component of a wetland include adsorption on ion exchange sites, binding to organic matter, incorporation into lattice structures and precipitation into insoluble compounds (Dunbabin & Bowmer, 1992). Reed *et al.*, (1988) ascribed microbial mediated reactions to determine the fate of the pollutants in wetland ecosystems. All these processes according to DeBustamante (1990), are affected by the biological, chemical and physical properties of soil, in particular pH, soil texture, cation exchange capacity, redox potential, salinity and nutrients. BijoyNandan & AbdulAziz (1996) are of the opinion that sediments are indicators of the overlying water quality and their study is a useful tool in work on environmental pollution.

Sedimentological parameters have been extensively studied in association with ecological aspects. The pioneering work was done by Sanders (1956,58) in U.S.A. and Jones (1951, 52, 55-56) in U.K. following which many workers have studied the sediment nutrient characteristics (Table S-1). In India, sediment studies were extensively done in ecosystems such as Mandovi & Zuari estuaries (Jagtap, 1987; Ansari, 1988; Nasnolkar *et al.,* 1996), Asthamudi estuary (Nair *et al.,* 1984), Rushikulya estuary (Gouda & Panigrahy 1990, 1991, 1996, 1999), Cochin backwaters (Sunil Kumar, 2001; Sankaranarayanan & Punampunnayil, 1979; Reddy & Sankaranarayanan, 1972; Murty & Veerayya, 1972), Ulhas River estuary (Sahoo & Khopkar 1986, 87; Mohapatra, 1985; Kotimere & Bhosale, 1976) etc. The sediment of Thane creek has been investigated by Govindan *et al* (1976), Varshney (1982), Athalye (1988), Annie Mathew (1989) Deshmukh (1990). However most of the studies were restricted to the sub-tidal and supra-tidal region of the creek. According to Reddy & Sankaranarayanan (1972), recycling of nutrients is affected through the sediments and the mud-water interface of the intertidal zone forms an active zone for mineralization of organic matter. In this zone, at mid water level mark, maximum of the benthic fauna is represented (Bourget & Missier, 1983). Hence present study was focused on the fauna of intertidal region. It is well known that the fauna being resident in the mudflats is directly affected by the properties of the sediment. To understand these effects, it is essential to assess the sediment parameters while studying the fauna. This chapter presents the results and discussion on sedimentological studies of the intertidal mud flats of Thane creek.

Table S – 1: Review of the sedimentology studies done in foreign countries.

Name of Aquatic body	Year	Authors
Northern Australian Mangrove	1981	Boto & Bunt
Australian mangrove forest	1984	Boto & Wellington
Southwestern Florida Estuary	1985	Twilley
Australian mangrove forest	1989	Boto *et al.*
Central Great Barrier Reef Lagoon	1990	Alongi
Klong Ngao mangrove swamp, Thailand	1990	Wattayakorn *et al.*
Raide Foz estuary, North West Spain	1990	Junoy & Vieitez
Dubai Creek	1992	Naim S Ismail
Well mixed Coastal Plain Estuary	1992	Lebo & Sharp
Galveston Bay, Texas	1994	Zimmerman & Benner
Jamican mangrove forest	1994	Nedwell e*t al.*
Ao Nam Bor mangroves, Thailand	1995	Kristensen *et al.*
Chuwei mangrove Forest, Taiwan	1995	Cheng
SaiKeng mangrove- Hongkong& Shenzhen mangrove -China	1995	Tam & Wong
East African mangroves (Gazi Bay, Kenya)	1996	Middelburg *et al.*
Hinchinbrook channel, Australia	1998	Alongi *et al.*
Lower estuary of river Great Ouse, England	1998	Trimmer *et al.*
Mangrove forest of Malaysia	1998a	Alongi *et al.*

Nauset Marsh estuary	1999	Nowicki *et al.*
Southern Chesapeake Bay	1999	Caunel & Zimmerman
River Colne estuary	2000	Dong *et al.*
South Texas estuary	2000	Riera *et al.*
Estuary of Caete River	2001	Dittmar & Lara
Tropical Brazilian coastal waters	2001	Dittmar *et al.*
Shark River estuary	1998 & 99	Chen & Twilley

Moisture Content

The amount of water present in the sediment at any given time is called the moisture content of that sediment. In marine ecosystems, tidal waters, land runoff and rainfall form the main source of water to the sediments. Presence of clay in the sediment is known to increase the water holding capacity, whereas sandy substrates hold less moisture. According to Robinson (1936), clay fraction is of colloidal character having high holding capacity for water and organic carbon. The moisture content also depends on the pore space; the presence of organic matter reduces the compactness of the soil and increases the porosity.

Table Mc-1: Monthly variations in moisture content (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	56.10	59.95	54.50	57.65	57.10	57.00	61.50	59.50	64.45	60.20	66.50	63.85	59.86
Jun-99	56.02	60.85	55.20	62.55	74.70	64.55	63.10	60.05	64.00	60.10	63.50	63.10	62.31
Jul-99	55.85	62.50	56.10	64.50	79.95	60.10	64.50	60.35	63.10	58.95	60.05	61.95	62.33
Aug-99	55.52	62.04	55.76	63.95	**80.12**	60.15	64.54	59.80	62.39	58.37	59.99	62.03	62.06
Sep-99	58.85	63.98	57.08	62.10	66.85	60.75	64.08	61.65	64.55	59.86	64.90	59.02	61.97
Oct-99	58.21	63.47	54.15	61.46	64.41	63.12	64.85	60.13	63.21	57.67	64.68	61.07	61.37
Nov-99	58.66	59.49	55.06	60.59	60.06	61.89	59.97	55.63	64.00	56.31	65.44	60.02	59.76
Dec-99	59.06	64.23	57.24	64.33	62.30	61.59	62.55	59.88	63.39	64.06	66.67	63.83	62.43
Jan-00	58.16	64.45	**53.94**	63.14	63.03	62.03	61.72	62.05	64.86	59.56	68.08	61.63	61.89
Feb-00	58.55	61.08	59.71	65.32	64.09	60.59	61.12	62.94	64.57	64.05	65.47	65.10	62.72
Mar-00	62.08	64.09	54.98	60.39	64.88	59.92	60.00	60.60	60.99	61.36	65.66	64.19	61.60
Apr-00	59.50	61.37	56.21	60.63	60.44	60.11	61.81	60.75	66.15	61.70	68.16	66.58	61.95
Stn Avg.→	58.05	62.29	55.83	62.22	66.49	60.98	62.48	60.28	63.80	60.18	64.92	62.70	**61.69**
Max	62.08	64.45	59.71	65.32	**80.12**	64.55	64.85	62.94	66.15	64.06	68.16	66.58	62.72
Min	55.52	59.49	**53.94**	57.65	57.10	57.00	59.97	55.63	60.99	56.31	59.99	59.02	59.76
SD	1.90	1.75	1.62	2.20	7.64	1.88	1.74	1.79	1.32	2.34	2.65	2.16	0.95

In the present study the moisture content varied from 53.94 % to 80.12 % with an annual average of 61.69 % (Table Mc-1). Athalye (1988) reported a range 57.89 % to 61.96 % for the shallow region of Thane creek. The minimum in the present study was observed at station 3 which had more sand in its substratum. The sediment at station 5 in general had high moisture content which during the monsoon had a rare maximum value of 80.12 %, This can be attributed to its close proximity to the major sewage out let of Thane city. The average moisture content of the sediment of Thane creek was high due to the dominance of silt and clay components increasing its water holding capacity. The range was comparatively broader than 63.5 % to 75.23 % reported by Matilal *et al.* (1986) and narrower than 20 % to 90 % reported by Elster *et al.* (1999) for Sunderban mangroves and Colombia mangroves respectively.

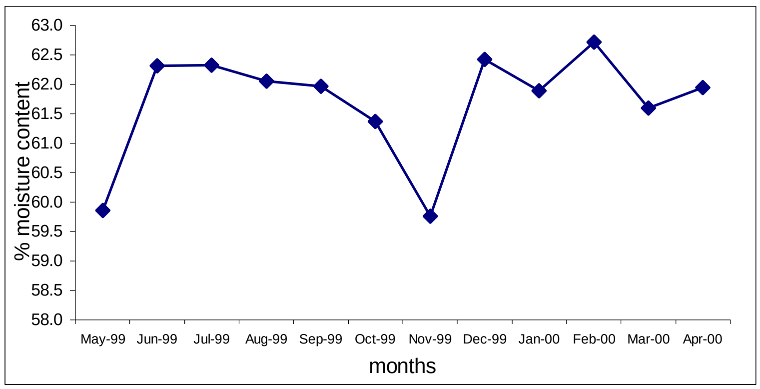


Fig.Mc-1: Monthwise variations in the average moisture content (%).

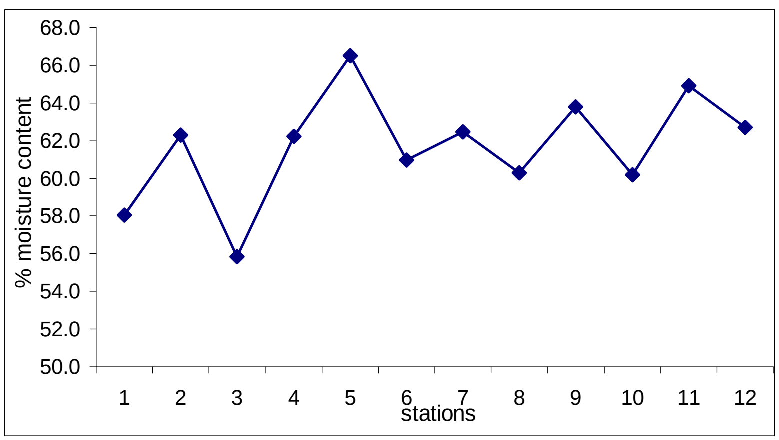


Fig Mc-2: Stationwise variations in the average moisture content (%).

Dittmar and Lara (2001) observed that the rainwater was stored within the mangrove forest and was then successively released causing seasonal fluctuations. In the present investigation moisture content increased at the onset of monsoon (June) & then declined up to November (Fig. Mc-1). Sharp rise in December 99 & the fluctuations thereafter are difficult to explain, but could be due to influence of tidal waters & effluent released in the creek.

The stationwise (Fig.Mc-2) comparison of average moisture content showed wide fluctuations at the stations on riverine end (1 to 5) probably because they are in shallow region, are exposed to lesser water mass and are subjected to varied anthropogenic activities such as soild waste dumping, minor to major sewage outlets etc., causing more fluctuations. As compared, the fluctuations from station 6 to 12 on seaward end were insignificant as they enjoy more stable environment. This is because they are in deeper area of the creek, get exposed to higher water mass and have relatively less anthropogenic influence.

The correlation coefficients studied revealed insignificant influence of all the environmental parameters, except for chlorides that showed positive correlation (r = 0.2096) and sand that had a significant negative correlation with moisture content (r = -0.4050).

Sediment Texture

Sediment grainsize or texture decides the nature of the substratum, which has the greatest influence on the distribution and abundance of benthic population (Sanders, 1958). The texture of the sediment depends on coarseness or fineness of the particles. The particles below 4 μ size are said to be clay, they are fine particles and remain suspended for a long time. The particles bigger than clay and smaller than 62 μ form the silt, those between 62 μ to 250 μ are called fine sand and bigger than 250 μ form the coarse sand component. The clay and silt substratum can hold more water and organic matter as opposed to sandy soil. The sediment distribution of estuarine and near shore region to a great extent depends, on the source and texture of sediment supplied, topography & hydrographic features of the concerned area (Sasamal *et al.*, 1986). According to Wilson (1981), the physico-chemical properties of muddy substratum directly influence the infaunal community that lives in the soft sediment. Moreover, Hopkinson *et al.* (1999) contented that sediments play an important role in organic matter degradation and nutrient recycling in aquatic ecosystems. According to Nair *et al.* (1983), fine grain sediment is associated with high organic matter and exchange of phosphorus with overlying water. Whereas Kristensen (1988) stated that exchange of nitrate is affected by the burrow dwelling infauna. Hence any disturbance to the soft sediment can damage the existing fauna and render the habitat available for new colonization and succession of species (Sanders *et al*., 1980).

Table ST-1- : Review of sediment quality from different water bodies.

Substratum	Estuary	Reference
Sand, Silty sand, Silty clay & clayey silt	Vembanad lake	Murty & Verrayya, 1972.
Clayey sand – silty sand – sand	Kakinada channel	Rao & Rao, 1976
Clayey-silt, sand, sand silt clay & Sandy mud	Cochin backwaters	Pillai, 1977
Clayey silt to sandy to sandy silt	Versova	Varshney *et al.*, 1984
Silty to silty clay	Mangrove forest – Sunderbans	Matilal *et al.*, 1986
Clayey silt to fine sand to silt free fine sand	Kakinada bay (Gautami-Godavari estuarine system)	Kondalarao & Ramanamurty, 1988
Clayey silt	Off Versova	Varshney *et al.*, 1988
Clayey type to sandy clay	Pitchavaram mangroves	Ramanamurthy *et al*., 1990
Silty sand	Cuddalore-Uppanar backwaters	Murugan &Ayyakkannu, 1991
Sandy silt & Silty clay	Kakinada bay & backwaters	Vijayakumar *et al.*, 1991
Sandy silt type	Mangrove strands of Madras	Selvam *et al*., 1991
Silty sand & Sand silt clay	Coleroon estuary	Jegadeesan & Ayyakkannu, 1992
Sandy	Kalpakkam coast	Suresh *et al.*,1992
Sandy	Mangrove swamps of Cochin	Sunil Kumar & Anthony, 1994
Sandy silt	Marmugoa Harbour	Ansari *et al*.,1994
Silty sand, Sandy silt & Sand silt clay	Rajapur bay	Harkantra & Parulekar, 1994
Sandy to silty sand	Cochin backwaters	Sunil kumar, 1995
Sandy to clayey sand	Cochin estuary	Sunil Kumar, 1997
Sandy mud & Silty clay	Mangalore coast	Gopalakrishnan & Nair, 1998
Sandy to silty sand	Vashishti estuary	Nair *et al.*, 1998
Fine silty mud to fine medium sand	Zuari estuary	Ansari & Parulekar, 1998
Sand, clayey sand, silty sand	Mangrove sediments of Cochin	Sunil Kumar, 2001

Govindan *et al.* (1983) while studying Gujarat estuaries have described 4 types of substrata; Silty-sand (50 % silt & clay), Sandy-silt (66 % silt & clay), Sandy (silt – clay less than 50 %) and Clayey-silt (more than 93 % clay-silt). In the present study the surface substratum of the creek was generally clayey-silt as it comprised of average 66.74 % silt and 28.65 % clay with negligible amount of sand (2.42 %). Parulekar *et al.* (1976) had described the Bombay sediment as silty-clay type i.e. more clay and less silt. Athalye (1988) observed silty-clay surface sediment in the shallow region of Thane creek. Mukherjee (1993) reported clayey-silt sediment at a station in Thane creek for the year 1988 – 89 and observed it to change to sandy in 1989 – 90. Gokhale & Athalye (1995), reported sediment texture in the same region to be clayey-silt in 1991 – 93. They attributed this destabilization of substratum to extensive reclamation and construction activities. Different types of substrata have been recorded from different aquatic bodies which are depicted in Table ST-1.

Table ST-2: Monthly variations in Coarse sand (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Jun-99	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Jul-99	0	0	4.4	0	0	0	0	0	0	0	0	0	0.37
Aug-99	0	0	2.6	0	0	0	0	0	0	0	0	0	0.22
Sep-99	0	0	3.6	0	0	0	0	0	0	0	0	0	0.30
Oct-99	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Nov-99	0	0	**7.6**	0	0	0	0	0	0	0	0	0	0.63
Dec-99	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Jan-00	0	0	2.2	0	0	0	0	0.6	0	0	0	0	0.23
Feb-00	0	0	1.2	0	0	0	0	0	0	0	0	0	0.10
Mar-00	0	0	5.8	0	0	0	0	0	0	0	0	0	0.48
Apr-00	0	0	3	0	0	0	0	0	0	0	0	0	0.25
Stn Avg.→	0.00	0.00	2.53	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.22
Max	0.00	0.00	7.60	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.63
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SD	0.00	0.00	2.50	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.21

Table ST-3: Monthly variations in Fine sand (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	8.80	3.60	5.60	1.80	0.60	0.20	0.40	0.40	0.60	0.50	**0.10**	0.80	1.95
Jun-99	3.80	5.80	7.60	1.40	0.40	0.40	0.40	1.20	0.20	0.20	**0.10**	0.20	1.81
Jul-99	3.80	5.00	14.00	0.40	0.20	0.20	1.60	0.20	3.80	3.80	0.20	1.40	2.88
Aug-99	2.20	4.40	9.20	7.80	1.60	1.40	0.20	0.80	6.80	2.60	1.80	1.60	3.37
Sep-99	5.40	11.40	13.00	2.20	4.20	2.20	2.60	0.20	2.80	0.80	5.40	2.20	4.37
Oct-99	1.20	6.60	**15.40**	2.00	2.20	5.40	1.40	0.40	0.20	12.60	0.40	3.60	4.28
Nov-99	0.80	4.20	4.40	**0.10**	0.20	1.60	0.40	0.80	0.40	1.40	0.80	0.20	1.28
Dec-99	1.40	3.00	5.80	0.80	2.00	1.40	**0.10**	1.80	0.40	0.40	0.40	0.20	1.48
Jan-00	1.00	1.40	10.20	0.20	0.20	**0.10**	**0.10**	2.20	0.40	0.20	**0.10**	**0.10**	1.35
Feb-00	1.40	0.40	8.80	0.20	0.40	0.20	0.20	0.40	**0.10**	**0.10**	**0.10**	**0.10**	1.03
Mar-00	0.80	1.00	10.80	1.00	0.60	0.20	**0.10**	**0.10**	**0.10**	0.80	0.20	**0.10**	1.32
Apr-00	1.40	0.80	10.00	0.20	0.20	**0.10**	**0.10**	0.60	0.20	1.40	0.20	**0.10**	1.28
Stn Avg.→	2.67	3.97	9.57	1.51	1.07	1.12	0.63	0.76	1.33	2.07	0.82	0.88	2.20
Max	8.80	11.40	15.40	7.80	4.20	5.40	2.60	2.20	6.80	12.60	5.40	3.60	4.37
Min	0.80	0.40	4.40	0.10	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.03
SD	2.42	3.11	3.42	2.12	1.23	1.53	0.80	0.66	2.09	3.50	1.52	1.12	1.21

Table ST-4: Monthly variations in Silt (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	60.00	80.00	60.00	70.00	70.00	40.00	80.00	40.00	80.00	50.00	60.00	40.00	60.83
Jun-99	50.00	50.00	60.00	60.00	50.00	**30.00**	80.00	80.00	50.00	60.00	40.00	50.00	55.00
Jul-99	**90.00**	**90.00**	50.00	80.00	70.00	80.00	70.00	**90.00**	70.00	70.00	70.00	80.00	75.83
Aug-99	80.00	70.00	50.00	60.00	70.00	**90.00**	40.00	60.00	50.00	60.00	60.00	60.00	62.50
Sep-99	70.00	70.00	80.00	80.00	70.00	80.00	**90.00**	60.00	40.00	50.00	60.00	70.00	68.33
Oct-99	60.00	80.00	70.00	70.00	60.00	80.00	80.00	60.00	70.00	60.00	80.00	80.00	70.83
Nov-99	70.00	60.00	70.00	80.00	**90.00**	70.00	60.00	60.00	70.00	40.00	50.00	70.00	65.83
Dec-99	70.00	80.00	90.00	60.00	80.00	70.00	60.00	50.00	**90.00**	60.00	**30.00**	70.00	67.50
Jan-00	60.00	70.00	50.00	80.00	60.00	70.00	80.00	70.00	50.00	50.00	80.00	**90.00**	67.50
Feb-00	**90.00**	50.00	**90.00**	70.00	80.00	30.00	50.00	70.00	**30.00**	50.00	50.00	70.00	60.83
Mar-00	60.00	80.00	60.00	**90.00**	80.00	60.00	**90.00**	80.00	70.00	70.00	**90.00**	80.00	75.83
Apr-00	60.00	70.00	40.00	70.00	80.00	60.00	70.00	50.00	80.00	**90.00**	80.00	**90.00**	70.00
Stn Avg.→	68.33	70.83	64.17	72.50	71.67	63.33	70.83	64.17	62.50	59.17	62.50	70.83	66.74
Max	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	75.83
Min	50.00	50.00	40.00	60.00	50.00	30.00	40.00	40.00	30.00	40.00	30.00	40.00	55.00
SD	12.67	12.40	16.21	9.65	11.15	20.15	15.64	14.43	18.15	13.11	18.15	15.05	6.20

Table ST-5: Monthly variations in Clay (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	20	**10**	40	30	**10**	40	**10**	40	20	**60**	30	30	28.33
Jun-99	40	30	30	30	30	**60**	40	20	40	30	30	40	35.00
Jul-99	**10**	**10**	40	20	50	30	30	**10**	30	**10**	**10**	30	23.33
Aug-99	20	**10**	40	30	30	20	30	30	30	30	40	40	29.17
Sep-99	30	20	20	20	30	20	30	30	50	50	30	20	29.17
Oct-99	30	**10**	20	20	40	20	20	40	30	30	20	20	25.00
Nov-99	20	30	20	**10**	**10**	20	30	30	20	50	50	**10**	25.00
Dec-99	30	20	**10**	40	**10**	20	40	50	20	50	**60**	20	30.83
Jan-00	50	20	30	20	20	40	20	40	40	50	**10**	20	30.00
Feb-00	30	40	**10**	40	20	50	40	30	**60**	40	30	**10**	33.33
Mar-00	40	30	20	**10**	20	40	20	30	40	30	**10**	15	25.42
Apr-00	40	30	40	30	20	40	30	50	20	**10**	30	**10**	29.17
Stn Avg.→	30.00	21.67	26.67	25.00	24.17	33.33	28.33	33.33	33.33	36.67	29.17	22.08	28.65
Max	50.00	40.00	40.00	40.00	50.00	60.00	40.00	50.00	60.00	60.00	60.00	40.00	35.00
Min	10.00	10.00	10.00	10.00	10.00	20.00	10.00	10.00	20.00	10.00	10.00	10.00	23.33
SD	11.28	10.30	11.55	10.00	12.40	13.71	9.37	11.55	13.03	16.14	15.64	10.76	3.50

Southward (1957) is of the opinion that the rains are the controlling factor of the nature of deposit. Matilal *et al.* (1986) observed coarse sand content in the mangrove forest of Sunderbans which they attributed to gradient factor and consequent increase in the rate of sedimentation in riverbeds. Seasonal variations were also observed at Versova by Varshney *et al* (1984). In the present study silt and clay showed monthly fluctuations antagonistic to each other, maintaining overall fine sediment percentage constant. Fine sand showed marginal rise from 2 to 4 % during monsoon and varied around 1 % during the post monsoon period whereas coarse sand was never more than 0.7 % (Fig ST-1 to 4).

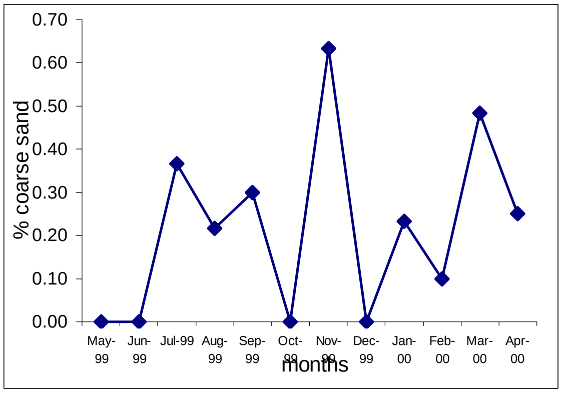


Fig ST-1: Monthly variations in the average Coarse sand component (%).

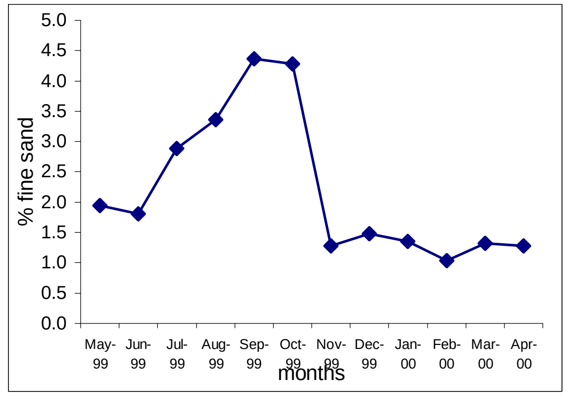


Fig ST-2: Monthly variations in the average Fine sand component (%).

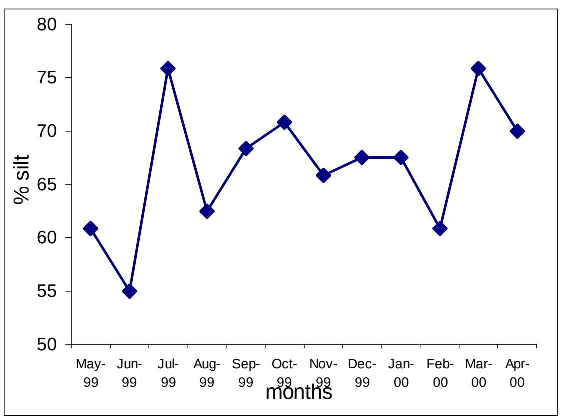


Fig ST-3: Monthly variations in the average Silt component (%).

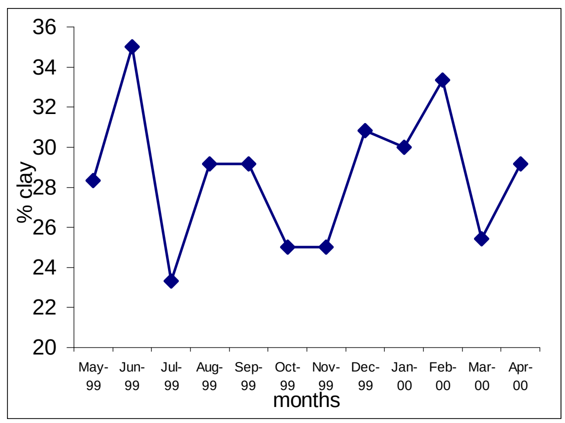


Fig ST-4: Monthly variations in the average Clay component (%).

Station to station variations is a common feature of most of the estuaries like Gautami-Godavari estuary (Kondalarao & Ramamurthy, 1988); Rajapur Bay (Harkantra & Parulekar, 1994); Sunderbans mangroves (Matilal *et al.*, 1986); Zuari estuary (Ansari & Parulekar, 1998); Kalpakam coast (Suresh *et al.*, 1992); Pitchavaram mangroves (Ramamurthy *et al.*,1990); Cuddalore-Uppanar backwaters (Murugan & Ayyakkannu, 1991); Kakinada bay & backwaters (Vijayakumar *et al.*, 1991); Cochin estuary (Sunil Kumar, 1997); Coleroon estuary (Jegadeesan & Ayyakkannu, 1992); Marine environs from east coast of India (Subbarao & Venkatarao, 1976). In the present investigation a station wise variation was observed although it was insignificant. From the Figures ST-5 to 8 it can be inferred that sand showed its significant occurrence only at station 3 while at all the other stations it was negligible. Silt showed a marginal decline from the river till the seaward station 10 and marginally increased at the extreme seaward zone. Clay showed an exactly opposite trend to that of the silt.

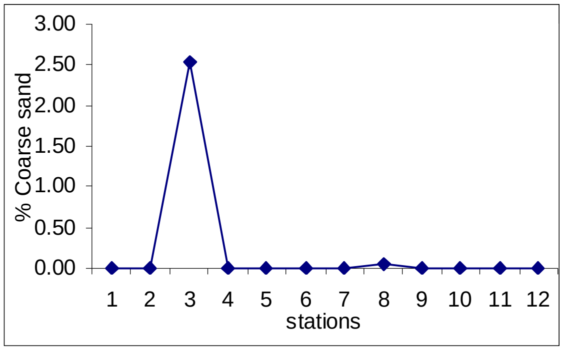


Fig ST-5: Stationwise variations in the average Coarse sand component (%).

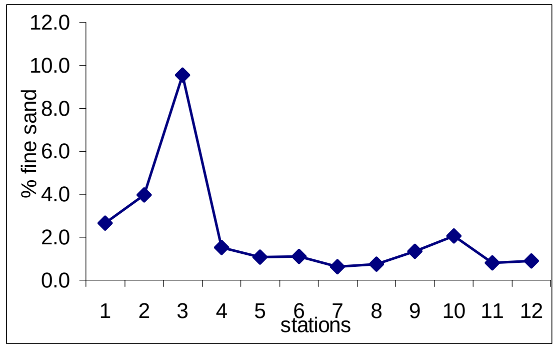


Fig ST-6: Stationwise variations in the average Fine sand component (%).

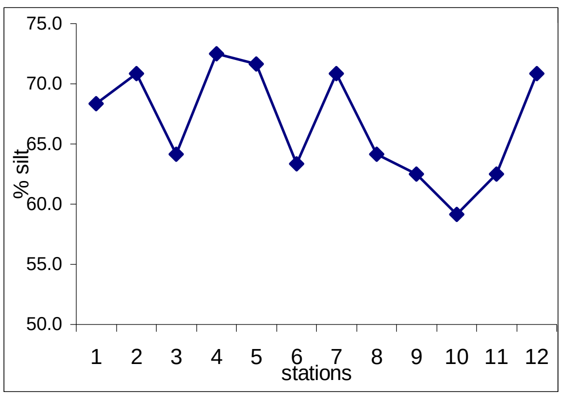


Fig ST-7: Stationwise variations in the average Silt component (%).

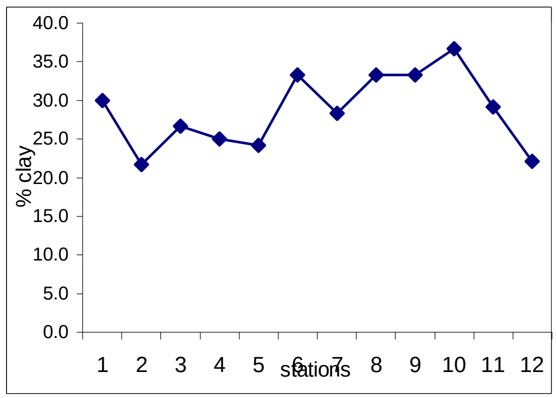


Fig ST-8: Stationwise variations in the average Clay component (%).

A comparison with the past comparable data from shallow region of Thane creek (Athalye, 1988 and Gokhale & Athalye 1995) revealed that in past 15 years the sediments showed a declining trend of fine sand and clay, while silt gradually increased (Fig. ST-9). This shows the growing siltation in the creek resulting from increased human pressure on the creek by way of activities like reclamation, construction, dredging and sewage disposal.

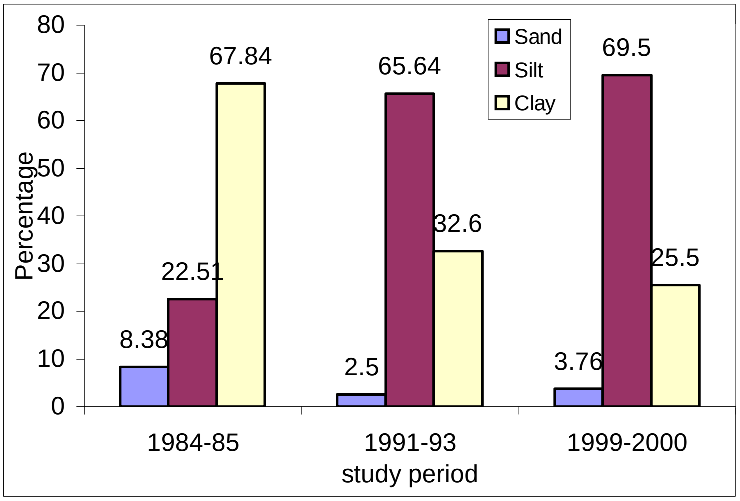


Fig. ST-9 : Comparison with the past comparable data for the shallow region of Thane creek.

Soil pH

pH is a parameter that plays an important role in the recycling of nutrients between water and sediments of an estuary (Nasnolkar *et al.*, 1996). The oxic and anoxic conditions indirectly affect the soil pH, rendering it from acidic to alkaline. Various studies have shown, that in a mangrove ecosystem the mangroves modify the sediment pH and redox conditions (Alongi *et al.*, 2000) as the mangroves release organic acids into the sediment (Ball, 1988). pH mainly governs the adsorption and desorption of phosphorus in marine environment with maximum adsorption taking place in acidic medium (Madhukumar & Anirudhan, 1996). According to Blasco (1975) in coastal soils pH usually varies between 6.5 to 7.

Fusher (1994) reported pH range 5.2 to 7 in the mangrove estuary, Australia; Tam and Wong (1995) recorded pH range 5.48 to 5.66 and 5.32 to 5.46 for Sai Keng mangrove soil from Hong Kong and Shenzhen mangroves of China respectively, while Ukpong (1997) reported pH in the range 3.6 to 6.15 in the Calabar mangrove swamp, Nigeria. They attributed the highly acidic pH to the mangrove litter. In the present study pH fluctuated between 6.83 to 8.24 with an annual average of 7.45 (Table SpH-1). This range is comparable to most of the coastal ecosystems reported by other workers (Table SpH-2).

Table SpH-1: Monthly variations in sediment pH at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	Stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	7.05	7.02	7.10	7.10	7.10	6.94	**6.83**	7.10	6.89	6.95	7.09	7.06	7.02
Jun-99	7.66	7.16	7.26	7.14	6.91	7.38	7.09	6.89	7.07	7.13	6.87	7.33	7.16
Jul-99	7.15	7.28	7.17	7.43	7.43	7.44	7.18	7.35	7.39	7.43	7.44	7.32	7.33
Aug-99	7.11	7.09	7.04	7.24	7.11	7.22	7.10	7.14	7.01	7.29	7.14	7.05	7.13
Sep-99	7.31	7.19	7.41	7.24	7.22	7.14	7.17	7.05	7.06	7.14	7.06	6.97	7.16
Oct-99	6.99	6.96	7.20	7.19	7.15	7.24	7.01	7.06	7.14	7.11	6.94	7.05	7.09
Nov-99	7.14	6.98	7.02	7.07	6.84	6.89	7.01	6.98	6.88	7.01	6.91	6.95	6.97
Dec-99	7.90	7.74	7.79	7.82	7.91	8.01	7.84	7.91	7.79	7.78	7.88	7.91	7.86
Jan-00	8.03	7.85	8.07	7.92	8.06	7.97	7.95	8.02	7.77	7.99	7.99	8.05	7.97
Feb-00	7.78	7.91	7.89	7.88	7.82	7.71	7.68	7.63	7.83	7.75	7.55	7.54	7.75
Mar-00	7.99	7.93	8.09	7.91	8.04	7.81	7.79	8.05	7.71	7.90	7.92	7.77	7.91
Apr-00	8.04	7.70	8.18	8.09	8.07	8.14	8.11	**8.24**	8.02	8.11	8.04	7.91	8.05
Stn Avg.→	7.51	7.40	7.52	7.50	7.47	7.49	7.40	7.45	7.38	7.47	7.40	7.41	**7.45**
Max	8.04	7.93	8.18	8.09	8.07	8.14	8.11	**8.24**	8.02	8.11	8.04	8.05	8.05
Min	6.99	6.96	7.02	7.07	6.84	6.89	**6.83**	6.89	6.88	6.95	6.87	6.95	6.97
SD	0.42	0.39	0.45	0.39	0.48	0.43	0.44	0.49	0.42	0.42	0.46	0.41	0.42

Table SpH-2: review of pH from different water bodies.

pH range	Water body	Reference
7.2 – 8	Cochin backwaters	Reddy & Sankaranarayan, 1972
7.9 – 8.4	Sunderbans Mangrove	Matilal *et al.*, 1986
7 – 7.5	Pitchavaram mangroves	Ramamurthy *et al.*, 1990
6.2 – 7.7	Mangroves of Madras coast	Selvam *et al.*, 1991
7.25 – 8.25	Mangrove swamps of Cochin	Sunil Kumar & Anthony, 1994
7.53 – 8.32	Sagar islands	Saha & Choudhury, 1995
7.14 – 7.36	Kadinamakulamkayal backwaters	Bijoynandan & Abdulaziz, 1996
6.4 – 7.2	Cochin estuary	Sunil Kumar, 1997
6.91 – 7.76	Zuari river	Ingole & Parulekar, 1998
6.64 – 7.8	Abu Dabhi creek	Shiriadh, 2000
6.48 – 7.94	Abu Dabhi mangroves	Shiriadh, 2000
7.23 – 7.54	Khoral Khuwair area	Shiriadh, 2000
7.42 – 8.06	Khoral Khuwair creek	Shiriadh, 2000
6.95 – 7.78	Rasal Khaimah area	Shiriadh, 2000
7.29 – 7.91	Rasal Khaimah creek	Shiriadh, 2000
6.95 – 7.42	Ummal Quwain area	Shiriadh, 2000
7.42 – 7.95	Ummal Quwain creek	Shiriadh, 2000
6.83 – 8.18	Thane creek	Present study

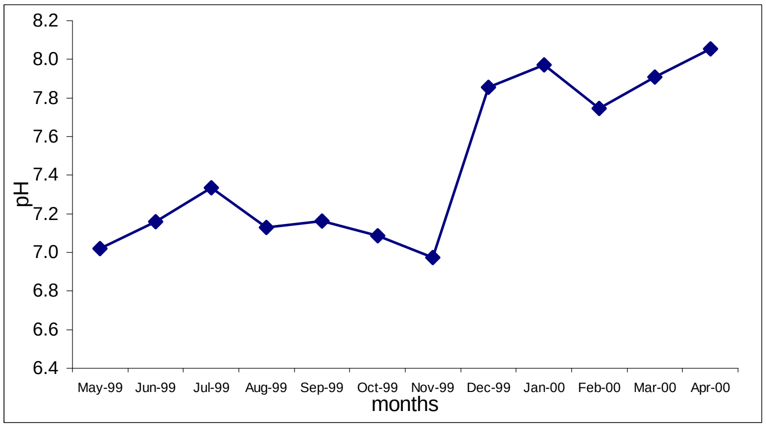


Fig.SpH-1: Monthly variations in the average sediment pH.

Comparison of the monthly variations indicate influence of freshwater and terrestrial runoff on the sediments from May to November (Fig.SpH-1). Since December the pH was more alkaline indicating dominance of neritic waters in the creek influencing the sediment pH.

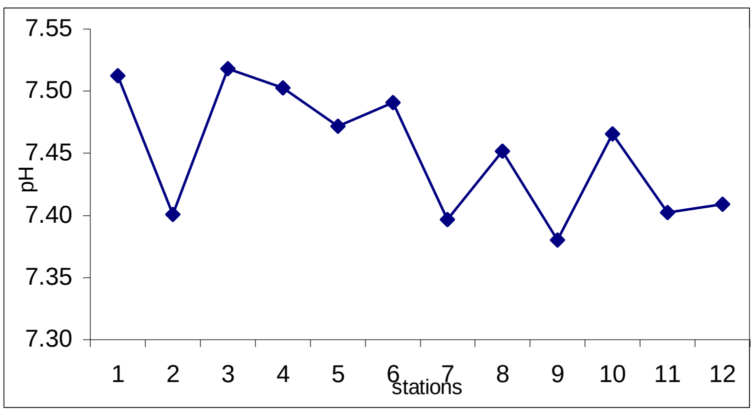


Fig SpH-2: Stationwise variations in the average sediment pH.

A stationwise comparison (Fig.SpH-2) revealed insignificant and minor fluctuations between the sampling stations. However, excluding station 2, the general trend showed decreasing pH towards the seaward side inspite of the dominance of marine water in that part of the creek. The difference in the sediment pH of the two extreme end stations (1 & 12) was not statistically significant. Hence the fluctuations could be said to be due to different metabolic processes in the sediment.

The correlation coefficient analysis revealed the significant positive correlation of sediment pH with light penetration (r =0.2891), salinity (r = 0.3594), PO4-P (r = 0.3324), SiO3-Si (r = 0.3808), Sediment chlorides (r = 0.227), Available Phosphorus (r = 0.2957) and Total nitrogen (r = 0.3383). while a negative correlation was obtained with water temperature (r = -0. 2914), dissolved oxygen (r = - 0.2058) and sediment organic carbon (r = -0.1796).

Chlorides %

In estuarine ecosystem salinity is not only a major parameter but also a determining factor for occurrence and distribution of biota (Athalye, 1988). According to Dyer (1972), salinity pattern in an estuary throws light on many a physical processes and biological processes taking place in an estuary. Further, Alam (1992) is of the opinion that due to wide fluctuations in salinity caused by land drainage during monsoon, only euryhaline species survive in the estuaries.

Table Cl-1: Monthly variations in sediment Chlorides (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	2.386	3.081	2.485	2.982	2.982	2.883	4.274	2.485	3.678	3.678	5.368	2.783	3.255
Jun-99	0.268	0.686	0.249	0.696	1.789	0.706	1.541	1.988	1.441	2.018	3.131	0.994	1.292
Jul-99	0.199	0.746	0.199	0.229	0.795	0.497	0.398	0.368	0.348	0.308	0.507	0.895	0.457
Aug-99	**0.099**	0.596	0.567	0.338	0.646	0.467	0.746	1.044	0.994	0.845	1.143	1.491	0.748
Sep-99	0.099	0.746	0.298	1.093	1.143	1.093	1.193	1.441	2.386	1.292	1.740	1.292	1.151
Oct-99	0.895	0.149	0.547	1.193	1.193	1.292	2.187	1.789	1.839	1.193	1.839	2.386	1.375
Nov-99	0.895	1.789	1.491	2.286	4.473	3.777	3.578	2.883	3.181	2.684	3.678	3.578	2.858
Dec-99	1.590	2.883	1.889	3.330	3.429	2.237	2.932	3.330	3.380	3.231	2.783	3.429	2.870
Jan-00	1.740	2.386	1.292	2.386	2.982	1.988	2.087	2.982	3.578	2.336	4.175	2.982	2.576
Feb-00	1.889	2.386	1.988	2.087	2.485	1.938	2.386	3.081	2.982	2.684	3.429	3.777	2.593
Mar-00	2.336	2.137	1.988	2.187	3.628	2.336	2.286	2.187	2.783	3.429	3.380	3.976	2.721
Apr-00	1.789	2.783	1.491	1.690	1.789	2.286	2.187	1.839	3.578	2.087	3.479	**5.616**	2.551
Stn Avg.→	1.18	1.70	1.21	1.71	2.28	1.79	2.15	2.12	2.51	2.15	2.89	2.77	2.04
Max	2.386	3.081	2.485	3.330	4.473	3.777	4.274	3.330	3.678	3.678	5.368	**5.616**	3.255
Min	**0.099**	0.149	0.199	0.229	0.646	0.467	0.398	0.368	0.348	0.308	0.507	0.895	0.457
SD	0.876	1.049	0.803	1.007	1.236	1.013	1.111	0.892	1.117	1.067	1.366	1.425	0.959

Chloride is a major salt influencing salinity and hence estimation of chloride gives a fair idea of the salinity in an ecosystem. In Thane creek the sediment chlorides varied from 0.099 to 5.616 % with an annunal average of 2.04 % (Table Cl-1). Similar range and average (1.12 to 4.28 % av. 2.7%) was also reported by Ukpong (1997) for the Calabar mangrove swamp in Nigeria. The minimum chlorides in the soil were attributed to the peak of monsoon that dominated the saline waters. In the present study also a seasonal comparison (Fig.Cl- 1) indicated low chloride contents during the monsoon and increase in concentration during the post monsoon period.

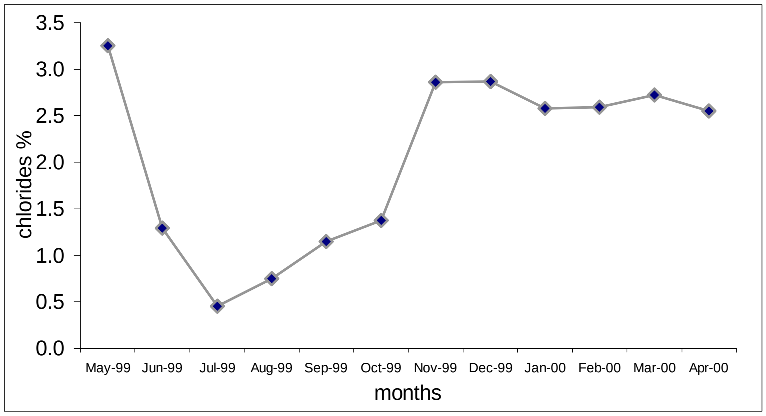


Fig Cl-1: Monthly variations in the average sediment Chlorides (%).

Comparison of stationwise averages (Fig. Cl-2) also depicted influence of the salinity of overlying water on the sediment salinity. The sediment chlorides increased from riverine end to the seaward end (i.e. Station 1 to station 12.).

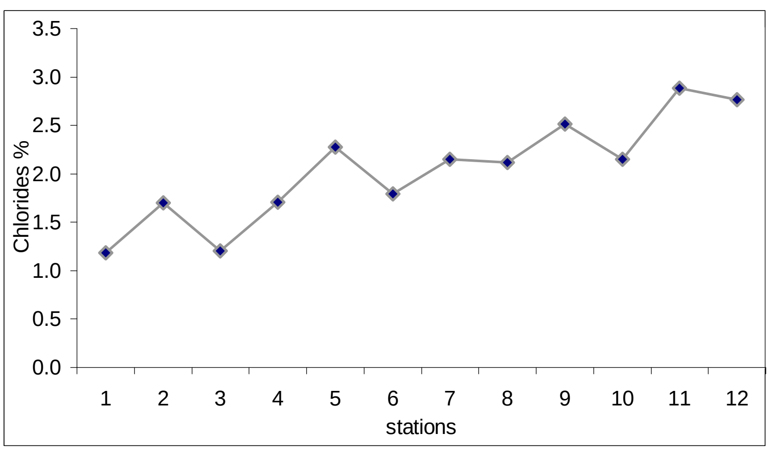


Fig Cl-2: Stationwise variations in the average sediment Chlorides (%).

The simple correlation coefficients showed a significant positive correlation with suspended solids (r = 0.2864), water salinity (r = 0.8126), PO4-P (r = 0.2509), NO3-N (r = 0.5464), SiO3-Si (r = 0.1737), sediment pH (r = 0.227) and moisture content (r = 0.2096). while significant negative correlation was obtained against dissolved oxygen (r

= - 0.2501), sediment total phosphorus (r = -0.1771), sediment organic carbon (r = -0.1880) and sand (r = -0.4412).

Redox Potential (mV).

The redox potential (Eh) is indicative of oxygenation of the sediment. Positive values are generally recorded for oxic condition while negative values indicate highly reducing condition in the sediment. According to Trivedy and Goel (1984), redox potential gives a fair idea of the oxidation and reduction processes going on in a system, and is a vital parameter in controlling the biological treatment of the wastes. Redox potential acts as a barrier for many organisms and according to Ansari (1988) it is generally located below 5 cm in a sandy substratum, but moves up or down depending on type of fauna, mixing and irrigation of sediment. Fenchel (1969) stated that due to the generally high productivity of estuaries the redox potential layer is close to the surface and that it often overlaps the photic zone. If the redox layer is near the surface then most of the infauna will be wiped out or restricted to a few species that can survive anaerobically. Further according to Luoma & Bryan (1981) only the oxidized surface layer of sediment readily interacts with the overlying water and is the most relevant to benthic fauna.

Table Eh-1: Monthly variations in sediment redox potential (mV) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	-2.94	-1.18	-5.88	-5.88	-5.88	3.53	10.00	-5.88	6.47	2.94	-5.29	-3.53	-1.13
Jun-99	-38.82	-9.41	-15.29	-8.24	5.29	-22.35	-5.29	6.47	-4.12	-7.65	7.65	-19.41	-9.26
Jul-99	-8.82	-16.47	-10.00	-25.29	-25.29	-25.88	-10.59	-20.59	-22.94	-25.29	-25.88	-18.82	-19.66
Aug-99	-6.47	-5.29	-2.35	-14.12	-6.47	-12.94	-5.88	-8.24	-0.59	-17.06	-8.24	-2.94	-7.55
Sep-99	-18.24	-11.18	-24.12	-14.12	-12.94	-8.24	-10.00	-2.94	-3.53	-8.24	-3.53	1.76	-9.61
Oct-99	0.59	2.35	-11.76	-11.18	-8.82	-14.12	-0.59	-3.53	-8.24	-6.47	3.53	-2.94	-5.10
Nov-99	-8.24	1.18	-1.18	-4.12	9.41	6.47	-0.59	1.18	7.06	-0.59	5.29	2.94	1.57
Dec-99	-52.94	-43.53	-46.47	-48.24	-53.53	-59.41	-49.41	-53.53	-46.47	-45.88	-51.76	-53.53	-50.39
Jan-00	-60.59	-50.00	-62.94	-54.12	-62.35	-57.06	-55.88	-60.00	-45.29	-58.24	-58.24	-61.76	-57.21
Feb-00	-45.88	-53.53	-52.35	-51.76	-48.24	-41.76	-40.00	-37.06	-48.82	-44.12	-32.35	-31.76	-43.97
Mar-00	-58.24	-54.71	-64.12	-53.53	-61.18	-47.65	-46.47	-61.76	-41.76	-52.94	-54.12	-45.29	-53.48
Apr-00	-61.18	-41.18	-69.41	-64.12	-62.94	-67.06	-65.29	-72.94	-60.00	-65.29	-61.18	-53.53	-62.01
Stn Avg.→	-30.15	-23.58	-30.49	-29.56	-27.75	-28.87	-23.33	-26.57	-22.35	-27.40	-23.68	-24.07	**-26.48**
Max	0.59	2.35	-1.18	-4.12	9.41	6.47	**10.00**	6.47	7.06	2.94	7.65	2.94	1.57
Min	-61.18	-54.71	-69.41	-64.12	-62.94	-67.06	-65.29	**-72.94**	-60.00	-65.29	-61.18	-61.76	-62.01
SD	24.94	22.96	26.51	22.78	28.00	25.14	25.99	28.75	24.60	24.51	26.87	24.17	24.65

In the present study the sediment redox potential varied from 10 mV to –72.94 mV with an annual average of –26.48 mV (Table Eh-1). Varshinin & Rozanov (1983) have given Eh values for categorizing the sediment as reduced or oxidized, they are -

1. Oxidised Eh +400 mV to +650 mV.
2. Weakly reduced Eh +200 mV to +400mV
3. Reduced Eh 0 mV to +200 mV.
4. Strongly reduced Eh –200 mV to 0 mV.

Accordingly the Thane creek sediment redox potential varied between reduced to strongly reduced condition. According to Ingole & Parulekar (1998), reduced condition of the intertidal sediments is a common characteristic. They recorded an Eh range of 16 mV to 61mV at Siridao beach - Goa. Similar redox values (12 mV to 216 mV) were also reported by Ansari & Parulekar (1998) from the near by Zuari estuary. However the Thane creek sediments showed more reduced conditions than the above ecosystems. But were comparatively better than the Pitchavaram mangroves and the mangrove estuary – Australia, where Ramamurthy *et al.* (1990) and Frusher *et al.* (1994) reported strongly reduced conditions, averaging -94 mV and –88 mV respectively.

The comparison of the monthly averages (Fig. Eh-1) revealed relatively less reduced condition during the monsoon and post monsoon months, whereas strongly reduced conditions in the pre monsoon period. The slight better conditions during the monsoon can be attributed to the physical disturbance of the sediment during rains which prevails even through some part of the post monsoon. The strongly reduced conditions during the pre monsoon could have resulted from the harsh environmental conditions and effluent load in the creek.

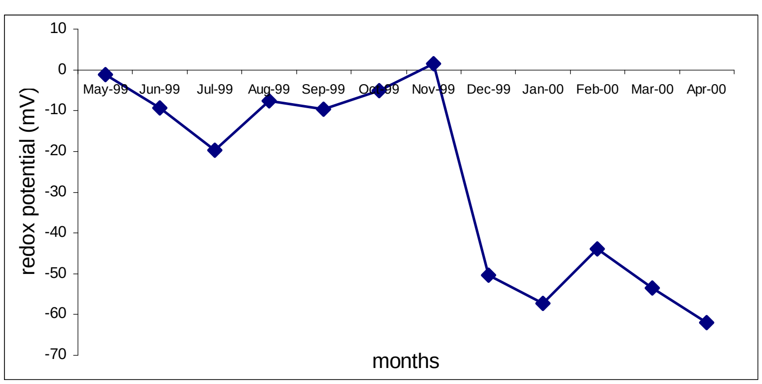


Fig Eh-1: Monthly variations in the average sediment redox potential (mV).

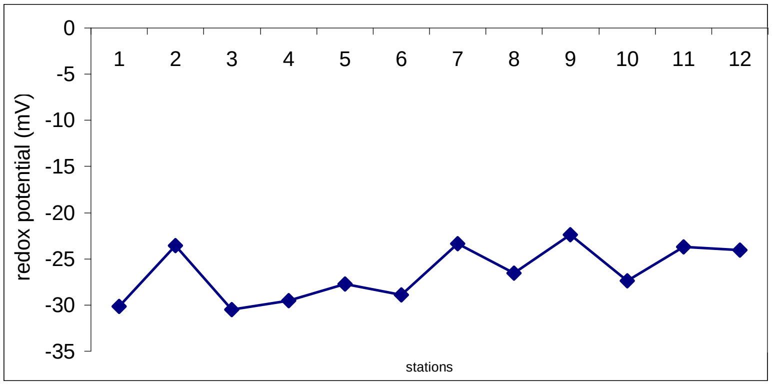


Fig Eh-2: Stationwise variations in the average sediment redox potential (mV).

A stationwise average (Fig. Eh-2) comparison revealed more reduced sediments at the riverine end which improved, although insignificantly, towards the sea. This can be attributed to the higher effluent pressure in the shallow and narrow riverine end (Stn.1) which got gradually diluted by the larger water volume towards station 12.

Organic Carbon %

Estuaries are characterized by abundant and diverse sources of organic matter including inputs from a variety of marine and terrestrial origins, each of which vary spatially along the estuarine salinity gradient (Canuel *et al*., 1995). In addition to the spatial variability in organic matter sources, the dynamic nature of the estuarine environment results in temporal changes. These spatial and temporal variations give rise to fluctuations in the abundance and composition of reactive organic matter including that assimilated by heterotrophs and incorporated into pelagic and benthic food webs. Estuaries act not only as sites of exchange between the reservoirs of terrestrial and oceanic organic matter but also as active zones where dissolved and particulate materials are produced, transformed or removed by physical and biological processes. These environments are characterized by high levels of biological production and are also active sites of heterotrophic metabolism (Smith *et al*., 1991).

Estuaries receive inputs of organic matter originating in the surrounding watershed and delivered by river or produced in surrounding habitats and tidal flats & marine derived organic matter from the adjacent coastal ocean (Canuel *et al*., 1995). According to Ansari

& Parulekar (1998), autocthonous sources like phytoplankton, benthic algae & vascular plants also form the organic matter. Industrial and municipal discharge may be important in some estuaries as well. Although each of these sources may contribute substantially to the input of organic matter, the relative importance of these sources may vary spatially and temporally within an individual estuary (Jassby *et al*., 1993). Study of organic matter is necessary, as it is well known that substrate organic matter represents a food source for deposit feeding organisms (Mare, 1942) apart from its value as an indicator of pollution (Parrish & Mackenthum, 1968; Wade, 1976). Organic carbon is directly related to organic matter and the % organic carbon in different estuaries is given in Table OC-1.

Table OC-1 Review of % organic carbon from different water bodies.

Water body	Avg. % OC	Reference
Vembanad Lake	2.55	Murty & Veerayya, 1972
Cochin backwaters	1.62	Sankaranarayanan & Punampannayil, 1979
Tropical estuary	2.06	Reddy & Sankaranarayanan. 1979
Vellar estuary	2.318	Thangaraj, 1984
Coleroon estuary	1.38	Jegadeesan, 1986
Goa estuary	4.56	Jagtap, 1987
Saphala salt marsh	1.02	Ingole *et al*., 1987
Kakinada backwaters	1.995	Vijayakumar *et al*., 1991
Kakinada bay	4.56	Vijayakumar *et al*., 1991
Mangrove estuary, Australia	1.572	Frusher *et al*., 1994
Marmugoa harbour	1.82	Ansari *et al*., 1994
Rajapur bay	1.94	Harkantra & Parulekar, 1994
Sai Keng mangrove, HongKong	1.77	Tam & Wong, 1995
ShenZhen mangrove, China	9.16	Tam & Wong, 1995
Calabar mangrove, Nigeria	6.4	Ukpong, 1997
Chesapeake Bay	1.69	Canuel & Zimmerman, 1999
AbuDhabi area mangrove	1.14	Shiradah, 2000
AbuDhabi creek	0.98	Shiradah, 2000
Ummal Quwain creek	0.24	Shiradah, 2000
Ummal Quwain Mangrove	0.79	Shiradah, 2000
Thane creek	2.63	Present study

In the present investigation the organic carbon varied between 1.21 % to 4.43 % with an annual average of 2.63 % (Table OC-2). The minimum value was recorded at the seaward end and the maximum at the riverine end. Nair *et al*. (1988) attributed high organic carbon at the riverine end to allocthonous sources in Asthamudi estuary corroborating the present investigation.

Table OC-2: Monthly variations in sediment organic carbon (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	2.51	3.53	2.11	2.14	2.91	2.45	2.94	2.11	2.57	2.01	2.39	2.85	2.54
Jun-99	2.85	4.25	3.36	3.39	4.28	2.61	3.21	2.91	3.00	2.35	2.64	2.41	3.10
Jul-99	2.54	4.06	1.86	2.39	2.45	2.08	2.66	2.01	2.32	1.92	1.95	2.11	2.36
Aug-99	2.14	4.18	3.32	3.47	3.63	2.32	2.88	2.17	2.32	1.98	2.32	2.11	2.74
Sep-99	2.23	**4.43**	3.01	3.22	3.63	2.48	2.45	2.11	2.73	2.20	2.23	2.17	2.74
Oct-99	3.78	3.53	2.82	2.26	3.53	2.73	3.13	2.14	2.63	1.77	2.39	2.39	2.76
Nov-99	2.60	3.90	2.85	3.19	3.47	2.51	2.85	1.92	2.45	2.05	2.23	2.32	2.70
Dec-99	2.29	3.44	2.23	2.94	3.25	2.57	2.73	2.17	2.48	1.98	2.20	2.14	2.54
Jan-00	2.48	**4.43**	2.85	2.88	4.09	2.29	2.42	2.26	2.11	2.05	2.08	1.86	2.65
Feb-00	2.70	3.56	3.19	2.91	3.90	2.54	2.82	2.45	2.45	2.39	2.48	2.23	2.80
Mar-00	2.91	3.47	3.35	2.70	3.41	2.23	2.45	1.52	2.08	1.64	2.14	1.86	2.48
Apr-00	2.32	4.06	2.20	2.48	2.97	1.80	2.26	1.49	1.74	1.70	1.70	**1.21**	2.16
Stn Avg.→													
	2.61	3.90	2.76	2.83	3.46	2.38	2.73	2.10	2.41	2.00	2.23	2.14	**2.63**
Max	3.78	**4.43**	3.36	3.47	4.28	2.73	3.21	2.91	3.00	2.39	2.64	2.85	3.10
Min	2.14	3.44	1.86	2.14	2.45	1.80	2.26	1.49	1.74	1.64	1.70	**1.21**	2.16
SD	0.44	0.38	0.53	0.44	0.52	0.26	0.30	0.38	0.33	0.23	0.25	0.39	0.24

Ghosh and Choudhury (1989) while studying the sediments of Hooghly estuary observed seasonal variations of organic carbon; ascribing it to the vital role of humic acid, the productivity of water and degradation of organic matter by organisms. Further, seasonal variation of organic matter in sediments is prevalent in estuaries, contented Mukherjee (1993). During the present study insignificant seasonal variations were recorded (Fig. OC-1); maximum average of 2.74 % was recorded during the monsoon followed by post monsoon (2.65 %) and pre monsoon (2.49 %). Similar trend was also reported by Varshney *et al*., (1984) and Ingole & Parulekar (1998) for the marine environments off Versova & Zuari estuary respectively, attributing the high values to shift in sediment texture and allocthonous input. Whereas Murugan & Ayyakkannu (1991) and Jegadeesan & Ayyakkannu (1992) observed minimum organic carbon during monsoon in the Cuddalore – Uppanar backwaters and Coleroon estuary respectively ascribing it to heavy runoff and erosion of surface sediment.

A stationwise comparison (Fig OC-2) also confirms the earlier observation of riverine / allocthonous source of organic carbon, as the percent organic carbon shows a declining trend from the river to the seaward zone. Similar observations were also reported by Varshney *et al*., (1988) and Nair *et al*., (1998) for the marine environment off Versova and Vasishti estuary respectively.

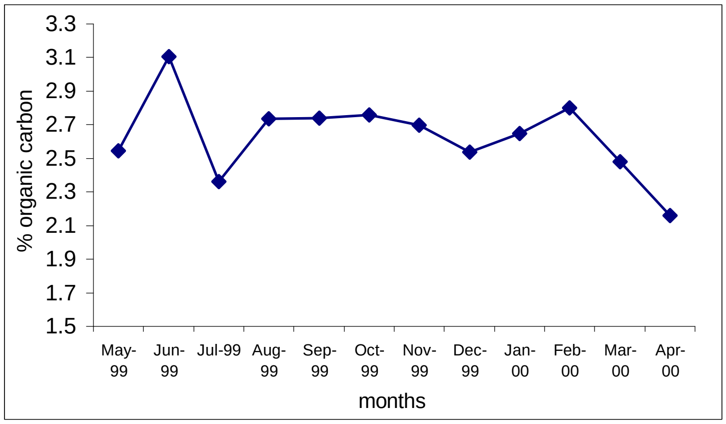


Fig OC-1: Monthly variations in the average sediment organic carbon (%).

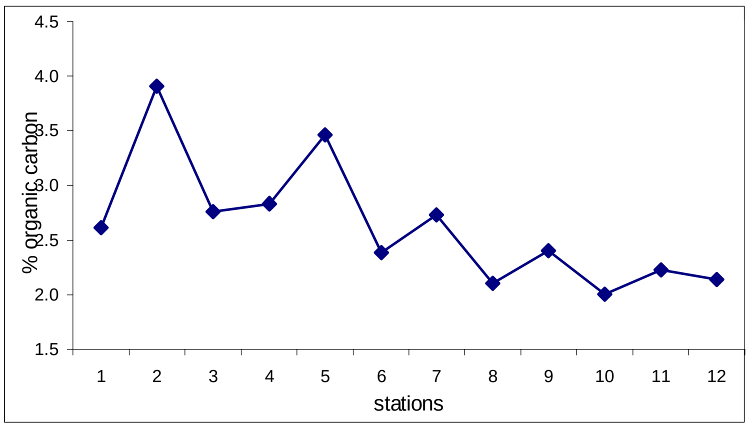


Fig OC-2: Stationwise variations in the average sediment organic carbon (%).

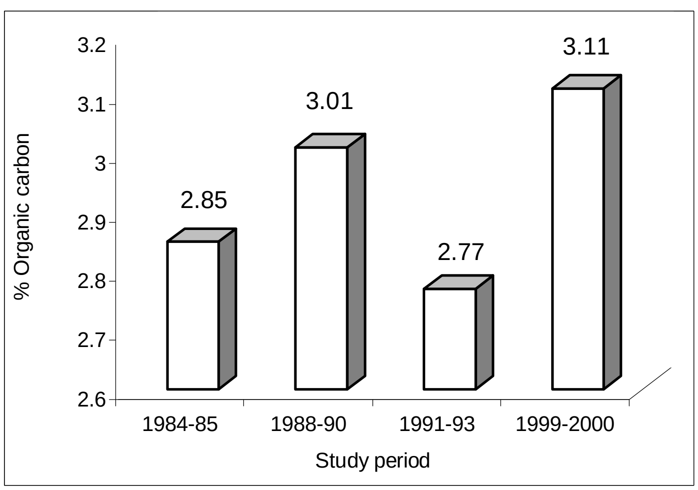


Fig. OC-3: Comparison of organic carbon (%) with the past comparable data.

A comparison of the organic carbon of the entire stretch of Thane creek with the past comparable data is not possible due to the paucity of information on the intertidal region.

But the upper shallow region of Thane creek was investigated by Athalye (1988), Mukherjee (1993) and Gokhale & Athalye (1995). And hence its comparison with the comparable present data is made in Fig. OC-3. It is evident that the % organic carbon in the upper stretches does not show any fixed pattern but fluctuates indicating the influence of effluents governing the organic carbon concentration.

Ganapati and Raman (1973), while studying the coastal waters of east coast of India reported that organic carbon more than 6 % was anoxic to bottom fauna. Whereas during the studies along the west coast of India, Harkantra *et al*. (1980) concluded that organic carbon more than 4 % can cause a decrease of benthic fauna. In the present study the annual average was 2.63 %, and the peak values over 4% were rarely recorded. Raman & Ganapati (1983) on the basis of organic carbon classified the Visakhapatnam harbour into 4 zones, viz., Very Polluted zone - % OC 1.47 to 4.24; Polluted zone - % OC 1.22 to 1.47; Semihealthy zone - % OC 0.54 to 1.22; Healthy zone - % OC below 0.54. If the present data of Thane creek is compared with the above, Thane creek can be categorized as very polluted, as the average % OC is 2.63 and the range varies from 1.21 % to 4.43 %.

Sediment organic carbon showed significant negative correlation with water parameters pH (- 0.2015), salinity (- 0.2993), dissolved oxygen (- 0.2158) and sediment parameters chlorides (- 0.1880) and clay (- 0.1917). Whereas it showed positive correlation with water parameters PO4-P (0.3483), SiO3-Si (0.347) and sediment parameters total nitrogen (0.5847) and sand (0.2067).

Total & Available Phosphorus %

In aquatic ecosystems, the knowledge of the role of sediment nutrients is especially useful in determining the sediment – water interactions which eventually affect the productivity (Nair *et al.,* 1994). According to Ketchum (1967) phosphorus is a parameter that determines the state of primary production in aquatic ecosystems. Phosphorus mainly occurs as inorganic phosphorus, organic phosphorus and particulate phosphorus. Knowledge of the phosphorus concentrations in the mud is important, especially in shallow water system, where mud acts as a reservoir of phosphorus in various forms from which phosphorus is regenerated into the overlying water under suitable conditions. Sarala Devi *et al.*, (1983) reported 80 to 90 % of phosphorus being trapped in the estuarine sediments. The total phosphorus concentration from the sediments of different aquatic ecosystems is presented in Table.TAP-1

Table TAP-1- : Review of literature on Total Phosphorus (%)

% TP range	Water body	Authors
0.069 – 0.12	Santamonica basin	Rittenberge *et al.*, 1955
0.13 – 0.19	Cochin backwaters	Qasim & Sankaranarayan, 1972
0.061 – 0.144	Cochin backwaters	Reddy & Sankaranarayan, 1972
0.004 – 0.168	Vembanad Lake	Murty & Veeraya, 1972
0.09 – 0.24	Cochin backwaters	Sankaranarayan & Punamapunnayil, 1979
0.005 – 0.0213	Vellar estuary	Sivakumar *et al.*, 1983
0.063 – 0.732	Ashtamudi estuary	Nair *et al.*, 1984
0.001 – 0.002	Netravati – Gurupur estuary	Reddy & Hariharan, 1986
0.345 – 28.816	Vellar estuary	Chandran, 1987
0.086 – 0.108	Pitchavaram mangroves	Choudhury 1988
0.046 – 0.674	Mandovi estuary	Nasnolkar *et al.*, 1996
0.035 – 0.0925	Malayasian mangroves	Alongi *et al.*, 1998
0.009 – 1.448	Thane creek	Present study.

Table TAP-2: Monthly variations in sediment Total Phosphorus (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	0.693	0.859	0.804	0.988	1.062	0.804	0.810	0.976	0.675	0.687	0.644	0.743	0.812
Jun-99	0.018	0.086	0.074	0.055	0.040	0.055	0.086	0.018	0.043	0.055	0.009	0.074	0.051
Jul-99	0.841	0.669	1.178	1.240	0.933	0.896	0.779	0.828	0.779	0.853	1.000	0.681	0.890
Aug-99	0.908	0.963	1.034	0.982	1.052	0.853	1.056	0.853	0.755	0.798	0.865	0.767	0.907
Sep-99	0.963	0.982	1.448	1.240	1.283	0.902	1.031	0.933	0.976	1.000	0.878	1.319	1.080
Oct-99	0.697	0.328	1.105	0.973	1.184	0.838	0.396	0.868	0.285	0.402	0.264	0.641	0.665
Nov-99	0.433	0.430	0.402	0.690	0.436	0.555	0.445	0.380	0.439	0.558	0.331	0.460	0.463
Dec-99	0.908	1.056	1.013	1.307	1.059	1.105	0.960	1.184	1.049	0.835	0.991	0.930	1.033
Jan-00	0.408	0.647	0.537	0.500	0.519	0.430	0.399	0.549	0.485	0.463	0.414	0.390	0.478
Feb-00	0.543	0.577	0.506	0.703	0.626	0.715	0.614	0.580	0.460	0.264	0.267	0.411	0.522
Mar-00	0.810	0.856	0.592	0.445	0.445	0.782	1.077	0.629	0.761	0.746	0.703	0.739	0.715
Apr-00	0.506	0.414	0.552	0.703	0.623	0.899	0.841	0.295	0.322	0.387	0.724	0.276	0.545
Stn Avg.→	0.644	0.656	0.770	0.819	0.772	0.736	0.708	0.675	0.586	0.587	0.591	0.619	**0.680**
Max	0.963	1.056	**1.448**	1.307	1.283	1.105	1.077	1.184	1.049	1.000	1.000	1.319	1.080
Min	0.018	0.086	0.074	0.055	0.040	0.055	0.086	0.018	0.043	0.055	**0.009**	0.074	0.051
SD	0.275	0.300	0.392	0.374	0.377	0.276	0.319	0.330	0.298	0.280	0.326	0.327	0.290

In the present study the total phosphorus ranged from 0.009 % to 1.448 % with an annual average of 0.68 % (Table TAP-2), while the available phosphorus varied from 0.005% to 0.026 % (av. 0.017 %) (Table TAP-3). Compared to most of the other water bodies the phosphorus values of Thane creek are high, but much lower than the values reported by Chandran (1987) for Vellar estuary which he attributed to the proximity of sewage outlets. The high values in the present study can be attributed to the presence of high percentage of fine-grained sediment than sand, which according to Nair *et al*. (1987) is responsible for higher percentage of organic carbon and phosphorus. The maximum and minimum values of total phosphorus were observed during the monsoon. While the available phosphorus was maximum during summer and minimum during monsoon. The minimum values can be attributed to leaching of phosphorus from the mud to the overlying waters (Sankaranarayanan & Punnampunnayil, 1979) and sudden unstable physical structure of the sediment (Nair *et al*., 1983). Further, according to Rochford (1951), total phosphorus is maximum in both freshwater and marine zones although their derivatives are different in these zones. This is also true in case of Thane creek where high and fluctuating total phosphorus was recorded.

Table TAP-3: Monthly variations in sediment Available Phosphorus (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	0.017	0.014	0.015	0.014	0.022	0.019	0.018	0.017	0.013	0.013	0.013	0.013	0.016
Jun-99	0.007	0.011	0.013	0.012	0.010	0.011	0.010	0.008	0.009	**0.005**	0.006	0.007	0.009
Jul-99	0.019	0.017	0.025	0.021	0.021	0.022	0.025	0.025	0.024	0.020	0.021	0.020	0.022
Aug-99	0.019	0.013	0.019	0.015	0.016	0.013	0.016	0.014	0.011	0.012	0.012	0.012	0.014
Sep-99	0.019	0.014	0.015	0.020	0.015	0.014	0.015	0.016	0.015	0.016	0.013	0.013	0.016
Oct-99	0.019	0.025	0.018	0.016	0.019	0.017	0.018	0.017	0.013	0.008	0.008	0.014	0.016
Nov-99	0.014	0.021	**0.026**	0.018	0.013	0.018	0.017	0.015	0.016	0.017	0.019	0.014	0.017
Dec-99	0.019	0.015	0.018	0.025	0.015	0.019	0.016	0.017	0.018	0.013	0.015	0.012	0.017
Jan-00	0.021	0.011	0.020	0.021	0.015	0.019	0.014	0.017	0.016	0.013	0.014	0.012	0.016
Feb-00	0.019	0.021	0.017	0.023	0.023	0.019	0.019	0.018	0.018	0.016	0.014	0.016	0.019
Mar-00	0.016	0.020	0.020	0.023	0.014	0.018	0.018	0.018	0.015	0.013	0.012	0.012	0.017
Apr-00	0.021	0.017	0.023	**0.026**	0.020	0.024	0.023	0.020	0.024	0.018	0.018	0.011	0.021
Stn Avg.→	0.018	0.017	0.019	0.020	0.017	0.018	0.017	0.017	0.016	0.014	0.014	0.013	**0.017**
Max	0.021	0.025	**0.026**	**0.026**	0.023	0.024	0.025	0.025	0.024	0.020	0.021	0.020	0.022
Min	0.007	0.011	0.013	0.012	0.010	0.011	0.010	0.008	0.009	**0.005**	0.006	0.007	0.009
SD	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004	0.003	0.003

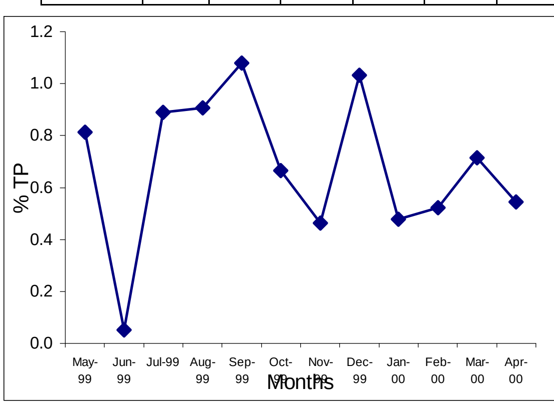


Fig TAP-1: Monthly variations in the average sediment Total phosphorus (%).

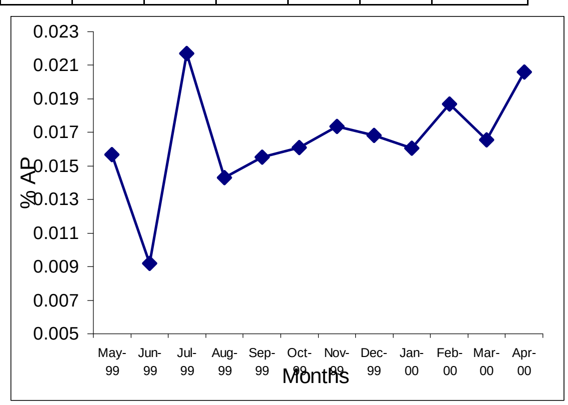
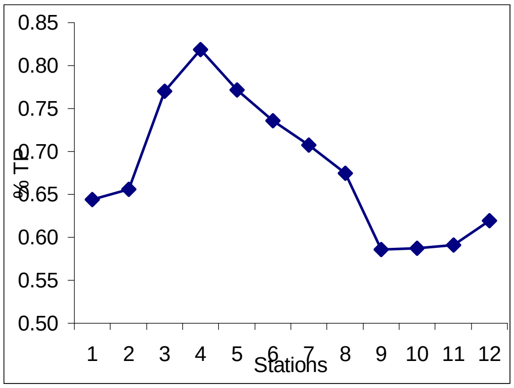


Fig TAP-2: Monthly variations in the average sediment Available phosphorus (%).



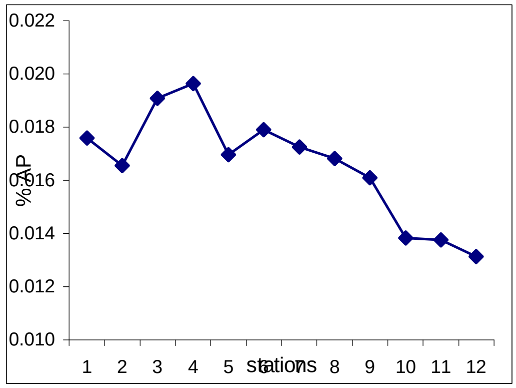


Fig TAP-3: Stationwise variations in the average sediment Total phosphorus (%).

Fig TAP-4: Stationwise variations in the average sediment Available phosphorus (%).

A seasonal comparison (Fig TAP-1) revealed wide fluctuations in the total phosphorus. In general it was maximum during the monsoon period then gradually lowered during the post monsoon (except December) and then again showed a marginal rise during the premonsoon. A seasonal comparison of the available phosphorus (Fig. TAP-2) revealed wide fluctuations in monsoon followed by an increasing trend from monsoon to premonsoon period. Sarma and Raju (1991) observed spatial variation in the phosphorus content of the shelf sediments off Vishakapatanam. They reported an increasing trend from the coastal region towards the inshore region and correlated it to the sediment texture. The comparison of stationwise variations in average total phosphorus and available phosphorus (Figs. TAP 3 & 4) show almost similar trend. Both showed an increasing trend from the seaward end to the riverine end. This could be mainly due to high amount of domestic sewage released in the creek. As discussed earlier the sewage concentration is high in the narrow & shallow riverine end of the creek. Whereas it gets diluted towards the downstream stations due to neritic water. Hence probably upstream stations had high sediment phosphorus than the downstream stations. However the extreme stations towards riverine end (i.e. Station 1 & 2 and to some extent station 3) showed deviation from the trend probably because of influence of the Ulhas river water. This influence is upto station 3 due to the geomorphic head between station 2 & 3.

The total phosphorus showed significant positive correlation with sand (0.1998) and available phosphorus (0.3455) only, whereas available phosphorus correlated positively with the water parameters pH (0.2366), PO4-P (0.3621) & SiO3-Si (0.3246) and sediment parameters pH (0.2957) and total nitrogen (0.3194). Negative correlation of total phosphorus was recorded with water parameters salinity (-0.2500) & NO3-N (-0.2336) and soil parameter chlorides (-0.1771) whereas available phosphorus did not show significant negative correlations with any of the parameters.

Total Nitrogen %

Nitrogen is a nutrient that is essential for the synthesis of proteins and is a primary regulator of oceanic productivity (Ryther & Dunstan, 1971). Coastal environments usually receive nitrogen from the rivers via estuaries. Middelburg & Nieuwenhuize (2000) attributed increased human activity to high riverine concentration of nitrogen. According to Howarth *et al.* (1996) fertilizers, atmospheric deposition in drainage basins and direct sewage discharge to rivers are the factors that affect the nitrogen cycling of estuaries and coastal seas. These disturbances result in eutrophication, changed phytoplankton community structure and enhanced production and release of nitrous oxide (Jickells, 1998).

Riverine nitrogen fluxes to the coastal seas are usually depleted during transit through estuaries, mainly through denitrification and burial in sediments (Nixon *et al.*, 1996). According to Dong *et al.* (2000), denitrification in estuarine sediment is known to be capable of removing significant quantities of nitrate from the water column, providing a sink for nitrogen in aquatic environments and thereby playing an important role in ameliorating the degree of eutrophication. Further, according to Henriksen & Kemp (1988), apart from denitrification in sediments there is nitrate diffusion to the overlying water column and nitrate production within the sediment by nitrification.

The benthic denitrification and nitrification is influenced by various factors which include freshwater flushing time (Nixon *et al.*, 1996); bioturbation by benthic infauna (Pelegri *et al.*, 1994); nitrate concentration in the water column and oxygen penetration depth (Christensen *et al.*, 1990); benthic microalgae (Rysgaard *et al.*, 1995) and availability of ammonium and oxygen (Blackburn, 1996).

In the present study the sediment total nitrogen varied from 0.063 % to 0.378 % with an annual average of 0.186 %(Table TN-1). The minimum was observed in monsoon and maximum in summer, as was observed by Reddy *et al.*, (1979)for Asthamudi estuary. Slightly lower sediment nitrogen levels have been reported by Ukpong (1997) (0.06 % to 0.12%) and Tam & Wong (1995) (0.162 % to 0.184 %) in Calabar mangroves – Nigeria & Shenzhen mangroves – China respectively. Whereas Mukherjee (1993) and Gokhale & Athalye (1995) also reported similar ranges from the shallow region of Thane creek. As against this, higher ranges were recorded by Canuel and Zimmerman (1999) (0.224 % to 0.495 %) for Chesapeake bay; Selvam *et al.* (1991) (0.21% to 0.67 %) for the mangrove strands of Madras coast; Reddy *et al.* (1979) (0.189 % to 0.656%) for Asthamudi estuary and Jagtap (1987) (0.03% to 1.94 %) for Goa estuaries.

Table TN-1: Monthly variations in sediment Total Nitrogen (%) at different stations.

Months↓	stn.1	stn.2	stn.3	stn.4	stn.5	stn.6	stn.7	stn.8	stn.9	stn.10	stn.11	stn.12	Average
May-99	0.119	0.294	0.203	0.224	0.203	0.168	0.182	0.112	0.133	0.105	0.133	0.119	0.166
Jun-99	0.140	0.252	0.189	0.210	0.252	0.168	0.182	0.126	0.196	0.112	0.154	0.119	0.175
Jul-99	0.182	0.294	0.168	0.224	0.224	0.161	0.210	0.168	0.182	0.133	0.175	0.140	0.188
Aug-99	0.070	0.112	0.126	0.112	0.126	0.077	0.084	0.070	0.070	0.070	0.084	0.063	0.089
Sep-99	0.154	0.301	0.217	0.245	0.266	0.077	0.182	0.140	0.182	0.154	0.140	0.133	0.183
Oct-99	0.266	0.252	0.217	0.189	0.266	0.182	0.196	0.133	0.147	0.098	0.168	0.112	0.186
Nov-99	0.161	0.266	0.224	0.210	0.273	0.182	0.196	0.126	0.140	0.133	0.147	0.126	0.182
Dec-99	0.168	0.287	0.154	0.168	0.224	0.182	0.182	0.140	0.154	0.126	0.154	0.112	0.171
Jan-00	0.182	0.294	0.231	0.210	0.322	0.147	0.196	0.175	0.168	0.147	0.182	0.154	0.201
Feb-00	0.217	0.294	0.259	0.231	0.350	0.231	0.245	0.217	0.217	0.259	0.224	0.182	0.244
Mar-00	0.231	0.378	0.252	0.217	0.315	0.210	0.238	0.224	0.189	0.168	0.196	0.161	0.232
Apr-00	0.224	0.343	0.231	0.224	0.266	0.182	0.238	0.154	0.189	0.189	0.182	0.182	0.217
Stn Avg.→	0.176	0.281	0.206	0.205	0.257	0.164	0.194	0.149	0.164	0.141	0.162	0.134	**0.186**
Max	0.266	**0.378**	0.259	0.245	0.350	0.231	0.245	0.224	0.217	0.259	0.224	0.182	0.244
Min	0.070	0.112	0.126	0.112	0.126	0.077	0.084	0.070	0.070	0.070	0.084	**0.063**	0.089
SD	0.054	0.064	0.040	0.035	0.060	0.046	0.042	0.043	0.039	0.049	0.035	0.033	0.039

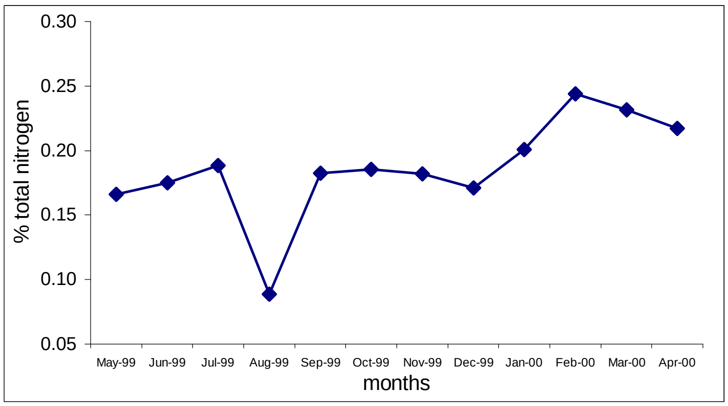


Fig TN-1: Monthly variations in the average sediment Total nitrogen (%).

Choudhury (1988) noticed no clear seasonal variations in the sediment nitrogen in Pitchavaram mangroves. Comparison of the seasonal variations in Thane creek indicated high total nitrogen during the pre monsoon with minor changes during monsoon (except a significant drop in August) and post monsoon (Fig. TN-1). Nair *et al* (1983) observed high values during the pre monsoon and attributed them to the oxidation of mangrove litter and pollution by industrial waste. This explanation also holds true for Thane creek.

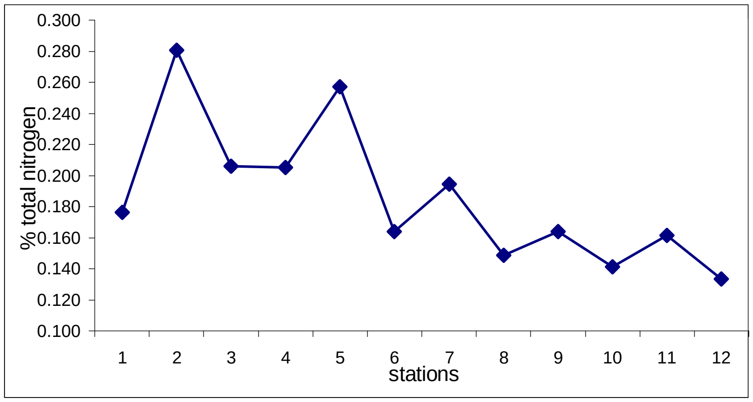


Fig TN-2: Stationwise variations in the average sediment Total nitrogen (%).

A stationwise comparison (Fig. TN-2) revealed high total nitrogen at the riverine end which gradually reduced towards the sea. Corroborating with the observation of Nair *et al.* (1983) for Asthamudi estuary, who attributed high organic carbon as the reason for high riverine total nitrogen. In the present study total nitrogen showed a significant positive correlation with silt (r =0.1839) and sediment organic carbon (r =0.5847). The other significant correlations were with water parameters pH (r =-0.1950), dissolved oxygen (r = -0.2666), PO4-P (r = 0.5212), SiO3-Si (r = 0.6255) and with sediment parameters pH (r =0.3383) & available phosphorus (r =0.3194).

Summary.

On the basis of soil parameters it can be concluded that the creek is gradually getting shallower due to increased siltation as revealed by the changing soil texture. Moreover the sediments are acting as a sink for nutrients, like organic carbon, phosphorus and nitrogen in the soil. It is also observed that the deterioration is maximum at the riverine end and lower towards the sea. The high degree of deterioration at the riverine end is attributed to shallow and narrow topography that faces maximum human pressure in addition to industrial effluents and domestic sewage.

Plankton

Introduction

The nearshore waters are biologically the most productive zones where inputs of land drainage in the form of inorganic and organic nutrients are effectively incorporated into the plant tissue producing the organic matter essential to sustain life in the sea (Ram, 1985). Further, the estuarine systems adjoining the nearshore environments are dynamic ecosystems where freshwater influx controls the environmental variability. The monsoon exerts additional stress to the area bringing drastic variations in salinity and nutrients. Because of the conflicting interactions, this zone permits the growth and survival of selected adaptive biota which can withstand the extreme variations in environmental parameters. Plankton community forms an important part of this biota.

The word plankton is derived from the Greek word ‘wanderers’ meaning free floating and is comprised of all those aquatic organisms which drift passively or whose power of locomotion is insufficient to enable them to move (Santhanam & Srinivasan, 1994). Based on the variations in character, composition and habit Krishnapillai (1986) described the plankton as Bacterioplankton (bacteria), Phytoplankton (plants) and Zooplankton (animals). The plankton form a major link in the energy transfer at primary and secondary level and play a significant role in the production potential of the aquatic environment. According to Lodh (1990), to a certain extent the success and failure of fishery particularly the pelagic fishery is dependant on the availability of plankton. Moreover the study of plankton is considered important in the pollution monitoring surveys, wherein the diversity and production estimates are used as indices to evaluate the biological sensitivity of the area.

Phytoplankton

The phytoplankton are the primary producers occupying the 1st position in the food chain. They build up complex organic matter directly from carbon dioxide and inorganic nutrients in the presence of sunlight. The energy thus fixed is partially transferred to higher trophic levels through the secondary producers which feed on phytoplankton (Lodh, 1990). According to Nielsen (1975) phytoplankton form a vital source of energy in the first trophic tier and constitute 95 % of the total marine production.

The phytoplankton mainly consist of Diatoms (Class: Bacillariophyceae); Dinoflagellates (Class: Dianophyceae); Coccolithophores (Class: Haptophyceae); Blue-Green algae (Class: Cyanophyceae); Green algae (Class: Chlorophyceae); Cryptomonad flagellates (Class: Cryptophyceae) etc. The diversity and number of phytoplankton may vary depending on the environmental setup of the ecosystem. The phytoplankton is studied in different parts of the world as well as in India, the work of some ecosystems is listed in Table P-1. Comparatively the data on the phytoplankton of Thane creek is meager. Ram (1985) recorded the phytoplankton of Thane creek while studying the polluted and unpolluted environs off Bombay. Lodh (1990) studied the plankton from Bombay harbour, Thane and Bassein creeks while Gokhale & Athalye (1995) observed the phytoplankton from the shallow region of Thane creek.

Table P-1: Review of phytoplankton study around the world.

Water body	Reference
Annual phytoplankton cycle of Cape Fear river estuary	Hobbie, 1971
Nutrient limitation of phytoplankton production in shallow estuaries near Beaufort	Thayer, 1974
Phytoplankton ecology of Cochin backwaters	Devassy& Bhattathiri, 1974
Seasonal distribution of phytoplankton in Vellar estuary	Santha Joseph, 1975
Ecology of Zuari estuary, Goa	Untawale & Parulekar, 1976
Production of different trophic levels in estuarine systems of Goa	Bhattathiri *et al.*, 1976
Diel variation in phytoplankton pigments off Bombay	Bhattathiri & Devassy, 1977
Organic Pollution & Skeletonema bloom in Visakhapatnam harbour	Ganapati & Raman, 1979
Phytoplankton in a sewage enriched tidal creek in North Carolina	Sanders & Kuenzler, 1979
Plankton of Narmada estuary & adjacent creeks	Gajbhiye *et al.*, 1981
Diurnal variation of phytoplankton from nearshore waters off Thal	Ram *et al.*, 1984
Organic nutrients & phytoplankton production in Mandovi estuary & coastal waters of Goa	Verlencar, 1984
Phytoplankton of Lesbos island (Greece)	Gotsis-Stretas & Satsmdjsis, 1984
Phytoplankton pigments of Gujarat estuaries	Desai *et al.*, 1984
Eutrophication in Visakhapatnam harbour	Raman & Ganapati, 1986
Phytoplankton in the Palmico river estuary	Stanley & Daniel, 1986
Effect of industrial effluents on biota off Mangalore	Devassy *et al.*, 1987
Phytoplankton division rates in open Arabian sea	Banse, 1988
Occurrence of diatom bloom in waters of Gopalpur, Bay of Bengal.	Choudhury & Panigrahy, 1989
Phytoplankton in relation to pollution in Visakhapatnam harbour	Raman & PhaniPrakash, 1989

Marine phytoplankton of mangrove delta, West Bengal	Santra *et al.*, 1991
Phytoplankton & pigments off Mauritius	Devassy & Goes, 1991
Table P-1 continued.	
Microphytoplankton of Pitchavaram mangroves	Kannan & Vasantha, 1992
Patterns of phytoplankton primary production in Neuse river estuary	Boyer *et al.*, 1993
Nutrient enrichment & phytoplankton growth in Louisiana Bright	Smith & Hitchcock, 1994
Phytoplankton ecology of North Carolina estuaries	Mallin, 1994
Phytoplankton from waters off Gopalpur	Gouda & Panigrahy, 1996
Nitrogen limitation of phytoplankton in Puget Sound, USA	Bernhard & Peele, 1997
Phytoplankton productivity along an Australian estuarine gradient	O'Donohue & Dennison, 1997
Long term phytoplankton studies in Bahia Blanca estuary, Argentina	Gayosa, 1998
Phytoplankton pigments & macrobenthos off Uran	Ram *et al.*, 1998
Phytoplankton from Dharamtar creek	Tiwari & Nair, 1998
Phytoplankton variability on the Faroe shelf	Gaard *et al.*, 1998
Phytoplanktonic productivity in Icelandic waters	Gudmundsson, 1998
Plankton variability in the Gulf of Trieste	Mozetic *et al.*, 1998
Blooms of phytoplankton in Vellar estuary	Perumal *et al.*, 1999
Phytoplankton biomass & euphotic layer off Kuwait	Subba rao & Faiza Al Yamani, 1999.
Dynamics of nutrients & phytoplankton biomass in Pearl river estuary, Hong Kong	Kedong Yin *et al.*, 2000
Phytoplankton of sewage polluted brackish water tidal ecosystem, North Sunderbans	Bikash Saha *et al.*, 2000
Riverine organic matter in plankton food webs	Rolff & Elmgren, 2000
Trace metal effects on diatom silica production	De La Rocha *et al.*, 2000
Effects of nutrient enrichment during a brown tide bloom	Gobler *et al.*, 2001
Winter phytoplankton blooms in Gironde plume waters	Labry *et al.*, 2001

Table P-2: Monthly variations in total Phytoplankton number (cells x 10^3/l) during high tide.

Months↓	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn 10	Stn 11	Stn 12	Avg
May-99	39000	25500	21000	15000	18000	9000	15000	10500	12000	10500	7500	6000	15750.00
Jun	49500	28500	24000	52500	39000	33000	22500	19500	13000	13000	13500	10500	26541.67
Jul	16500	51000	25500	20000	18000	12000	21000	15000	9000	9000	7500	33000	19791.67
Aug	322000	162000	142000	357500	267000	362500	369000	199000	238500	303000	245000	105500	256083.33
Sept	24000	44000	38000	31000	40000	36000	25000	32500	25500	40000	46000	66000	37333.33
Oct	22000	174000	300000	103500	210000	**543000**	244000	174080	181500	64500	94500	82000	182756.67
Nov	67500	39000	60000	41000	30000	11500	9000	20000	8000	6500	**1200**	7000	25058.33
Dec	17000	12500	53500	35500	24500	26000	41000	22000	11500	14000	20000	12000	24125.00
Jan-00	10000	13000	29000	37500	40000	25500	30000	9000	20000	11000	13500	12000	20875.00
Feb	42000	111000	24000	32000	33000	30000	31500	41000	31500	46500	28500	25500	39708.33
Mar	29000	48000	46500	76500	87000	41000	30000	27000	20000	31000	30000	32000	41500.00
Apr	21000	31000	52000	22000	49000	35000	49000	30000	38000	29000	19000	15000	32500.00
Stn.Avg →	54958.33	61625.00	67958.33	68666.67	71291.67	97041.67	73916.67	49965.00	50708.33	48166.67	43850.00	33875.00	60168.61
Min	10000	12500	21000	15000	18000	9000	9000	9000	8000	6500	**1200**	6000	15750
Max	322000	174000	300000	357500	267000	**543000**	369000	199000	238500	303000	245000	105500	256083
SD	85670.5	55905.8	80114	94381.8	81087.6	170860	112365	64662.5	75945.7	82248.3	68056.8	32907	76440.4

Table P – 5 : Overall station wise average distribution of different phytoplankton genera (no x 10^3 /l).

	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn 10	Stn 11	Stn 12	Avg	%
Centric D														**70.560**
Biddulphia	41.7	83.3	0.0	0.0	41.7	83.3	541.7	437.5	625.0	125.0	395.8	0.0	197.917	0.382
Chaetoceros	1083.3	625.0	854.2	2583.3	2229.2	2333.3	2145.8	937.5	2020.8	1291.7	1020.8	583.3	1475.69	2.850
Coscinodiscus	8104.2	12437.5	11895.8	15458.3	16479.2	19916.7	17000.0	7958.3	9958.3	9500.0	4104.2	5395.8	11517.4	22.247
Cyclotella *	1791.7	1687.5	2125.0	2541.7	2041.7	2354.2	1875.0	562.5	1437.5	2937.5	2041.7	270.8	1805.56	3.488
Leptocylindrus	7104.2	5958.3	9020.8	3916.7	7187.5	13708.3	11562.5	9791.7	9104.2	8708.3	8020.8	3062.5	8095.49	15.637
Melosira *	208.3	125.0	62.5	229.2	375.0	375.0	562.5	312.5	208.3	437.5	1312.5	583.3	399.305	0.771
Rhizosolenia	270.8	41.7	270.8	41.7	83.3	145.8	187.5	62.5	0.0	187.5	0	291.7	131.944	0.255
Skeletonema	2875.0	4479.2	6312.5	6395.8	11729.2	12937.5	11625.0	8166.7	12062.5	14000.0	10666.7	6020.8	8939.24	17.267
Thalassiosira	1875.0	3083.3	3458.3	7041.7	10479.2	6145.8	6500.0	2041.7	2937.5	791.7	1104.2	666.7	3843.75	7.425
Triceratium	145.8	0.0	125.0	0.0	0.0	0.0	145.8	125.0	0.0	291.7	208.3	437.5	123.264	0.238
Pennate D														**20.600**
Achnanthes *	104.2	187.5	104.2	0.0	145.8	104.2	479.2	312.5	41.7	166.7	166.7	541.7	196.18	0.379
Asterionella *	0.0	83.3	0.0	104.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.0	26.0417	0.050
Campylodiscus	0.0	0.0	0.0	0.0	0.0	83.3	83.3	0.0	0.0	0.0	0.0	41.7	17.3613	0.034
Fragilaria *	416.7	0.0	0.0	0.0	0.0	0.0	83.3	0.0	0.0	0.0	0.0	0.0	41.6667	0.080
Gyrosigma	437.5	166.7	166.7	0.0	125.0	0.0	62.5	0.0	62.5	62.5	62.5	312.5	121.528	0.235
Mastogloia	166.7	83.3	208.3	0.0	0.0	104.2	62.5	0.0	0.0	83.3	0.0	83.3	65.9721	0.127
Navicula *	5562.5	17500.0	10562.5	7687.5	5979.2	6208.3	4270.8	2437.5	2416.7	1750.0	1708.3	2437.5	5710.07	11.030
Nitzschia *	1520.8	14083.3	2979.2	3250.0	4479.2	2875.0	3000.0	1458.3	1145.8	2625.0	1145.8	2312.5	3406.25	6.579
Pinnularia *	83.3	645.8	41.7	125.0	62.5	583.3	166.7	166.7	0.0	0.0	0.0	83.3	163.195	0.315
Pleurosigma	1416.7	375.0	562.5	333.3	1041.7	229.2	20.8	395.8	458.3	104.2	250.0	1208.3	532.986	1.030
Pseudonitzschia	291.7	62.5	83.3	229.2	104.2	0.0	229.2	145.8	83.3	0.0	0.0	0.0	102.43	0.198
Surrilella *	62.5	62.5	0.0	104.2	125.0	104.2	187.5	0.0	0.0	0.0	0.0	0.0	53.8192	0.104
Synedra *	0.0	0.0	62.5	0.0	125.0	0.0	0.0	0.0	62.5	0.0	0.0	0.0	20.8333	0.040
Tabellaria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.0	250.0	0.0	0.0	31.25	0.060
Thalassiothrix	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.3	0.0	125.0	1812.5	83.3	175.348	0.339
Green Algae														**5.842**
Crucigenia *	291.7	166.7	187.5	875.0	0.0	395.8	145.8	83.3	312.5	125.0	312.5	0.0	241.319	0.466
Euglena *	750.0	541.7	1020.8	791.7	708.3	291.7	333.3	770.8	750.0	1083.3	375.0	145.8	630.208	1.217
Gloeocystoid form	666.7	0.0	520.8	625.0	375.0	1812.5	0.0	41.7	0.0	562.5	312.5	62.5	414.931	0.801
Golenkinia	0.0	83.3	187.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5696	0.044
Kirchneriella	0.0	0.0	0.0	1250.0	812.5	625.0	0.0	0.0	0.0	0.0	0.0	0.0	223.958	0.433
Nostoc	250.0	83.3	0.0	125.0	62.5	416.7	0.0	41.7	104.2	0.0	0.0	187.5	105.903	0.205
Pediastrum *	229.2	41.7	0.0	0.0	0.0	0.0	0.0	0.0	166.7	0.0	0.0	0.0	36.4579	0.070
Rivularia	2375.0	1187.5	833.3	104.2	83.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	381.945	0.738
Scenedesmus	270.8	83.3	0.0	125.0	0.0	62.5	0.0	250.0	62.5	0.0	104.2	0.0	79.8613	0.154
Tetraedron	0.0	62.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.20833	0.010
Anabaena *	2562.5	770.8	458.3	895.8	416.7	312.5	41.7	83.3	0.0	187.5	145.8	0.0	489.583	0.946
Oscillatoria *	104.2	750.0	833.3	270.8	541.7	541.7	458.3	375.0	250.0	62.5	416.7	104.2	392.361	0.758
Others														**2.998**
Spirulina *	0.0	0.0	0.0	0.0	0.0	208.3	0.0	0.0	0.0	62.5	125.0	20.8	34.7225	0.067
Chilomonas	0.0	0.0	0.0	0.0	0.0	104.2	0.0	0.0	0.0	0.0	0.0	0.0	8.68042	0.017
Dictyocha	0.0	0.0	0.0	0.0	0.0	62.5	0.0	0.0	83.3	0.0	0.0	0.0	12.1529	0.023
Flagellate Form *	0.0	83.3	0.0	166.7	0.0	0.0	41.7	62.5	62.5	125.0	0.0	312.5	71.1804	0.137
Mallamonas	0.0	0.0	0.0	104.2	0.0	0.0	0.0	0.0	0.0	0.0	62.5	0.0	13.8888	0.027
Porocentrum	0.0	0.0	0.0	62.5	0.0	62.5	62.5	0.0	0.0	0.0	0.0	0.0	15.625	0.030
Tribonema *	83.3	0.0	0.0	41.7	0.0	166.7	0.0	0.0	291.7	0.0	125.0	83.3	65.9725	0.127
unidentified forms.	416.7	937.5	2416.7	3125.0	3187.5	1312.5	1145.8	1062.5	562.5	687.5	729.2	375.0	1329.86	2.569

TOtal	41562.5	66562.5	55354.2	58604.2	69020.8	74666.7	63020.8	38166.7	45395.8	46333.3	36729.2	25833.3	51770.8	**100.000**
No. of genera	31	31	26	29	26	31	28	26	26	26	25	26	45	

Dominant genera   Palmers Pollution tolerant genera*

In the present investigation the phytoplankton density varied in a wide range between 1200 to 543000 x 10^3 cells/l with an annual average of 52106.88 x 10^3 cells/l (Table P-2 & 3). The minimum and the maximum densities were recorded during high tide in November at station 11 and October at station 6 respectively. The phytoplankton density in Thane creek is much higher than many of the reported observations (Table P- 4), but are lower than Calico creek (Sanders & Kuenzler, 1979) and Vishakapatnam harbour (Raman & PhaniPrakash, 1989). The phytoplankton density of Thane creek is comparable only to Pamlico river estuary (Hobbie, 1971).

Table P-3: Monthly variations in total Phytoplankton number (cells x 10^3/l) during low tide.

Months↓	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn 10	Stn 11	Stn 12	Avg
May-99	3000	7500	4500	9000	88500	39000	15000	13500	22500	7500	7500	4500	18500.00
Jun	3000	12000	7500	9000	111000	54000	16500	19500	25500	12000	6000	6000	23500.00
Jul	15000	17000	3000	7000	5000	7500	10000	16500	6000	7500	8000	37500	11666.67
Aug	34000	240000	120000	45000	14000	110000	148000	20000	72000	172500	52500	24000	87666.67
Sept	37500	78000	24000	51000	42000	37500	36000	10000	38000	34500	35000	48000	39291.67
Oct	24000	36000	44000	55500	120000	116000	160000	156000	136000	222500	165000	92000	110583.33
Nov	57000	10000	29000	14000	20000	13000	7000	3000	8000	2500	3500	11500	14875.00
Dec	11000	7500	7000	30000	45000	25500	31500	33000	24000	18000	22500	6000	21750.00
Jan-00	28000	132000	54000	110000	158000	105000	82500	11000	20000	6500	4500	9000	60041.67
Feb	66000	110000	44000	21500	79500	43500	44000	10000	25500	13000	10500	28500	41333.33
Mar	33500	170000	146000	230000	36000	26000	22000	13000	25500	13500	13500	30000	63250.00
Apr	27000	38000	30000	42000	30000	52000	55000	12000	73000	19000	33000	22000	36083.33
Stn.Avg →	28250.00	71500.00	42750.00	52000.00	62416.67	52416.67	52291.67	26458.33	39666.67	44083.33	30125.00	26583.33	44045.14
Min	3000	7500	3000	7000	5000	7500	7000	3000	6000	2500	3500	4500	11666.7
Max	66000	240000	146000	230000	158000	116000	160000	156000	136000	222500	165000	92000	110583
SD	19460.3	76364.3	45751.1	63095.5	48329.8	37661.1	52115.9	41453.4	37056.1	72909.6	45118.6	24811.9	30924

During the investigation 44 genera and 7 unidentified forms were recorded, of which 43 were observed during the high tide and 38 genera during the low tide. In general 7 genera of phytoplankton were dominant during the high tide and 8 during low tide. From the total 44 genera, 25 represented the diatoms, 11 genera consisted of green algae and one each of blue green algae(*Spirulina spp.*), Desmophyceae (*Porocentrum spp.*), Dictyochophyceae (*Dictyocha spp.*), Cryptophyceae (*Chilomonas spp.*), Chrysophyceae

(*Mallamonas spp*.), Xanthophyceae (*Tribonema spp.*) and Zygnemaphyceae (Flagellate form) (Table P - 5). The dominance of diatoms is known to be a common feature of the west coast of India (Devassy, 1987). The dominant phytoplankton observed in Thane creek were *Coscinodiscus spp*. followed by *Skeletonema spp*. & *Leptocylindrus spp.* belonging to the centric diatoms that formed the bulk (70%) of the population density. These were followed by *Navicula spp.* and *Nitzschia spp*. of the pennate diatoms that occurred throughout the year. Dominance of *Skeletonema spp.*, *Coscinodiscus spp. Navicula spp. Nitzschia spp*. is a common feature of Indian estuaries as they have also been reported from Vellar estuary (Santha Joseph, 1975); Visakhapatnam harbour (Ganapati & Raman, 1979; Raman & PhaniPrakash, 1989); Pitchavaram mangroves (Kannan & Vasantha, 1992); coastal waters off Thal (Ram *et al*., 1984) and Dharamtar creek (Tiwari & Nair, 1998).

Table P-4 : Review of phytoplankton densities from different water bodies.

Phytoplankton number	Water body	Year	Authors
130 – 5400 /ml	Beaufort channel	1966	Williams & Murdoch
250 – 7300 /ml	Cape Fear river estuary	1971	Carpenter
1000 – 340000 /ml	Pamlico river estuary	1971	Hobbie
360 – 8200 /ml	Beaufort estuaries	1974	Thayer
22200 – 299700 /l	Cochin backwaters	1974	Devassy & Bhattathiri
1530 – 49290 /10ml	Vellar estuary	1975	Santha Joseph
200 – 6000 /l	Borim mangroves, Goa	1976	Untawale & Parulekar
0.37 – 0.15 million cells /l	Mandovi estuary	1976	Bhattathiri *et al.*
0.39 – 0.004 million cells /l	Zuari estuary	1976	Bhattathiri *et al.*
1000 – 1000000 /ml	Calico creek	1979	Sanders & Kuenzler
0.03 – 604.7 x 10^2/ml	Visakhapatnam harbour	1979	Ganapati & Raman
4 –581.8 x 10^3 /l	Nearshore waters off Thal	1984	Ram *et al*.
24 –13565 /10 ml	Off Lesbos island	1984	Gotiss-Skretas & Satsmadjis
630 – 20600 /ml	Pamlico river estuary	1986	Stanley & Daniel
7 – 1195 x 10^3/l	Off Mangalore	1987	Devassy *et al*.
40 – 6258000 /ml	Visakhapatnam harbour	1989	Raman & PhaniPrakash
0.09 – 6.8 x 10^3/l	Mauritius (Indian ocean)	1991	Devassy & Goes
210 – 4200 /ml	Neuse river estuary	1991	Mallin *et al*.
560 – 4400 /ml	Neuse river estuary	1992	Mallin
360 – 784320 /l	Pitchavaram mangroves	1992	Kannan & Vasantha
9 – 759.5 x 10^3/l	Coastal waters off Gopalpur	1996	Gouda & Panigrahy
17 –5980 x 10^3/l	Dharamtar creek	1998	Tiwari & Nair
39500 – 199600 /l	Vellar estuary	1999	Perumal *et al.*
47.07 – 89.70 x 10^5/m^3	Brackish water tidal ecosystem, West Bengal	2000	BikashSaha *et al.*

Gotsis-Skrenetas (1990) gave a generalization that, if the phytoplankton cell number exceeds 11 x 10^3 /l, it can be considered as bloom of the phytoplankton. In the present study the minimum phytoplankton density recorded is much higher than the above value, indicating eutrophication. Gokhale & Athalye (1995) also observed phytoplankton blooms in the shallow region of Thane creek and attributed them to the shallowness of the mangrove mudflats and pollution by sewage. However the phytoplankton population consists of various species of varying sizes and generalization can be misleading. So when the species wise blooms were decided depending on the size of the species and density (Santhanam *et al*., 1987), persistent blooms of *Coscinodiscus spp., Skeletonema spp. Leptocylindrus spp.* and *Nitzschia spp.* were observed. According to Ganapati and Raman (1979) several workers have noted phytoplankton blooms resulting from the enrichment of nutrients due to the discharge of domestic and industrial effluents. Thane creek acts as a sewer for its industrialized and urbanized surroundings which contribute to the nutrient enrichment leading to phytoplankton blooms.

Outburst of phytoplankton during monsoon period synchronized with low salinity and high nutrient values were reported by Tiwari and Nair (1998) for Dharamtar creek and Qasim (1972) from Cochin backwaters which receive domestic and industrial effluents. They also observed bimodal pattern with 2 peaks in an annual cycle. Thane creek also receives domestic and industrial effluents in large quantities and showed similar trend as above. The primary peaks were observed in August & October whereas the secondary peaks from January to March (Fig. P-1)

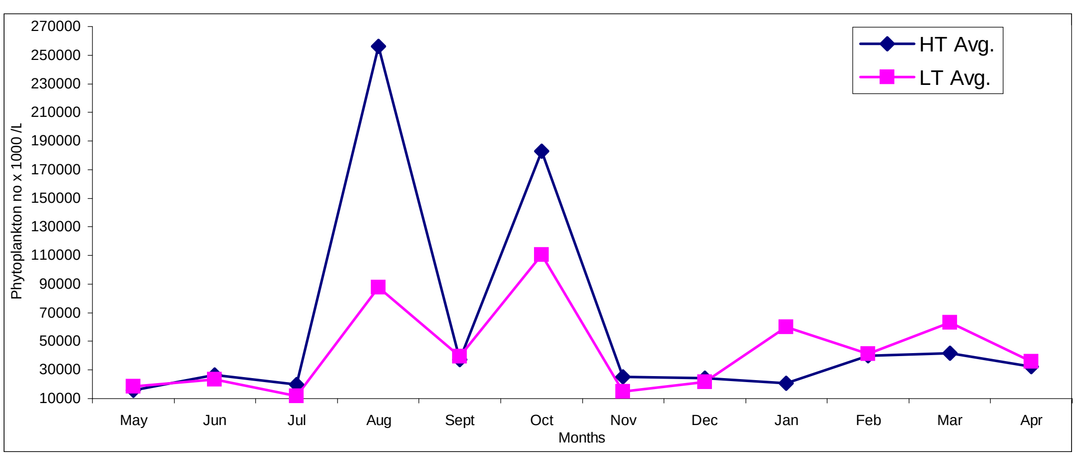


Fig. P-1 : Monthly variations in phytoplankton (no x 10^3/l)during high tide and low tide.

A stationwise comparison (Fig P-2) revealed in general higher density and species number at the upstream riverine end than the downstream seaward end during low tide, which could be due to higher sewage pollution in the upstream region providing high amount of nutrients for phytoplankton growth. The density during high tide showed an increasing trend from station 1 to 6 and thereafter declined up to station 12. During high tide probably the phytoplankton from the downstream stretches probably get pushed upstream, thus increasing their number at these stations. Whereas at the downstream stations large quantity of neritic water has a diluting effect, thus giving a different trend during high tide.

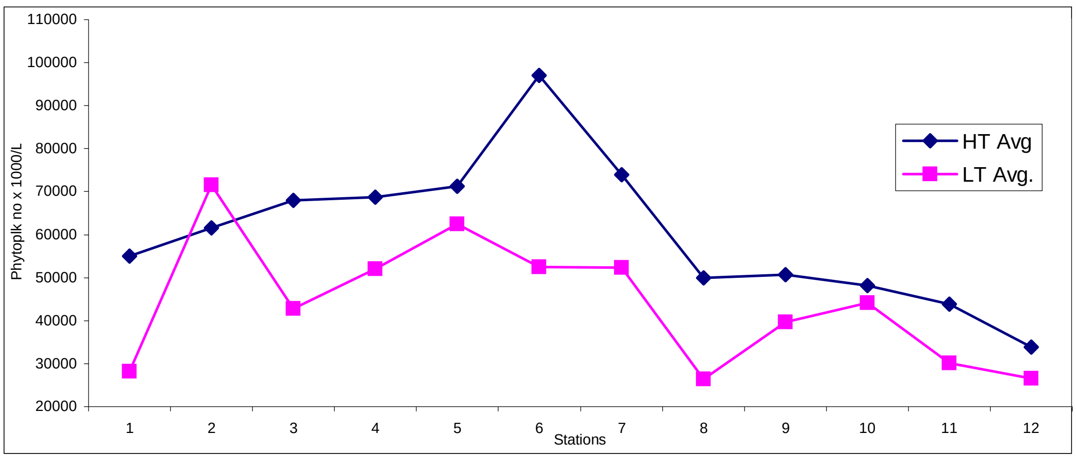


Fig. P-2 : Stationwise variations in phytoplankton (no x 10^3/l) during high tide and low tide.

Hydrographical conditions greatly influence the phytoplankton population (Ganapati & Raman, 1979), of which the most important are temperature, nutrient and light availability (Thordardottir, 1986). The correlation coefficients of the dominant phytoplankton and the total phytoplankton are presented in Table P-6.

Table P-6: Simple correlation coefficients of dominant phytoplankton with water parameters.

	Anabaena	Chaetoceros	Coscinodiscus	Cyclotella	Euglena	Leptocylindrus	Navicula	Nitzschia	Oscillatoria	Pleurosigma	Skeletonema	Thalasiosira	Total
High tide													
Temprature	0.040	0.081	0.097	0.131	-0.235	0.028	0.016	0.055	0.095	-0.068	0.146	-0.205	0.105
LP	0.070	0.088	0.035	0.026	0.083	0.004	-0.031	0.031	-0.111	0.110	0.069	0.156	0.041
SS	-0.074	-0.055	-0.050	-0.043	0.018	0.037	0.072	-0.066	-0.082	-0.042	-0.020	-0.019	-0.038
pH	-0.049	0.307	0.304	0.177	-0.191	0.391	-0.015	0.0001	-0.034	-0.051	0.366	0.046	0.364
Sailnity	-0.229	-0.146	-0.305	-0.217	0.162	-0.090	-0.278	-0.274	-0.388	-0.093	-0.186	0.068	-0.296
DO	-0.052	0.025	-0.058	-0.100	-0.043	0.055	-0.075	-0.102	0.174	0.036	-0.037	-0.222	-0.061
PO4P	-0.026	-0.062	-0.106	-0.108	0.127	-0.212	0.178	0.111	-0.048	-0.167	-0.191	0.271	-0.138
NO3-N	-0.099	0.071	0.053	0.036	0.054	0.067	-0.048	-0.145	-0.254	-0.114	0.096	0.149	0.040
Sio3-Si	-0.074	-0.064	-0.064	-0.065	0.135	0.128	0.114	-0.087	-0.206	-0.068	-0.053	0.363	0.002
Lowtide													
Temprature	0.108	-0.055	0.223	0.126	-0.281	-0.107	0.073	-0.006	0.166	0.207	0.124	-0.327	0.006
LP	-0.035	0.061	-0.098	-0.002	0.214	-0.034	-0.115	-0.069	-0.184	-0.197	0.095	0.098	-0.041
SS	-0.102	-0.061	-0.080	-0.061	-0.144	-0.033	-0.133	-0.087	-0.051	-0.027	-0.065	-0.118	-0.174
pH	-0.025	0.056	0.181	0.136	-0.131	0.237	-0.119	-0.113	-0.065	-0.100	0.337	-0.091	0.195

Sailnity	-0.341	0.132	-0.200	-0.126	0.133	-0.010	-0.164	-0.082	-0.324	0.057	-0.043	0.205	-0.108
DO	0.048	-0.224	-0.030	0.127	-0.095	0.122	0.044	-0.026	0.071	-0.075	-0.033	-0.220	-0.019
PO4P	-0.096	0.100	-0.013	0.130	0.188	-0.192	0.239	0.226	-0.143	0.040	-0.204	0.196	0.073
NO3-N	-0.174	-0.014	-0.106	-0.053	0.066	0.004	-0.045	-0.100	-0.210	0.010	-0.158	0.067	-0.110
Sio3-Si	0.023	0.073	-0.066	0.033	0.153	0.075	0.046	-0.200	-0.134	0.004	-0.064	0.159	0.056

Values above ± 0.1673 are significant at 5% level of significance.

According to Eppley (1972), temperature is known to have a positive effect on the growth rate of phytoplankton. This view has been endorsed by many workers (Williams & Murdoch, 1976; Goldman, 1977). However in the present study except for *Euglena spp*. & *Thalassiosira spp*. temperature had insignificant or varying correlations with the other species corroborating the view of Kannan and Vasantha (1992) that the influence of surface water temperature on phytoplankton density is obscure in tropical marine environments. Svedrup (1953) considered the availability of light as the most important factor for the initiation of phytoplankton blooms. In Thane creek phytoplankton always showed bloom conditions and had insignificant or variable correlations with light penetration. According to Raman and Ganapati (1979), availability of nutrients governs the density of phytoplankton. In the present study nutrients had variable relations with the phytoplankton species probably because they were never too low to limit the plankton growth. Ketchum (1964) ascribed salinity to be the major ecological factor controlling the distribution and seasonal succession of phytoplankton. Devassy and Bhattathiri (1974) considered salinity to be an important factor in an estuarine system governing phytoplankton population and observed a negative correlation between salinity & phytoplankton in the Cochin backwaters. In Thane creek most of the dominant species of phytoplankton were euryhaline and showed either a significant negative or insignificant correlation with salinity corroborating with the above view.

Table P- 7: Diversity indices for phytoplankton during high tide and low tide.

High tide	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn 10	Stn 11	Stn 12	Avg
N0	27	24	24	23	22	27	23	20	18	24	21	22	43
N1	14.140	9.030	8.694	10.732	9.821	9.039	7.975	8.684	7.191	9.277	10.099	10.381	11.253
N2	10.029	6.390	6.338	6.823	7.151	6.291	6.082	6.093	5.029	6.362	6.556	6.824	7.301
R1	2.382	2.085	2.067	1.975	1.879	2.264	1.938	1.756	1.566	2.131	1.867	2.073	3.820
R2	0.115	0.097	0.092	0.088	0.082	0.087	0.079	0.090	0.079	0.109	0.099	0.139	0.176
Lambda	0.100	0.156	0.158	0.147	0.140	0.159	0.164	0.164	0.199	0.157	0.153	0.147	0.137
H'	2.649	2.201	2.163	2.373	2.285	2.202	2.076	2.161	1.973	2.228	2.312	2.340	2.421
E5	0.687	0.671	0.694	0.598	0.697	0.658	0.729	0.663	0.651	0.648	0.611	0.621	0.615
Low tide	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn 10	Stn 11	Stn 12	Avg
N0	25	22	22	21	16	22	19	20	19	18	18	20	38
N1	11.008	7.516	10.433	9.799	7.743	8.475	8.518	8.684	10.497	6.303	8.165	10.330	11.004
N2	7.523	5.064	6.672	7.978	6.019	5.705	6.349	6.093	7.443	4.467	5.519	7.587	8.089
R1	2.342	1.879	1.969	1.842	1.354	1.933	1.688	1.756	1.694	1.590	1.648	1.865	3.458
R2	0.149	0.082	0.106	0.092	0.063	0.096	0.092	0.090	0.094	0.086	0.104	0.123	0.180
Lambda	0.133	0.197	0.150	0.125	0.166	0.175	0.158	0.164	0.134	0.224	0.181	0.132	0.124

H'	2.399	2.017	2.345	2.282	2.047	2.137	2.142	2.161	2.308	1.841	2.100	2.335	2.398
E5	0.652	0.624	0.601	0.793	0.744	0.629	0.711	0.663	0.712	0.654	0.631	0.706	0.709

Diversity index gives a measure of the way in which individuals in an ecological community are distributed among species (Devassy & Bhattathiri, 1974). The diversity indices calculated for the present study of phytoplankton of Thane creek are presented in Table P-7. As already discussed the number of genera (N 0) observed was more during high tide than the low tide, but the number of most dominant species (N 2) was slightly higher during the low tide. All the indices in general, depicted higher values at the riverine end stations indicating preference of the phytoplankton to less saline conditions. Hendey (1977) classified marine habitat on the basis of species diversity indices as severely polluted (0-1), moderately polluted (1 – 2) and slightly polluted (2 – 3). On the basis of this classification Thane creek varies between moderately polluted to slightly polluted as the Shannon's diversity index (H') in Thane creek varied between 1.973 to 2.649 (av. 2.421) during the high tide and 1.841 to 2.399 (av. 2.398) during the low tide. Similar values have been reported from Cochin backwaters & Dharamtar creek by Qasim (1972) and Tiwari & Nair (1998) respectively. Palmer (1969) gave a list of 60 pollution tolerant genera of phytoplankton and prepared an algal genus index by assigning numbers to each of them depending on their relative tolerance. In Thane creek 19 of the 60 pollution tolerant genera (Table P-5) were observed of which *Navicula spp*. and *Nitzschia spp*. were the most dominant. The algal genus index for them was calculated by totaling the number assigned by Palmer which totaled a score of 25 indicating high organic pollution in the creek.

A comparison of phytoplankton density with the past available data revealed considerable increase in the phytoplankton density during the past 15 years (Fig.P-3), indicating growing eutrophication in Thane creek.

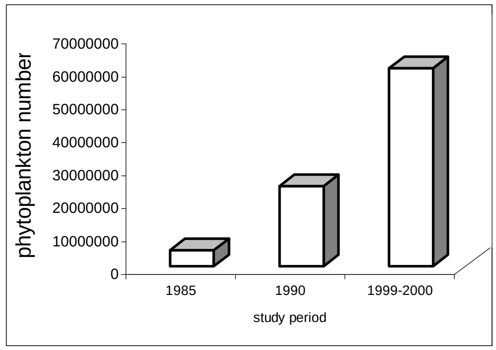


Fig P- 3: Comparison of phytoplankton number
with the past available data.

Summary

The phytoplankton studies revealed considerable increase in the number of phytoplankton, with dominance of pollution tolerant species. The number of phytoplankton and species density was higher in the shallow and narrow upstream stretches of the creek. In Thane creek during the present study, 19 of the 60 pollution tolerant genera suggested by Palmer (1969) were observed. Further the Palmers algal genus totaled a score of 25 indicating high level of organic pollution in the creek.

Zooplankton

Zooplankton are small heterotrophic animals, inhabiting the oceans at all depths and occupy almost every type of ecological environment. The zooplankton have individual powers of movement but they are negligible in comparison to water currents, hence are virtually at the mercy of currents and drift about passively. According to Chandramohan *et al.* (1990), the zooplanktonic organisms have various behavioural adaptations like the utilization of tidal currents, vertical migration, high reproductive rate and changes in the larval behavior by which they have been successfully thriving well in the dynamic systems like estuaries and bays. Another aspect relating to the zooplankton movement is that the species inhabiting a water mass will tend to have an overall distribution beyond the area where it reproduces and maintains itself successfully and it will be carried to greater or lesser degree outside its own area by drift (Raymont, 1983).

The zooplankton community mostly consists of invertebrates and larvae & immature stages of both invertebrates and vertebrates. According to Nair *et al.* (1999), the zooplankton community comprises of herbivores, omnivores and carnivores, of which generally herbivores form a major fraction. Associated with the phytoplankton bloom initial zooplankton standing stock will be dominated by herbivore and omnivore community, which later develop into a region with higher ratio of carnivores (Nair, 1980). Further, Lodh (1990) attributed the changes from normal pattern to relatively higher share of carnivores, to the stress induced on the ecosystem. According to Krishnapillai (1986), depending on the nature of the animals that form the community, plankton is divided into holoplankton (i.e. animals planktonic throughout their life cycle, eg. Copepods) and meroplankton (i.e. animals planktonic for a brief period of their life cycle, eg. Fish larvae). Zooplankton are further classified on the basis of their habitat as freshwater plankton or limnoplankton and marine plankton or haliplankton. The haliplankton consist of oceanic plankton (plankton inhabiting waters beyond the continental shelf), neritic plankton (plankton inhabiting waters overlying the continental shelf) and brackish water plankton (plankton inhabiting areas like estuaries, creeks, etc.).

Study of zooplankton is necessary as it forms the vital link in the pelagic food chain (Misra & Panigrahy, 1999) and are considered as the chief index of utilization of aquatic biotope at the secondary trophic level (Goswami & Padmavati, 1996). Zooplankton also constitutes the major food item for crustaceans, mollusk and fishes. Thus the abundance of zooplankton practically acts as an index to assess the fertility of water mass. A correlative study of zooplankton distribution, their intensity and abundance in relation to environmental parameters is necessary for a correct understanding of fishery resources (Sarkar *et al*., 1985). According to Nasser *et al.* (1998), some fishes are exclusively zooplankton feeders and therefore their abundance is directly linked to the presence of zooplankton. Furthermore, many zooplankton species are used as the water quality indicators including pollution (Mishra & Panigrahy, 1999). In recognition to this view the zooplankton has been extensively studied. However the detailed zooplankton studies in Indian waters are mainly reported from Cochin backwaters, Gautami-Godavari estuary Hooghly estuary, Mandovi-Zuari estuarine complex, Rushikulya estuary & Vellar estuary,. The zooplankton data on Thane creek, though meager, has been reported by Desai *et al.* (1977), Gajbhiye (1979 & 82), Lodh (1990) and Gokhale & Athalye (1995).

As mentioned in materials & methods, in the present study the zooplanktons were not assessed at all the 12 stations. They were sampled from 5 zones as follows, Zone 1- stn. 1 to stn. 3; Zone 2- stn. 4 to stn.6; Zone 3 – stn. 7 to stn. 9; Zone 4 – stn. 10 & 11 and Zone 5 – stn. 11 to stn 12.

The monthly average zooplankton density varied between 902.31 to 492100 no/m^3 and annual average density of 27917.7 no/m^3 for the entire creek during the present study (Table Z-1). The minimum and the maximum values were observed at the riverine end of the creek during April and November respectively. The density of zooplankton of Thane creek is high as compared to most of the other Indian estuaries, however it is lower than Pullavazhi backwaters, Vellar estuary, Bahuda estuary, Kakinada Bay and Pitchavaram mangroves (Table Z-2). The high zooplankton density in Thane creek can be attributed to the nutrient load and consequent phytoplankton blooms in the creek as suggested by Gajbhiye (1982).

Table Z-1 : Monthly variations in total Zooplankton number (no/m3) and biomass (ml/m3).

	Abundance no/m3						Biomass ml/m3					
Months↓	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Avg.	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Avg
May -99	4617.8	7197.5	3609.3	10439.0	14791.0	8130.9	5.31	2.55	2.65	3.54	5.31	3.87
Jun	4373.7	5069.0	6066.1	6521.1	11182.0	6642.4	3.19	2.65	2.27	3.03	5.31	3.29
Jul	3949.0	4458.6	8007.3	5232.0	15570.0	7443.4	3.19	3.54	3.03	2.27	6.19	3.64
Aug	8227.2	22965.0	5307.9	9614.8	16897.0	12602.4	4.25	0.88	1.52	1.52	3.54	2.34
Sept	12229.0	7607.9	12739.0	86442.0	70064.0	37816.4	2.12	0.88	1.52	2.27	3.54	2.07
Oct	3821.7	2242.0	74593.0	3963.2	2264.7	17376.9	1.33	1.91	1.77	1.77	6.19	2.59
Nov	492100.0	10599.0	6266.3	17445.0	15127.0	108307.5	1.33	1.91	0.88	1.77	3.54	1.89
Dec	3503.2	489170.0	2972.4	11182.0	5874.0	102540.3	3.98	5.10	1.77	5.31	3.54	3.94
Jan -00	10616.0	1222.9	24239.0	7077.1	23496.0	13330.2	5.31	5.10	5.31	5.31	1.77	4.56
Feb	7961.8	2242.0	5590.9	4494.0	7802.5	5618.2	2.65	1.27	0.88	0.44	5.31	2.11
Mar	9925.7	8598.7	17622.0	10527.0	7147.9	10764.3	1.33	1.27	1.77	3.54	1.24	1.83
Apr	902.3	3057.3	10297.0	2459.3	5484.8	4440.1	2.65	5.10	5.31	0.88	4.42	3.67
Stn.Avg →	46852.3	47035.8	14775.9	14616.4	16308.4	27917.7	3.05	2.68	2.39	2.64	4.16	2.98
Min	902.3	1222.9	2972.4	2459.3	2264.7	4440.1	1.33	0.88	0.88	0.44	1.24	1.83
Max	492100.0	489170.0	74593.0	86442.0	70064.0	108307.5	5.31	5.10	5.31	5.31	6.19	4.56
SD	140258.3	139358.5	19845.0	22986.3	17968.9	37287.0	1.43	1.65	1.50	1.57	1.60	0.95

Table Z-2 : Review of Zooplankton density and biomass average values.

Av. density, no/m3	Av. biomass	Ecosystem	Reference
8739	74.71 cc	Godavari estuary	Chandramohan, 1963
1396	350 mg/m^3 (d.w.)	Cochin backwaters	Madhupratap & Haridas, 1975
302000	--	Vellar estuary	Santhanam ***et al***., 1975
1690	9 mg/m^3 (d.w.)	Ambica estuary	Nair ***et al***., 1981
2746	8 mg/m^3 (d.w.)	Auranga estuary	Nair ***et al***., 1981
55	0.007 ml/ m^3	Bukki creek	Gajbhiye ***et al***., 1981
102	0.021 ml/ m^3	Dahej creek	Gajbhiye ***et al***., 1981
1297	8 mg/m^3 (d.w.)	Mindola estuary	Nair ***et al***., 1981
1315	7 mg/m^3 (d.w.)	Purna estuary	Nair ***et al***., 1981
5094	176 mg/m^3 (d.w.)	Chemaguri creek, Sunderbans	Bhunia & Choudhury, 1982
4169.31	0.954 ml/ m^3	Hooghly estuary	Baidya & Choudhury, 1985
9682.78	--	Pitchavaram mangroves	Palaniappan & Baskaran, 1985
9803.35	0.425 ml/ m^3	Sagar island, Sunderbans	Sarkar ***et al***., 1985
12619.5	--	Inland sea of Japan	Madhupratap & Onbe, 1986
4329.17	0.977 ml/ m^3	Pitchavaram mangroves	Sanmugum ***et al***., 1986
263000	498 mg/m^3 (d.w.)	Pullavazhi backwaters	Srinivasan & Santhanam, 1991
Table Z-2 continued.			
202	--	Mangrove creek Gazi, Kenya	Osore, 1992
265.5	0.1825 ml/ m^3	Coastal waters of Murud	Gajbhiye ***et al***.,1995
244.63	0.3 ml/ m^3	Coastal waters of Goa to Gujarat	Padmavati & Goswami, 1996
15834	0.44 ml/ m^3	Gaderucanal Southeast coast of India	Chandramohan & Sreenivas, 1998
20.85	--	Minicoy lagoon	Nasser ***et al***.,1998
45261	3.5 ml/ m^3	Bahuda estuary	Mishra & Panigrahy, 1999
38408.33	2.17 ml/ m^3	Kakinada bay	Chandramohan ***et al***., 1999
29200	--	Pitchavaram mangroves	Karuppassamy & Perumal, 2000
27918	2.984 ml/ m^3	Thane creek	Present study, 1999-2000.

The zooplankton biomass varied from 0.442 to 6.192 ml/m^3 (av. 2.984 ml/ m^3) (Table Z-1) and is comparable with the other Indian estuaries (Table Z-2) that report pollution stress. Further according to Nair *et al*. (1983), the polluted areas around Bombay sustain high biomass of zooplankton due to the congregation of gelatinous organisms. However Srinivasan & Santhanam (1991) are of the view that biomass obtained through displacement volume & wet weight methods are not dependable owing to the presence of water and detritus in samples. Thane creek has high amount of suspended solids which may affect the biomass. Qasim (1977) quoted that the zooplankton of mangrove environments are poorly studied and their role in the food chain is meagerly known. Goswami (1984) ascribed this to the difficulty of zooplankton sampling in the mangrove ecosystem. Further the plankton obtained in such areas are adapted to the shallow depth of water, turbidity and periodic fluctuations of the different physical and chemical parameters that influence the occurrence and abundance of zooplankton. The occurrence and distribution of zooplankton observed during the present study on Thane creek is presented in Table Z-3.

During the present study a total of 34 zooplankton types were observed which can be grouped into 4 categories viz. 1) Zooplankton occurring throughout the creek. 2) Zooplankton occurring almost in the entire creek. 3) Zooplankton influenced by the salinity gradient and 4) Zooplankton showing sporadic occurrence.

1) **Zooplankton occurring throughout the creek**:- In this category only nine types of zooplankton were observed. They are cyclopoid & calanoid copepods, nematode, nauplius of balanus, zoea of crab, insect larvae, larval stages of gastropods, larval stages of bivalve and fish eggs. The copepods namely cyclopoid, calanoid and harpacticoid formed a significant part (25 %) of the zooplankton density in the creek. According to Levinton (1982) and Ramaiah & Nair (1997), the copepods form the largest group of crustaceans in the world, zooplankton fauna contributing over 80 – 90 % of the zooplankton counts in the estuarine habitats. In present case however, their contribution was only 25 %, contrary to the fact that calanoid copepods out number all the other groups (Rosamma Stephen, 1984), in the present study cyclopoid copepoda was the most dominant type. Lodh (1990) observed that the density of copepods in Thane creek increased from the creek to the offshore stations, corroborating with the present study, wherein the percentage of copepods increased from the riverine to the seaward stations. Moreover gravid female copepods were observed only from the middle to the seaward stations of the creek.

Table Z-3 Stationwise occurrence and distribution of zooplankton (no/m3).

Groups ↓	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Avg	% occurrance	Groupwise %
Foraminifera	0	0	0	0	324.67	64.934	0.23	0.23
Tintinnida	0	0	61.92	550.69	554.38	233.398	0.84	0.84
Coelentrates								1.12
Hydromedusae	260.97	0	401.18	195.56	172.51	206.044	0.74	
Medusaezooids	0	0	0	10.32	17.69	5.602	0.02	
Siphonopore	0	0	128.27	116.06	258.02	100.47	0.36	
Annelida								60.051
Polychaete	2.21	0	0	0	0	0.442	0.002	
II Setiger larvae	17.69	33.97	25.28	0	0	15.388	0.06	
III Setiger Larvae	103.5	43.52	106.58	0	0	50.72	0.18	
IX Setiger Larvae	41302	41221	298.67	207.15	0	16605.764	59.49	
Nematode	163.66	28.66	5.9	23.59	207.89	85.94	0.31	
Oligochaete	2.21	16.99	0	0	0	3.84	0.01	
Rotifera	86.47	288.63	0	0	0	75.02	0.27	0.27
Arthropods								32.07

Ant	0	50.96	0	1.47	0	10.486	0.04	
Water mite	70.77	5.31	162.18	0	56.03	58.858	0.21	
Insect Larvae	122.97	78.47	10.53	5.06	14.74	46.354	0.17	
Calaniod	952.76	966.09	628.52	4750	2892.8	2038.034	7.30	
Cyclopoid	2221.8	1563.5	7698.1	5506.4	7010.8	4800.12	17.20	
Harpactacoid	242.39	105.92	25.28	0	837.46	242.21	0.87	
Crustacean eggs	0	0	85.52	53.13	147.44	57.218	0.20	
Penilia	374.2	5.31	0	0	0	75.902	0.27	
Ostracod	333.95	154.4	41.28	37.91	0	113.508	0.41	
Mysis	0	0	0	1.47	5.9	1.474	0.01	
Nauplius of Balanus	225.58	357.16	1938.5	1664.4	1303.4	1097.808	3.93	
Shrimps	0	0	0	0	44.23	8.846	0.03	
Zoea of crab	15.04	65.67	629.57	11.8	1226.7	389.756	1.40	
Megalopa of Crabs	7.08	33.97	0	12.64	0	10.738	0.04	
Mollusc								5.10
Gastropod larvae	241.51	1359.7	2100.8	1336	756.37	1158.876	4.15	
Bivalve Larvae	26.54	555.85	259.71	119.95	365.65	265.54	0.95	
Fish eggs	63.69	86.4	166.82	6.32	106.16	85.878	0.31	0.31
Unidentified	0.1592	14.74	0	0	5.9	4.15984	0.01	0.01
Total	46837.1	47036.2	14774.61	14609.92	16308.74	27913.328	100.00	

Zooplankton occurring through out the creek; almost through out the creek ; restricted by salinity gradient; sporadic.

The larval stages of phylum mollusca (gastropoda and bivalvia) were next to copepoda in dominance (5 %) among the organisms of this category. Annie Mathew (1989) reported increase in the molluscan fauna of Thane creek during the period 1985-86 and attributed it to the slow currents and sheltered nature of the creek. This could have fascilitated the proliferation of the molluscan larvae in the creek waters. The meroplanktonic crustaceans i.e. nauplius of balanus and zoea of crab were recorded through out the year except a few months. They and the molluscan larvae showed an increasing trend from the riverine end to the seaward end. The nematodes though not pure planktonic form were observed in the entire creek during pre monsoon & post monsoon and did not show any particular trend. The fish eggs showed an increasing trend from the riverine end to the seaward end. The fish eggs however, were poorly represented and were restricted to the monsoon season only when the environmental conditions become less hostile due to dilution of pollutants.

2) **Zooplankton occurring in almost the entire creek** include polychaete larvae, ostracod, megalopa of crab, and water mite. According to Levinton (1982), polychaetes are mostly meroplanktonic in existence with few families adapted exclusively for holoplanktonic existence. In the present study the meroplanktonic polychaete larvae comprising of polyniod larvae, II, III & IX setiger larvae were the most abundant especially at the riverine end of the creek. In November the IX setiger larvae were highly abundant at the riverine end and overshadowed the annual copepod dominance in the creek. Due to this they formed 60 % of the total zooplankton abundance. Relatively higher numerical abundance and dominance are often considered to be measures of

successful adaptation (c.f.Briggs, 1974). However, the occurrence of polychaete larvae were irregular as was observed in Mandovi and Zuari estuaries by Goswami & Singbal (1974). This observation also corroborates with the observation of Nair *et al.* (1981), that the variability and patchiness are unique features in plankton distribution. The basic factors responsible for such patterns are many, of which the effect of additional environmental stress imposed on the ecosystem by pollution or any other man made modification is the major one. Thane creek faces high pressure of anthropogenic activities & pollution pressure (Lodh, 1990) causing patchy distribution of zooplankton.

According to George *et al*. (1975), ostracods constitute a major group of tropical zooplankton. But during the present study ostracods along with the megalopa larvae of crab and watermite despite their occurrence in the entire stretch of the creek showed poor (0.66 %) representation.

3) **Zooplankton influenced by the salinity gradient** :- Salinity is the main physical parameter that can be attributed to the plankton diversity acting as a limiting factor which influence the planktonic community and its distribution (Chandramohan & Sreenivas, 1998). During the present study salinity showed an increasing trend from the riverine to the seaward side (Fig SL-2). According to Stephen & Iyer (1979), most of the zooplankton can withstand fluctuations in salinity, while Bowman (1971) is of the view that salinity is a parameter that affects the habitat. During the investigation though some zooplankton were cosmopolitan in their occurrence there were some types that were restricted to the riverine end and some to the sea ward end.

The zooplankton occurring at the riverine end include rotifera, penelia and oligochaeta. While foraminifera, tintinnida, coelentrates, mysis & shrimps were observed at the seaward end. The zooplankton of phylum rotifera (rotifers) are important in aquatic environments because their reproductive rates are among the fastest of the metazoans due to their parthenogenetic production and short developmental periods (Herzig, 1983). Consequently they can populate vacant niches with extreme rapidity, and convert primary production into a form unusable for secondary consumers, producing up to 30 % of the total plankton biomass (Nogrady *et al.*, 1993). However, rotifers are not as diverse or abundant in marine environments as microcrustaceans (Park & Marshall, 2000). According to Battish (1992) rotifers predominantly inhabit freshwaters and very few species occur in marine environment. Corroborating with the above, rotifers were observed only at the riverine end during the present study. Similarly cladocera form an important group in freshwaters and are of little importance in the marine waters. In Thane creek the cladocera were represented by only one genera i.e. ***Penelia spp.*** and was restricted to the riverine end of the creek. Oligochaete were also observed only at the riverine end, though not zooplankton they might have got suspended in the waters by anthropogenic influences or turbulance.

The zooplankton observed at the seaward stations were coelentrates, foraminifera, tintinnids, mysis, & shrimps. According to Nair & Selvakumar (1979) neritic species are found to thrive well in high saline region and their presence is indicative of salinity regime. The coelentrates comprising of hydromedusae and siphonopores often function as key organisms in the pelagic ecosystems (Alldredge, 1984). They contribute substantially to the total zooplankton standing stock in the estuarine and near shore waters. According to Shantakumari ***et al***. (1997), occasionally these forms occur in dense swarms and thus the entire zooplankton appears to be nothing but a soup of medusae. Similar observations were recorded in Thane creek during the present study, wherein the coelentrates formed the 3rd most abundant group after crustacea & mollusca excluding polychaetes. They formed 1.1 % of the total zooplankton abundance. Shantakumari and Nair (1999), are of the opinion that these organisms are ecologically important as they are carnivores and compete with other predators like the fish larvae. In an estuarine environment the hydromedusae serves as an index of industrial pollution (Shantakumari ***et al.***, 1999). During the present study the tintinnida group was next to coelentrates in abundance and is equally important in the food chain. There are about 800 species of tintinnids which are predominantly marine (Krishnamurthy & Santhanam, 1975) with less than 2 % of known species occurring in freshwater (Campbell, 1954). According to Goghantaraman and Krishnamurthy (1997), tintinnids and rotifers form the dominant groups feeding on small diatoms and nanophytoplankton. Inspite of similar feeding the two groups did not show competition in Thane creek due to their different distribution. The other groups namely foraminifera, mysis & shrimps were poorly represented in the creek and were restricted only to the extreme seaward end.

4) **Sporadic occurring zooplankton** consisted of mangrove associated ants that are not zooplankton but were sporadically observed in the net samples of Zone 2 and 4. The miscellaneous group comprised of appendicularia, cirripede larvae, gammarus spp., prawn & salpa. These groups were recorded in insignificant numbers during the study.

The occurrence of zooplankton is known to vary with regions (Krishnamoothy *et al.*, 1999). During the present study **excluding** the unusually high polychaete density the total density of other zooplankton showed an increasing trend from the riverine to the seaward end (Fig.Z-1**)** However, the riverine end had marginally higher species number (N 0) as compared to the seaward end, but the number of dominant species (N 1 & N 2) showed increasing trend towards the sea (Fig Z-2). This increasing diversity at the seaward stations can be attributed to the high saline regime where the zooplankton flourish (Rao *et al.*, 1981).

Fig.Z-1 : Stationwise variations in the density of zooplankton (no/m3).

Similar observations were recorded in the Hooghly estuary and Mandovi – Zuari estuary by Baidya & Choudhury (1985) and Goswami & Singbal (1974) respectively. According to Krishnamurthy (1964) pronounced seasonality in zooplankton composition is characteristic feature of tropical estuaries. During the present study minor seasonal variations were observed with low values during monsoon and 3 peaks, one in September and the other two in January and March excluding the exceptionally high values due to polychaetes in November and December (Fig.Z-3). According to Sarkar *et al.* (1985) bimodality of zooplankton is a common feature of Indian estuaries. The low values during early monsoon can be attributed to dilution and land runoff (Goswami *et al.*, 1979).

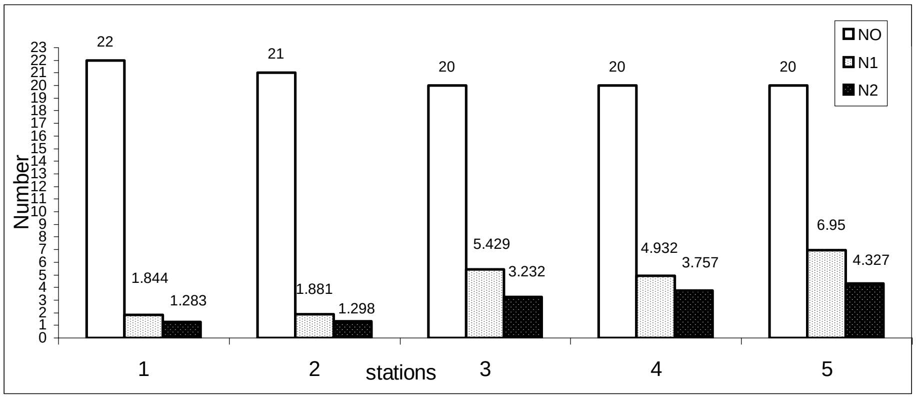


Fig Z-2 : Stationwise variations in the total number (N 0), dominant number (N 1) and most dominant (N 2) number of zooplankton.

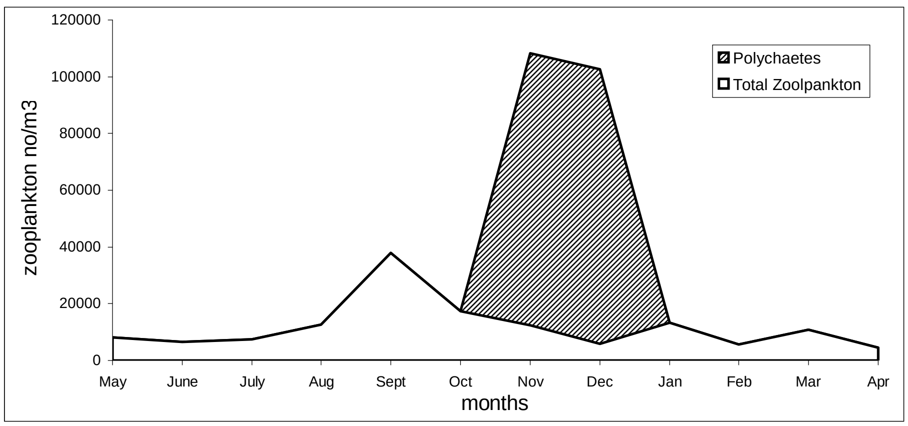


Fig Z-3 : Monthly variations in the density of zooplankton (no/m3).

Table Z-4: Correlation coefficients of zooplankton with environmental parameters.

	Environmental parameters							
Groups ↓	Temperature	salinity	DO	SS	PO4-P	NO3-N	SiO3Si	Phytoplankton
Foraminifera	-0.3221	0.2363	-0.2455	-0.177	0.218	0.1771	0.2048	-0.0163
Tintinnida	-0.4859	0.3206	-0.3299	0.4022	0.3234	0.1163	0.3586	-0.2068
Hydromedusae	0.1483	-0.3872	0.6908	-0.1515	-0.4181	-0.4179	-0.5302	-0.2457
Medusaezooids	-0.3952	0.3158	-0.3029	-0.1543	0.3781	-0.0339	0.5403	-0.0839
Siphonopore	0.2528	0.3009	-0.1917	0.0814	0.0021	0.2151	0.5997	0.3063
Polychaete	0.4387	0.2772	-0.1754	0.0144	0.3268	0.1383	0.1755	-0.1088
II Setiger larvae	-0.1134	-0.2258	-0.0735	-0.0979	-0.1183	-0.2374	-0.1758	-0.1155
III Setiger Larvae	-0.3917	0.1542	-0.3166	-0.1966	0.2766	-0.1433	0.4275	-0.1325
IX Setiger Larvae	-0.507	0.2526	-0.2451	0.7235	0.186	0.4342	0.1645	-0.2791
Nematode	-0.4013	0.435	-0.458	-0.2209	0.461	0.1635	0.721	-0.0471
Oligochaete	-0.2342	0.2048	-0.145	0.55	0.1289	0.5892	-0.006	-0.2112
Rotifera	0.0776	-0.4112	0.0368	0.1409	-0.3054	-0.2582	-0.3046	-0.1431
Water mite	-0.1978	-0.0366	0.0941	0.3668	-0.1801	0.4173	-0.0915	0.0031
Insect Larvae	-0.2931	-0.1648	0.4278	-0.0276	-0.1447	0.155	-0.2856	-0.1978
Calaniod	0.2088	-0.5584	0.1802	-0.0422	-0.4156	-0.4628	-0.4371	-0.0585
Cyclopoid	0.1815	-0.4855	0.1492	-0.0789	-0.6446	-0.1541	-0.1999	0.388
Harpacticoid	-0.2687	-0.0417	-0.1559	-0.3158	0.0907	-0.0366	0.0044	-0.0264

Crustacean eggs	-0.3341	0.3207	-0.2622	-0.0993	0.3263	0.2622	0.1629	-0.1027
Penelia	0.1659	-0.3392	0.0991	-0.2864	-0.3578	-0.2784	-0.5752	0.487
Ostracod	0.4428	-0.12	-0.195	0.0858	-0.0363	0.026	-0.4859	0.3214
Mysis	0.6217	0.4649	-0.1214	0.3976	0.4468	0.2891	0.0045	-0.2389
Nauplius	-0.0242	-0.3405	-0.0599	-0.139	-0.3007	-0.2741	0.0038	0.0431
Shrimps	0.3825	0.0056	-0.2691	-0.2758	0.1018	-0.0271	-0.1622	0.4619
Zoea	0.162	-0.5918	0.1696	-0.1801	-0.6422	-0.4698	-0.1169	0.2533
Megalopa of Crabs	-0.1831	-0.0965	-0.0688	0.4832	-0.1026	-0.287	-0.1857	-0.221
Gastropod larvae	0.0573	-0.3668	-0.2442	-0.4713	-0.3137	-0.2532	-0.2119	0.6594
Bivalve Larvae	0.2609	-0.3005	0.0032	-0.5616	-0.1244	-0.2506	-0.535	0.5463
Fish eggs	0.2788	-0.5259	0.4605	-0.3784	-0.6146	-0.4393	-0.3916	0.5809
Total	0.2568	0.4231	-0.3273	-0.0372	0.4892	0.2967	0.401	-0.1354

Values above ± 0.5673 are significant at 5% level of Significance.

The zooplankton distribution in estuaries is generally influenced by some physico-chemical and biological properties of the ambient waters (Mishra & Panigrahy, 1999). Hence a correlative study on zooplankton distribution, their intensity and seasonal abundance in relation to environmental parameters is necessary for a correct understanding of the fishery resources (Sarkar, *et al.*, 1985). The relationship of zooplankton with the environmental parameters in Thane creek was studied by calculating the correlation coefficients (r) (Table Z-4). Baskaran (1984) stated that in tropical estuaries the temperature has no important role to play in zooplankton distribution and abundance, as also observed in Pitchavaram mangroves (Shanmugam *et al.*, 1986); Mandovi-Zuari estuaries (Nair & Selvakumar, 1979); Hooghly estuary (Sarkar *et al.*, 1986) and Bahuda estuary (Mishra & Panigrahy, 1999). The results in Thane creek corroborate with the above studies, as although the correlation values varied with the zooplankton type indicating its influence, it was mostly insignificant.

Salinity is another major parameter that governs the distribution of zooplankton in tropical estuaries (Srikrishnadas *et al.*, 1993; Mishra & Panigrahy, 1999). In the present study the occurance and distribution of some zooplankton types is influenced by salinity as already discussed. However except for calanoid copepods and zoea of crab that reported significant negative correlation with salinity the other zooplankton were insignificantly related. Further the diversity and density of zooplankton is also dependent on the availability of food material (Shantakumari & Nair, 1999). According to Elton (1927), the primary driving force of all animals is the necessity of finding the right kind of food and enough of it. But in Qasim's (1970) view, food supply seldom acts as a limiting factor in a tropical estuary. In Thane creek, most of the zooplankton had insignificant correlations with suspended solids, nutrients and phytoplankton, except the siphonopores, IX setiger larvae & oligochaetes which had significant positive relation with some of these parameters and cyclopoid copepods, bivalve larvae, fish eggs, penilia and zoea which had significant negative relation with some of these parameters.

Ecological observations on zooplankton communities are important in assessing the health of coastal ecosystems (Ramaiah & Nair, 1997). Further pollutants are known to reduce the species diversity and increase population sizes of tolerant species causing episodic pulses in their abundance. The diversity indices in the present study (Fig Z-4) indicated increasing diversity and evenness indices towards the seaward zone 5.

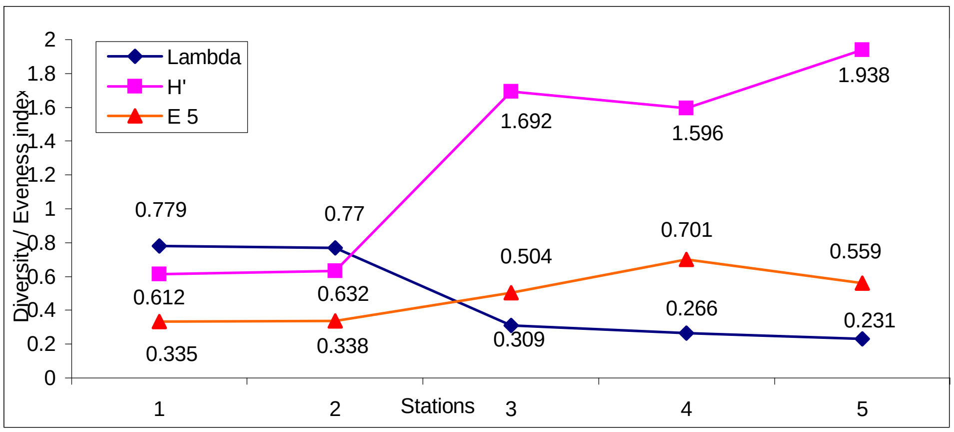


Fig Z-4 : Comparison of stationwise diversity (H' & λ) indices and Eveness (E 5) index.

However in general low diversity was observed in comparison to the zooplankton density, and can be attributed to the effluents and sewage load in the creek. According to Lindo (1991) coastal waters that receive sewage and other effluents generally result in an increase in zooplankton population. Moreover from the low H' (overall av. = 1.477) and λ (overall av. – 0.39) it is possible to suggest that there is pollution stress on the zooplankton community of the creek (Ramaiah & Nair, 1997). Similar observations were reported from the regions receiving industrial and sewage effluents by Sivaswamy (1990) from the east coast of India. Madhupratap & Onbe (1986) stated that the low plankton diversity can be considered as an index of poor and deteriorating water quality.

The richness indices during the present study were also low but showed an increasing trend from the river to the sea (Fig Z-5). Santhakumari *et al.* (1999) had similar results for Dharamtar creek and attributed it to the presence of holoplanktonic forms which is true for Thane creek as well. They further ascribed the low diversity of estuarine fauna to the rigours of the environment. According to Ricklefs (1973), among the several arguments advanced to explain low species diversity encountered in nature, the more cogent reasoning with respect to the tropical estuaries pertains to the lack of stability.

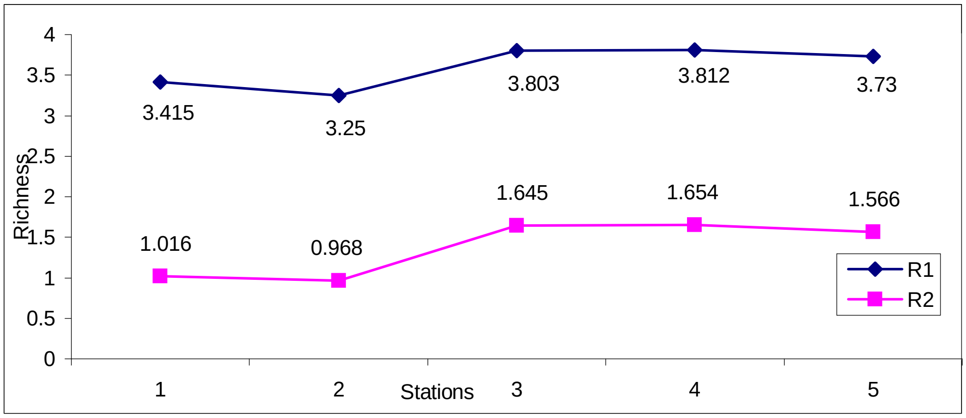


Fig Z-5 : Comparison of stationwise richness (R 1 & R 2) index.

The zooplankton community in the highly variable mangrove environment alters from time to time (Qasim, 1977). A comparison with the past available data reveals a gradually increasing abundance of zooplankton in Thane creek (Fig.Z -6) during the past 2 - 3 decades. This indicates that the zooplankton is not fully utilized at the tertiary level to obtain fish yield, corroborating with the concern raised by Varshney *et al*. (1982-83).

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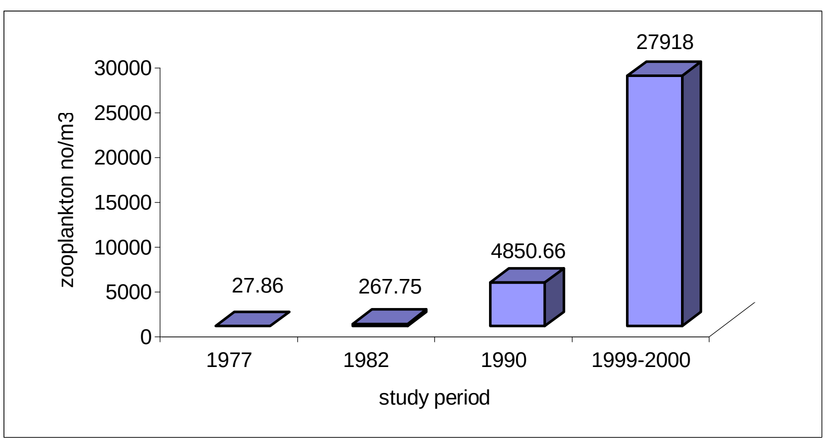


Fig Z-6 : Comparison of the present zooplankton density (no/m3) with the past available data

Summary.

In conclusion it is important to note that although the density of zooplankton has increased in Thane creek, certain types of zooplankton like fish larvae, ctenophora, gammarus and chaetognaths reported in earlier studies were totally absent during the present investigation. According to Nair (1975) chaetognaths form an important constituent of neritic and oceanic plankton, estuaries can sustain them in appreciable quantity only during certain months. Nair *et al*. (1981) further pointed out that certain species of chaetognaths are sensitive to industrial pollution and reported them in lower density in Thane creek. Later Lodh (1990) observed absence of certain chaetognath species that were reported to be prevalent and cautioned the impending deterioration of the creek environment. However the disappearance of the chaetognaths and the carnivores like the fish larvae and ctenophora highlights the dire state of Thane creek.

Microphytobenthos

Shallow water sediments are widely distributed around the world but despite the fact that they are recogonised as important feeding and nursery grounds for fish and fish prey (Wulff, 1999), much less is known about the microphytobenthic communities inhabiting these sediments (c.f.Round *et al*., 1990). The microbenthic community consist of microalgae, meiofauna and microfauna. Of which the benthic microalgae form the autotrophic component and are also called as 'microphytobenthos'. The microphytobenthos consist of unicellular algae living on or in the sediment, mainly comprising of diatoms, chlorophytes, euglenoids & cyanobacteria. According to Kelly *et al.* (2001) they inhabit the top few cms. of the intertidal sediment in estuarine and coastal systems worldwide.

The shallow-water sediments and tidal estuaries with extensive mudflats are recogonised as highly productive areas (Serodio & Catarino, 1999). Among the main primary producing components in such areas, microphytobenthos have the widest spatial distribution, accounting for 50 % or more of the primary production in shallow estuaries (Underwood & Kromkamp, 1999; Sundback & Miles, 2000). Even though the photosynthetic activity is restricted to the narrow illuminated layer of surface sediment (Yallop *et al.,* 1994; MacIntyre & Cullen. 1996) their production and biomass can equal or surpass that of phytoplankton in the overlying water column (Cahoon *et al.*, 1999). According to Reise (1985), microphytobenthos can supply up to 33 % of the organic budget of an estuarine coastal system, providing an important energy source for the estuarine food web (Sullivan & Moncreiff, 1990) and a primary carbon source for

sediment bacteria (Pinckney *et al*., 1994). Further, microphytobenthos can also influence the microstructure and properties of the sediment, due to the secretion of extracellular polymeric substances (Decho, 1990; Underwood *et al*.,1995) which may increase sediment stability (Paterson, 1997). The microphytobenthic community, according to Sundback *et al*. (2000), can function as a ‘filter’ that controls the flux of dissolved nutrients at the sediment / water interface and also the photosynthetic oxygenation of the sediment surface.

Given the importance of microphytobenthos in estuarine systems, scientist in recent decades have focused their interest to study these communities. However the first definite record regarding a benthic diatom originating from the year 1703 was published in the philosophical transactions of the Royal Society of London (Round *et al*., 1990). Among the noteworthy contributions towards the understanding of the microphytobenthos are the studies done by Pomeroy (1959); Grontved (1960); Pamatmat (1968); Round (1971 & 79); Pomeroy & Stockner (1976); Cadee & Hegeman (1974); deJonge (1980); Admiraal (1984); Steel & Baird (1968); Sundback (1986 & 2000); Sundback *et al*. (1991); Charpy-Roubaud & Sournia (1990); Sabbe & Vyerman (1991); Underwood *et al*. (1995); VanEs (1982); Zedler (1980 & 82);Wulff (1997 & 99); Cahoon (1999); Lucas *et al*. (2001) and Kelly *et al* (2001). These studies indicated a pattern of generally higher benthic microphytobenthic production in the tropical ecosystems with somewhat lower values for the temperate regions and much lower in the polar regions. They also included production in the intertidal areas which was generally higher than the subtidal habitats.

In India Ganapati *et al*.(1959) was one of the pioneers to study the microphytobenthos, following which many workers have mentioned the occurance of microphytobenthos in their study areas, but an indepth study is however lacking. This could be due to the difficulties connected with sampling and quantifying the microbenthos, a problem faced by scientist world wide (Wulff, 1999). Due to similar difficulties the microphytobenthic data of Thane creek is also lacking except for the passing reference made by Gokhale & Athalye (1995) for the shallow region of Thane creek. Internationally microphytobenthic studies have gained increased attention (Wulff, 1999) and despite the substantial amount of work done in the area scientist have raised concern over the lack of data to significantly overview the role of microphytobenthos in the estuarine systems. With this in mind in the present study on Thane creek microphytobenthos also formed a part of the investigation.

Table Mp-1 : Monthly variations in the microphytobenthic number (no/cm2) at different stations.

Months↓	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12	Average
May -99	83500	0	0	0	**163000**	37500	92000	30000	53500	0	21500	59500	45041.7
Jun	27500	36000	17500	15000	40000	14000	42000	18500	30000	0	50000	65500	29666.7
Jul	63000	0	86000	59500	43000	55000	65000	56500	40444	45500	35000	26500	47953.7
Aug	69500	47500	59500	40500	82000	49000	48000	35500	43000	28000	13000	9000	43708.3
Sept	57500	37500	53000	44500	34000	26000	0	9500	15000	19000	34000	0	27500.0
Oct	89000	84000	92500	96500	79500	35000	72500	51500	44000	88000	68500	53500	71208.3
Nov	77000	112500	62000	45000	48000	22000	40500	34000	18500	0	43500	48500	45958.3
Dec	49500	45500	66000	34500	69000	39500	65500	51500	13500	34500	36500	0	42125.0
Jan -00	64500	41000	61000	35000	79500	16000	46000	58000	30500	71000	43500	60000	50500.0
Feb	162000	35500	52000	44500	62000	8500	49000	19000	68500	53500	57500	26500	53208.3
Mar	22500	60500	23000	25000	32500	40500	46500	9500	14000	28000	45500	35500	31916.7
Apr	22000	43000	67500	59500	48000	66000	29500	7000	15000	39500	20500	20500	36500.0
Stn.Avg →	65625	45250	53333	41625	65042	34083	49708	31708	32162	33917	39083	33750	**43774**
Min	22000	**0**	0	0	32500	8500	0	7000	13500	0	13000	0	27500
Max	162000	112500	92500	96500	**163000**	66000	92000	58000	68500	88000	68500	65500	71208
SD	37958	31073	27277	24294	35730	17472	23046	19176	17998	27949	15920	23630	11950

Table Mp-2: Stationwise distribution of different microphytobenthos (no/cm2)

	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12	Avg	%	Total %
Centric Diatoms															15.57
Biddulphia	0	125	0	166.67	0	0	0	0	0	0	0	0	24.31	0.06	
Chaetoceros	166.67	0	125	83.33	208.33	0	0	291.67	125	208.33	83.33	0	107.64	0.25	
Coscinodiscus	7416.67	1458.33	3666.67	4041.67	4458.33	3791.67	2833.33	2333.33	3125	3333.33	2208.33	3958.3	3552.08	8.12	
Leptocylindrus	291.67	916.67	1166.67	0	1583.33	458.33	708.33	1958.33	750	125	1125	166.7	770.84	1.76	
Rhizosolenia	6875	291.67	1125	125	166.67	1375	708.33	333.33	41.67	458.33	625	41.7	1013.89	2.32	
Skeletonema	708.33	2333.33	1208.33	458.33	208.33	625	916.67	333.33	1000	708.33	666.67	500	805.55	1.84	
Thalassiosira	375	208.33	375	875	375	500	541.67	875	875	666.67	791.67	0	538.20	1.23	
Triceratium	0	0	0	0	0	0	0	0	0	0	0	41.7	3.48	0.01	
Pennate Diatoms															64.64
Achananthes	0	208.33	0	0	0	291.67	0	0	83.33	0	0	0	48.61	0.11	
Asterionella	0	0	0	0	0	0	0	0	0	0	0	83.3	6.94	0.02	
Gyrosigma	291.67	208.33	0	83.33	125	208.33	250	250	83.33	166.67	375	291.7	194.45	0.44	
Mastogloia	0	0	166.67	0	125	0	125	0	0	0	0	0	34.72	0.08	
Navicula	23291.7	18000	24666.7	19958.3	28625	12958.3	21291.7	13666.7	14000	16291.7	16333.3	14875	18663.2	42.64	
Nitzschia	15083.3	5916.67	7333.33	5750	4250	4750	6625	5833.33	7291.67	3541.67	8333.33	5666.7	6697.92	15.30	
Pinnularia	0	0	125	0	0	0	0	0	0	0	291.67	0	34.72	0.08	
Pleurosigma	4833.33	4541.67	3333.33	1375	2625	1958.33	875	958.33	3583.33	1166.67	2916.67	3083.3	2604.16	5.95	

Surrirella	0	0	0	0	0	41.67	0	0	0	0	41.67	0	6.95	0.02	
Green Algae															17.33
Euglena	0	125	0	0	0	0	458.33	166.67	0	500	0	0	104.17	0.24	
Nostoc	0	0	0	0	0	0	333.33	0	166.67	0	41.67	0	45.14	0.10	
Pediastrum	41.67	0	0	0	0	0	0	0	0	0	0	0	3.47	0.01	
Rivularia	166.67	0	83.33	0	208.33	0	0	0	0	0	0	0	38.19	0.09	
Anabaena	458.33	1291.67	1458.33	2291.67	5833.33	1625	5125	1958.33	541.67	1083.33	1541.67	1041.7	2020.84	4.62	
Oscillatoria	5625	7500	6791.67	5291.67	13125	4625	8416.67	2458.33	458.33	4833.33	3125	2208.3	5371.53	12.27	
Blue Green algae															2.32
spirulina	0	2125	1416.67	1125	3125	875	500	291.67	0	833.33	375	1500	1013.89	2.32	
unidentified	0	0	291.67	0	0	0	0	0	0	0	208.33	291.7	65.98	0.15	0.15
Total	58041.7	43666.7	49541.7	37333.3	60375.0	30291.7	46875.0	29083.3	28875.0	30375.0	36791.7	29791.8	43770.8	100	100.0

The microphytobenthos is present throughout the year (Daehnick *et al.*,1992) and according to Cahoon (1999) they frequently form mats on the sediment / water interface, and at times are very patchy in their distribution. Corroborating with this view, in the present study the microphytobenthos density varied between 0 to 163000 no/cm^2 (Table Mp-1) representing 24 genera & one unidentified form of benthic algae. Among the 24 genera the diatoms were the most dominant (Table Mp-2) followed by the green algae, which is similar to the findings of Wulff (1999); Cahoon (1999) and Lucas *et al* (2001).

Round (1971) distinguished supratidal, intertidal, subtidal, estuarine and cryophilic biotopes for benthic diatoms. He also characterized the substratum affinities of diatoms as epilithic (on rock substrata), epipelic (on mud), epipsammic (on sand), endopelic (inside sediment) endolithic (inside rock), epiphytic (on macrophytes), epizooic (on animals) and psychrophilic (on ice). The substratum of Thane creek is predominantly clayey silt and hence the microphytobenthos encountered is of epipelic and episammic type. According to Round *et al.* (1990), the epipelon consist of larger, motile species while the epipsammon are typically small and immobile or only slow moving species. The typical epipelic genera are *Navicula spp., Nitzschia spp., Gyrosigma spp., Pleurosigma spp., Oscillatoria spp.*, etc. while the epipsammon genera are *Achnanthes spp.* and *Fragilaria spp.*. Sabbe (1997) ascribed the epipelic community to prefer more sheltered conditions and silt accumulation while the epipsammic community preferred the presence of larger sand grains within the sediment. Siltation is the common feature in Thane creek and hence the microphytobenthos was mainly of the epipelic type with dominance of diatoms both centric and pennate diatoms.

Among the diatoms the pennate diatoms formed the major bulk (64 %) of the population. The dominant members of the pennate diatoms during the study were *Navicula spp., Nitzschia spp., Pleurosigma spp.* and *Gyrosigma spp.* According to Cahoon (1999) these pennate diatoms are the most important benthic microalgal taxa due to their mobility. The centric diatoms encountered during the present study were *Coscinodiscus spp., Rhizosolenia spp., Skeletonema spp., Leptocylindrus spp., Thalassiosira spp., Chaetoceros spp., Biddulphia spp.* and *Triceratium spp.* Bold & Wynne (1985) are of the opinion that the variety of these centric diatoms that are found in the benthic assemblages include some that have probably settled from the plankton and some closely associated with the benthos but are frequently resuspended also called 'tychopelagic'.

A number of other taxa also form important members of the microphytobenthos, as microscopic analysis have shown the presence of cyanobacteria and euglenoids (Burkholder *et al.*,1965); chlorophytes (Zedler, 1982) and dinoflagellates (Gracia-Baptista & Baptista, 1992). The taxa other than diatoms observed in the present study were green algae and blue green algae. Most of the green algae were sporadic in their occurance except for *Oscillatoria spp.* and *Anabaena spp.* while among the blue green algae *Spirulina spp.* was the most dominant. Cahoon (1999) further, contented that the presence of these other taxa suggests that in addition to the production, oxygen flux and nitrogen uptake associated with all microalgae, nitrogen fixation by cyanobacteria and heterotrophic uptake of organic material might be of significance in interface processes.

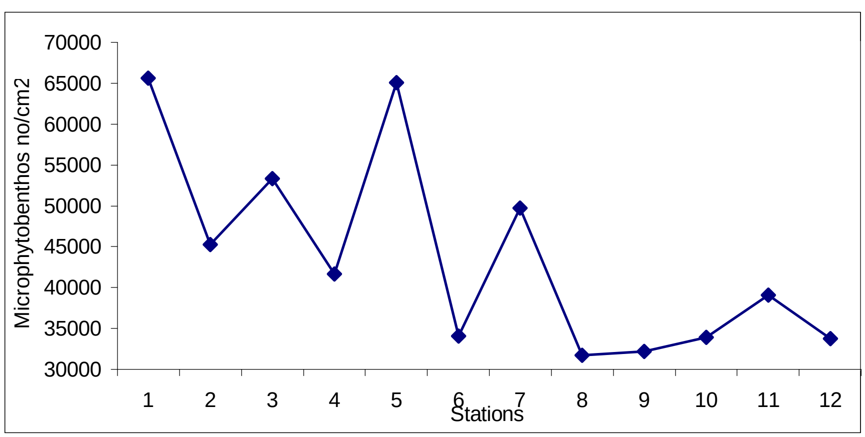


Fig Mp-1: Stationwise variations in the microphytobenthos no/cm2.

In shallow estuaries much of the spatial variability is due to resuspension of benthic cells in association with the tidal cycles. The present study showed a decreasing trend from the riverine to the seaward end (**Fig**.Mp-1). The microphytobenthos was observed throughout the year and formed algal mats at the sediment / water interface, but showed patchiness in its distribution. This can be attributed to vertical migration, physical disturbance and bioturbation (Cahoon, 1999). The reason for high density from the riverine end till middle region of the creek could be due to comparatively slow currents and sheltered nature of the region while the seaward regions were disturbed due to the tidal currents as was observed by Wulff (1999) in the shallow water sediments along the west coast of Sweden. Although the microphytobenthos was recorded throughout the year, minor seasonal variation as higher density during the post monsoon, lower density during the premonsoon and moderate density during monsoon were observed in the study (**Fig**.Mp-2). According to Serodio & Catarino (2000), seasonal variability in microphytobenthic productivity is determined by factors associated to the particular geographical location of each estuary and is expected to increase with latitude. Thane creek being tropical the seasonal variations are marginal and the lower values during monsoon and premonsoon can be attributed to physical disturbance due to rains and desication due to high temperatures respectively (Admiraal, 1984).

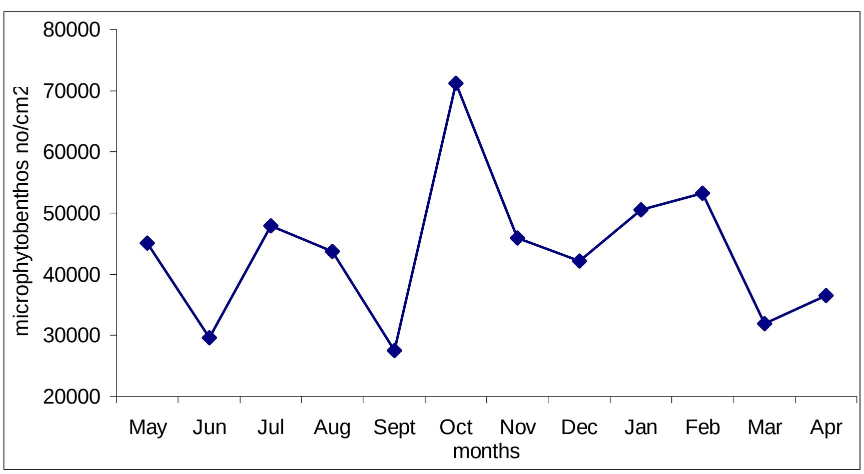


Fig. Mp-2: Monthly variations in the microphytobenthos no/cm2.

In shallow aquatic ecosystems, a variety of physical, chemical and biological factors may regulate the standing stock of microphytobenthos, hence according to Cahoon *et al.*

(1999), assessment of these factors is important in understanding and managing these ecosystems. The relevant factors include light flux, depth, physical disturbance, grazing, nutrient availability and sediment characteristics (McIntyre *et al.,* 1996). In the present study some of these factors were assessed by calculating the simple correlations (Table Mp-3). Although the dominant genera showed fluctuating influence of the water parameters. The microphytobenthos in general reported significant positive correlations with pH, water temperature, salinity, nutrients from the water. This indicates that the microphytobenthic density was governed by the overlying water characteristic.

Except for the dominant genera the total microphytobenthos showed a positive correlation to sediment pH and redox potential indicating its preference for higher pH and redox potential. According to MacIntyre *et al.* (1996) benthic primary production is not nutrient limited, as nutrients in the estuarine sediments are typically well above limiting values. Further Sigmon & Cahoon (1997) are of the opinion that microphytobenthos are likely to be important in nutrient cycling and may act to control nutrient availability to other primary producers. Thane creek is a nutrient rich creek due to the release of domestic and industrial effluents (Gajbhiye, 1982). During the study the total microphytobenthos showed a negative correlation with sediment total nitrogen and organic carbon while it had a positive influence of the water nutrients. This indicates that the sediment probably acts as a sink for the excess nutrients in the creek and gradually exerts a negative impact on the microphytobenthic density. These observations are contrary to those of Wullf (1997), who reported a positive relation between sediment nutrient and microphytobenthic density.

According to Cahoon *et al.* (1999) sediment grain size must be considered as one of the important factors limiting the microphytobenthos. Some studies have reported a negative relationship (Fielding *et al*., 1988) others have found no clear relationship (Cammer, 1982) while few studies have documented positive correlations between grain size and microphytobenthos (McIntire & Amspoker, 1986). In the present study, in general the sediment texture had insignificant correlations with the microphytobenthos. However silt showed a significant positive correlation with *Navicula spp., Leptocylindrus spp.* and *Pleurosigma spp.* while clay had a significant positive effect on occurance of *Nitzschia spp.* and *Spirulina spp.* & moderate effect on *Pleurosigma spp.* & *Anabaena spp.*

According to Cahoon *et al*. (1999), the relationship between microphytobenthos and sediment grainsize is not simple and is likely to be strongly influenced by a complex set of interacting factors. While studying the North Carolina estuaries they observed a negative effect of increasing percent of fine sediment on the microphytobenthos and ascribed it as a factor helping to control the distribution of benthic microalgae.The present study on Thane creek was contrary to the above observation and corroborated with the findings of Wulff *et al*. (1997) who reported increase in the motile forms of diatoms with increase in fine sediment.

Table Mp-3: Simple correlation coefficients of microphytobenthos with environmental parameters.

	Coscinodiscus	Leptocylindrus	Rhizosolenia	Skeletonema	Thalssiosira	Navicula	Nitzschia	Pleurosigma	Anabena	Oscillatoria	Spirulina	Total
Water												
pH	0.1927	0.2367	0.0249	0.2084	0.0398	0.1147	0.1182	-0.0137	-0.0301	-0.1036	-0.1011	0.309
SS	-0.1498	-0.0278	-0.0021	0.0926	-0.0302	-0.1052	-0.169	-0.0295	0.1326	0.0379	0.1015	0.0072
Temp	0.0778	-0.1503	-0.0689	-0.0436	-0.0322	-0.1033	-0.092	-0.2314	-0.0246	-0.0067	-0.1257	0.3659
DO	0.1263	0.1757	-0.0198	0.0432	-0.0673	-0.129	0.1495	-0.0823	-0.1051	-0.1204	-0.1677	-0.1538
Salinity	-0.2319	-0.0637	-0.056	-0.0265	0.0473	-0.0728	-0.2649	0.0375	0.2415	0.1347	0.1884	0.3405
PO4-P	-0.091	-0.1765	-0.0228	-0.0398	-0.0336	0.01	-0.2052	0.001	0.2545	0.266	0.1581	0.367
NO3-N	-0.1568	0.0519	-0.0394	0.21	0.0814	-0.0109	-0.1937	0.1575	0.2169	0.3073	0.1244	0.2723
SiO3-Si	-0.1896	0.0909	0.1235	0.0535	0.0564	0.1022	-0.0458	0.2243	0.2455	0.3784	0.2283	0.3086
Soil												
pH	-0.1168	-0.1184	-0.0019	-0.0579	-0.1482	-0.111	-0.3232	-0.0983	0.3063	0.3704	0.338	0.6503
Eh	-0.1875	-0.1063	-0.1509	-0.1012	-0.0793	-0.2958	-0.3849	-0.1107	0.3115	0.2903	0.3579	0.4907
Chlorides	-0.0597	-0.1427	-0.2462	-0.0695	-0.0059	-0.2149	-0.271	-0.1138	0.1405	0.1403	0.1338	0.3077
TN	-0.0574	-0.1105	-0.0769	0.0481	-0.1049	0.2731	-0.071	-0.0901	-0.0849	-0.0195	-0.0886	-0.0859
TP	-0.147	-0.0455	0.0058	-0.0521	-0.1609	0.1499	-0.0758	-0.1056	-0.0406	0.0557	-0.0116	0.0946
AP	0.0868	0.0444	0.0958	0.21	-0.1091	0.1537	-0.2063	-0.0614	0.0763	0.129	-0.037	0.1425
OC	0.0263	-0.0756	0.0432	-0.2114	0.0196	-0.1408	-0.031	-0.1894	-0.2013	-0.3108	-0.0878	-0.1375
Sand	-0.0093	-0.0058	0.0192	-0.0003	-0.0124	0.1973	-0.0742	0.0639	-0.045	0.0342	-0.0363	-0.0054
Silt	-0.0054	0.858	0.1003	0.1255	-0.0556	0.2429	-0.0428	0.2219	-0.1358	-0.004	-0.0519	-0.145
Clay	-0.0823	-0.0806	0.0537	-0.0922	-0.0069	-0.0223	0.1753	0.134	0.1211	0.0557	0.1675	0.0187
Moisture	0.0746	-0.0544	-0.0665	-0.0436	0.0385	-0.0357	-0.1881	0.0991	-0.0406	-0.0379	-0.0607	-0.0973
Phytoplankto	0.1339	0.2331	0.0302	0.0169	0.0425	0.1707	0.1735	-0.036	-0.0394	0.0084	-0.0487	-0.0983
Meiobenthos	-0.0454	-0.1539	-0.1119	0.1319	-0.1372	-0.1241	0.1397	-0.1062	0.1609	0.1574	0.116	0.772
Macrobenthos	0.0136	0.0057	-0.0458	-0.035	-0.0568	-0.1234	-0.2293	-0.162	-0.1535	-0.1305	-0.0337	-0.1622

Grazing also poses the potential to reduce benthic microalgal biomass and production (Cahoon,1999). The broad diversity of organisms feeding on microalgae and the abundant evidence of their importance in the marine food chain suggests that microalgae probably do not employ defences against grazing. Plante-Cuny & Plante (1983) reviewed the literature on grazing of marine diatoms by benthos and classified the grazers as microfauna, meiofauna and macrofauna. In the present study grazing on the microphytobenthos was observed in zooplankton, meiofauna and macrofauna. Total microphytobenthos showed significant positive correlation with meiobenthos and significant negative with macrobenthos..

Table Mp-4:Stationwise diversity indices for microphytobenthos.

	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12	Average
Hill's Numbers													
NO	14	15	16	13	15	14	15	14	14	14	17	14	25
N1	5.973	6.609	6.139	5.364	5.769	7.126	6.109	6.43	5.374	5.854	6.538	5.795	6.676
N2	4.639	4.543	3.837	3.571	3.906	4.915	4.078	4.153	3.758	3.627	4.186	3.966	4.266
Richness index													
R1	1.172	1.306	1.378	1.128	1.263	1.246	1.295	1.254	1.253	1.246	1.513	1.247	2.246
R2	0.055	0.071	0.069	0.062	0.059	0.076	0.067	0.079	0.078	0.076	0.086	0.076	0.119
Diversity indices													
H'	1.787	1.888	1.815	1.679	1.753	1.964	1.809	1.861	1.682	1.767	1.877	1.757	1.899
Lambda	0.216	0.22	0.261	0.28	0.256	0.203	0.245	0.241	0.266	0.276	0.238	0.252	0.234
Eveness index													
E5	0.732	0.632	0.552	0.589	0.609	0.639	0.602	0.581	0.63	0.541	0.575	0.619	0.575

From the above discussion it is evident that the microphytobenthos follows the internationally set format in its distribution in Thane creek i.e. dominance of diatoms followed by the other taxa. However to assess the health of the ecosystem it is necessary to use statistical and biological indices. The indices calculated for the present study are presented in Table Mp-4. A total of 25 algal genera were observed in the entire creek, but only about 7 were dominant of which 4 were highly dominant viz., *Navicula spp.*, *Nitzschia spp.*, *Coscinodiscus spp.* and *Oscillatoria spp.*, indicating insignificant / poor contribution of the remaining genera. The richness indices showed an increasing trend from the riverine to the seaward end, while the diversity and eveness indices showed wide fluctuations.The Palmers' algal genus index for microphytobenthos totaled a score of 15 indicating probable evidence of high organic pollution in the creek.

Summary.

Hence to conclude, the microphytobenthos in Thane creek comprise mostly of diatoms of the epipelic and epipsammic type, represented dominantly by *Navicula spp., Nitzschia spp., Coscinodiscus spp.* and *Oscillatoria spp.* The benthic algae are patchy in their distribution and are governed in a complex manner by the environmental factors. Further although the present study forms the baseline data for microphytobenthos of Thane creek, it highlights the organic pollution in the creek as is evident from the negative influence of sediment nutrients on the microphytobenthos and Palmer's algal genus index.

Benthos

Introduction

Estuaries often serve as receivers and accumulators of organic matter at the bottom, which in turn affects the fauna (Fernando *et al*., 1983). All ocean bottoms are more or less heavily populated by invertebrate species, and the organisms that live within (infauna) or on the bottom (epifauna) or are associated with the aquatic sediments (phytal) are called benthos and their mode of life as benthic. This bottom fauna, according to Ziegelmeier (1972), is involved in the recycling of materials in the marine ecosystem and plays an important role in food chains, as the plankton do in the pelagic zone. Studies on the benthic fauna inhabiting the coastal water bodies have gained importance in the context of assessing the brackish water and estuarine production (Srinivasarao & Ramasarma, 1983). Further, Athalye (1988) asserted that the estuarine bottom and the extensive mudflats with their diverse littoral mangrove swamps are known to contribute significantly to the total productivity by harbouring a great variety of organisms, by producing a large amount of detritus and providing food to demersal fishery. Hence any alteration in benthic community would affect the productivity and the demersal fishery, thus emphasizing the importance of benthos in the food chain. Mare (1942), classified the benthic fauna on the basis of size, into microfauna (1 – 100 μm), meiofauna (100 – 1000 μm) and macrofauna (>1000 μm). Since then scientist around the world have studied the various types of benthos from different ecosystems in relation to the ecological aspects and have continuously increased the list of invertebrates with new finds almost every year (Gerlach, 1972). In India also the study of benthos was initiated in the early 20th century but dealt mainly with systematics, while the ecological aspects gained importance much later (Annie Mathew, 1989). In the present study, meiobenthos and macrobenthos have been investigated and correlated with the environmental parameters.

Meiobenthos

The term 'meiobenthos' was first coined by the English marine biologist M.R.Mare (1942) for semi microscopic multicellular organisms with a size range of 100 to 1000 μm. According to Gerlach (1972), the attention of the marine biologists has only recently turned to the minute fauna of the ocean floor, although individual systematic studies on certain animal groups were carried out in early 19th century. Significant among them are the works of Remane (1933) and his students who studied a variety of minute fauna representing different phyla.

Meiofauna has been the subject for quantitative study due to the role it plays in the marine food chain (Ansari & Parulekar, 1998). According to Moens *et al.* (2000), over the past 3 decades considerable evidence has demonstrated the importance of meiofauna in the marine and estuarine benthos. Ingole and Parulekar (1998) ascribed the estuarine intertidal habitats to harbour rich meiofaunal communities which in turn serve as live food for higher trophic levels. Despite their small biomass contribution compared to macrofauna, their relatively high metabolic rates, according to Moens *et al*. (2000 & references therein), render them potentially important in marine benthic energitics. Moens *et al*. (1999) further attributed the meiobenthos as a black box, receiving energy inputs from the lower trophic levels i.e. primary producers and microheterotrophs, but not contributing in the energy flow to the higher trophic levels. As such they would act as an energy sink, the main importance of which is in the regeneration of nutrients (Kuipers *et al.*, 1981). However MacIntosh (1984) differed with the view and attributed meiobenthos as a food source for the larger fauna, as reports on the occurrence of meiofauna in the gut of holothurians, crabs and fish are available (Platt &Warwick, 1980; Krishnamurthy *et al.*, 1980 and Wolff 1983). This was further corroborated by the studies of Gee (1989); Coull (1990); Service *et al.* (1992); Martens & Schockaert (1986); Kennedy (1994) and Moens & Vincx (1997) who reported significant consumption of meiofauna by macrofauna.

Meiobenthos being an important part of the food web, is considered as the best indicator of water pollution. Annie Mathew (1989) ascribed that the meiofauna being a dynamic element of the marine environment, forms a good tool for monitoring the interactions and hypothesis relevant to ecology. Hence meiobenthic study is important for better understanding of benthic productivity and benthic food chain. Moreover according to Giere (1993), meiofauna studies are not only a valuable supplement to the common macrofauna bioassays but can also render conclusions on anthropogenic pollution in a more rapid and reliable range than that possible with macrofauna.

Since the classification of benthic fauna by Mare in 1942, meiobenthos has gathered fair amount of interest among scientists around the world. In India, the meiobenthos have been investigated along both the east and west coasts but lack consistency. Also information on the meiobenthic fauna of the present study area is meager. Shetty (1982), Varshney (1984); Annie Mathew (1989) investigated the meiofauna from the subtidal region of Thane creek, while Quadros *et al.* (1996) studied the meiofauna from the intertidal mudflats of the upstream region of Thane creek. The present study is the first account of the meiobenthos from the intertidal region of the entire stretch of Thane creek.

Table Me-1: Monthly variations in the abundance of meiobenthos at different stations (no/m^2)

Months ↓	Stn.1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn10	Stn 11	Stn 12	Average
May-99	1003230	185300	763970	1958880	1840120	716100	334800	540500	1979760	1782000	372780	436280	992810
June	339200	494325	349890	365175	475800	619500	262800	242420	278610	184920	1115570	805970	461182
July	490100	632000	449280	232360	173250	376470	468640	627405	505925	187790	576000	525420	437053
Aug	371875	616560	252280	148490	181125	278875	242720	106975	255150	248750	675450	194020	297689
Sept	522600	547575	311525	479400	115500	569900	534040	160400	338240	223650	153720	353130	359140
Oct	153920	154350	219700	91715	179400	294640	87000	104940	315205	237900	356440	199000	199518
Nov	130150	111930	402960	209960	71440	101065	31610	275040	49450	450765	126000	279660	186669
Dec	188680	181250	68600	162630	**18200**	152880	192510	49025	21840	68575	125925	116400	112210
Jan-00	88760	408590	506325	626280	102350	349800	905655	336660	1060740	446880	473680	133120	453237
Feb	208890	267300	233600	139200	66000	256800	70455	286635	309380	234240	125280	428860	218887
Mar	87840	56970	50720	668020	724740	2088290	1770000	1238550	1094140	136300	1163750	1042720	843503
Apr	3598272	3656150	3613878	5084771	3947925	5804320	4913337	3987107	**6208440**	4213504	5270731	4514580	4567751
Stn.Avg→	598626	609358	601894	847240	657988	967387	817797	662971	1034740	701273	877944	752430	**760804**
Min	87840	56970	50720	91715	**18200**	101065	31610	49025	21840	68575	125280	116400	112210
Max	3598272	3656150	3613878	5084771	3947925	5804320	4913337	3987107	**6208440**	4213504	5270731	4514580	4567751
SD	979606	980750	968141	1428742	1154321	1611623	1377216	1096396	1722824	1196462	1429540	1216785	1227619

Table Me-1 & Me-2 show the meiobenthic abundance and biomass during the present study. They varied between 18200 to 6208440 no/m^2 (av. 760804 no/m^2) and 0.980 to 166.702 gm/ m^2 (av. 34.07 gm/m^2) respectively. The minimum abundance and biomass were recorded at station 5 and station 9 respectively in December while the maximum abundance was observed at station 9 in April and the biomass at station 6 in month of March. However if the average values are considered the maximum abundance and biomass were observed at station 9 and 6 respectively. While their minima were recorded from station 1 & 2 respectively. A comparison of meiobenthic abundance with other estuaries and creeks is given in Table Me-3, from which it is evident that the density in Thane creek is intermediate one. Ansari (1988) & Annie Mathew (1989) reviewed the meiofauna from different places and observed variations from place to place, which they attributed to the geography and environmental setup. In Thane creek monthly and stationwise variations in meiofaunal density and biomass were observed corroborating with the above inference.

Table Me-2: Monthly variations in the biomass of meiobenthos at different stations (gm/m^2 wet wt.).

Months ↓	Stn.1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn10	Stn 11	Stn 12	Average
May-99	63.676	10.642	43.556	101.500	93.039	43.197	26.125	52.454	111.369	116.012	27.686	23.176	59.369
June	19.001	25.635	21.922	23.296	37.128	60.127	22.805	37.841	23.901	15.816	82.584	51.197	35.104
July	27.318	34.280	23.396	13.480	11.743	34.487	35.176	55.465	35.179	20.153	36.005	28.482	29.597
Aug	19.254	33.111	13.445	10.179	9.765	24.032	33.454	18.964	22.053	23.225	49.020	13.617	22.510
Sept	26.832	28.839	18.523	26.524	7.508	55.183	47.463	23.868	32.450	16.380	11.102	21.645	26.360
Oct	10.691	9.305	16.942	5.231	10.212	25.700	9.048	11.178	19.723	54.281	21.581	11.802	17.141
Nov	10.446	4.404	23.126	16.452	11.704	12.705	7.330	31.515	4.543	41.761	12.243	23.234	16.622
Dec	18.298	12.063	8.840	20.917	1.612	18.134	13.336	7.937	**0.980**	16.068	12.865	10.140	11.766
Jan-00	10.144	24.228	39.152	37.536	13.817	21.780	73.257	25.195	63.261	38.603	41.008	7.467	32.954
Feb	15.926	12.637	24.820	17.922	5.280	41.345	9.935	36.140	34.431	39.235	13.702	27.888	23.272
Mar	12.568	7.355	3.626	40.950	36.224	**166.702**	139.993	87.001	78.992	22.253	69.709	134.936	66.692
Apr	66.752	15.233	36.327	55.840	137.030	62.326	76.568	40.643	96.113	145.485	29.544	47.081	67.412
Stn.Avg→	25.08	18.14	22.81	30.82	31.26	47.14	41.21	35.68	43.58	45.77	33.92	33.39	**34.07**
Min	10.144	4.404	3.626	5.231	1.612	12.705	7.330	7.937	**0.980**	15.816	11.102	7.467	11.766
Max	66.752	34.280	43.556	101.500	137.030	**166.702**	139.993	87.001	111.369	145.485	82.584	134.936	67.412
SD	19.62	10.48	12.02	26.45	41.73	41.16	38.93	21.85	35.72	42.02	23.32	34.75	19.62

Table Me-3 : Review of meiofauna from different water bodies

Water body	Total meiofauna no/m2	Reference.
Waltair Coast	228000	Ganapati & Rao, 1962
Port Nova	2887500	McIntyre, 1964
Danish mesohaline	9680	Muss, 1967
Malaya coast	2440	Renaud-Mornant & Serene, 1967
ProtoNova	13070	McIntyre, 1968
Vellar estuary	26250	McIntyre, 1968
Waltair	2280	McIntyre, 1968
Rhode island, estuary	25290	Tietjen, 1969
Pamlico river estuary	1360	Reid, 1970
Off North Carolina, U.S.A.	11740	Tietjen, 1971
Saltmarsh, New Jersey	8305	Brickman, 1972
Table Me-3 continued.		
Visakhapatanam harbour	4280000	Sarma & Ganapati, 1975
Sardinia bay	37100	Mclachlan, 1977
Chilka Lake	1467000	Sarma & Rao, 1980
Andamans	2478	Ansari & Parulekar, 1981
Narmada estuary	54725	Varshney *et al.*, 1981
Godavari river estuary	7150	Ansari *et al.*, 1982
Hooghly river estuary	4310	Ansari *et al.*, 1982
Krishna river estuary	3140	Ansari *et al.*, 1982
Mahanadi river estuary	7050	Ansari *et al.*, 1982
Northeastern Bay of Bengal	109811.7	Rodrigues *et al.*, 1982
Andamans	61160	Ansari & Ingole, 1983
Gautami-Godavari estuary	13863.3	Kondalarao, 1983
Sagar Island	3420	ChandrashekarRao & Mishra, 1983
Off Versova	428564.71	Varshney *et al.*, 1984
Digha	15260	ChandrashekarRao & Mishra, 1986
Saphala salt marsh	34350	Ingole *et al.*, 1987
Kakinada bay	21300	Kondalarao & Ramanamurty, 1988
Agatti	65550	Ansari *et al.*, 1990
Bingaram	41170	Ansari *et al.*, 1990

Gopalpur, Orissa coast	21420	Pattnaik & LakshmanaRao, 1990
Kadmat	47160	Ansari *et al*., 1990
Kalpani	52400	Ansari *et al*., 1990
Kavaratti	26200	Ansari *et al*., 1990
Minicoy	31940	Ansari *et al*., 1990
Gazi bay, Kenya	47530	Vanhove *et al*., 1992
Bhitarkaninka mangroves	505.585	Sarma & Wilsanand, 1994
Siridao beach, Goa	3856.66	Ingole & Parulekar, 1998
Zuari estuary	14180	Ansari & Parulekar, 1998
Gosthani estuary	7294.71	SunitaRao, 2000
Signy island	62000	Vanhove *et al*., 2000.
Thane creek	760804	Present study

Meiobenthos often show an aggregated spatial distribution within the sediment (Rodrigues *et al*., 1982 and Steyaert, 1999). Further according to Moens *et al*. (1999), the meiofauna of estuarine and marine sediments typically have a strong heterogenous distribution, with pronounced horizontal patchiness. The patch sizes are defined on a range from kilometer to subcentimeter scales (Findlay 1981; Fleeger *et al*., 1990; Moens *et al*., 1999) with the larger scales related to the abiotic gradients. In Thane creek the meiofauna was very abundant but did show an increasing trend from the river to the middle region of the creek thereafter marginally declining towards the seaward end (Fig.Me-1). But on the whole despite the fluctuations, the trend was increasing towards the sea. These observations corroborated with the findings of Annie Mathew (1989) for the subtidal zone of the same study area. The present trend can be attributed to anthropogenic impacts including pollution and physical disturbance which were predominant on the narrow and shallow riverine end than the broad and deep seaward end (due to relatively difficult access and dilution caused by neritic water). Steyaert *et al*. (1999) also observed a substantial influence of physical disturbance on the meiofauna of the North sea near Belgium.

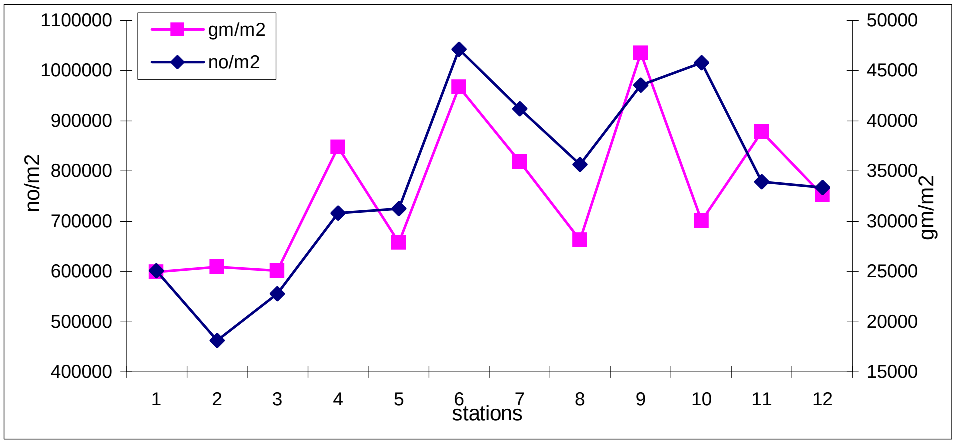


Fig.Me-1: Stationwise variations in the annual average meiobenthic abundance (no/m^2) and biomass (gm/m^2)

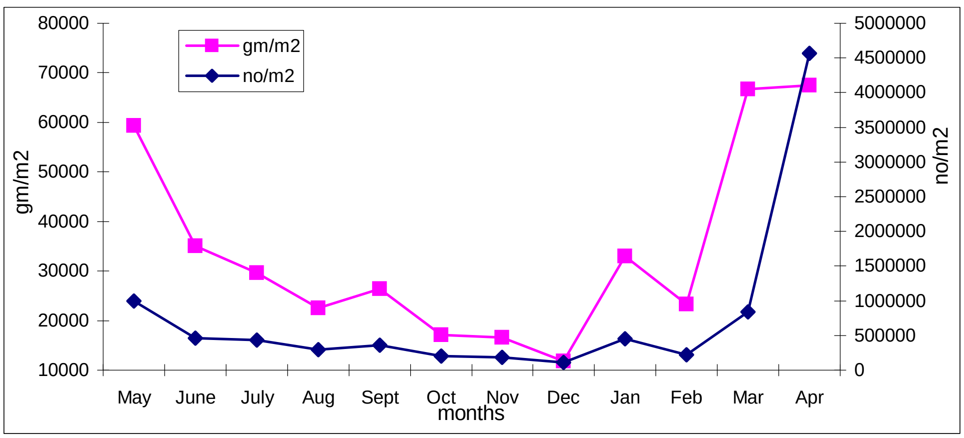


Fig.Me-2: Monthly variations in the annual average meiobenthic abundance (no/m^2) and biomass (gm/m^2)

Further in addition to spatial variations the marine meiobenthos inhabiting the intertidal zone also vary seasonally with the physicochemical regime (Ansari & Parulekar, 1993; Guiddi-Guilvard & Buscail, 1995; Vanhove *et al.*, 2000 and Sunitha Rao, 2000). According to Chatterji *et al.* (1995) the study of seasonal patterns of meiofauna provides information on the productivity of the area. However Ingole & Parulekar (1998) are of the opinion that the tropical estuaries subjected to distinct seasonality are comparatively less studied for the seasonal variations than the temperate estuaries. From the few seasonal studies of meiobenthos in the tropics the significant influence of rainfall has been revealed (Alongi, 1987). In the present study a declining trend was observed from the monsoon period to the post monsoon, with enhanced aggregation and accumulation of meiobenthos during the premonsoon months January to April (Fig Me-2.), corroborating with the observation of Ingole & Parulekar (1998), who attributed the premonsoon season as most suitable for colonizing of meiofauna in the intertidal sediment of Siridao estuarine beach.

Most of the organisms inhabiting the estuary are euryhaline species. True euryhaline forms are rare and euryhaline freshwater forms almost non existent (Coull, 1973). The meiofaunal organisms observed during the present study in Thane creek occurred in the following decreasing order of abundance : Nematodes (86.40 %) **à** foraminifera (9.45 %) **à** Oligochaeta (1.05 %) **à** Polychaeta (0.919 %) **à** eggs (0.791 %) **à** Bivalve (0.507 %) **à** Gastropods (0.416 %) **à** Insect Larvae (0.139 %) **à** Copepoda (0.138 %) **à** Sea anemones (0.107 %) **à** Zoea (0.029 %) **à** Crustacean eggs (0.022 %) **à** Tube polychaetes (0.018 %) (Table Me-4).

Table Me-4: Stationwise variations in the annual average occurrence (no/m^2) of different meiobenthic groups.

Groups ↓	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	St.12	Avg	Avg.%	Phyla %
foraminifera	9765.8	1018.3	14638	19251	5935.4	91721	75071	72260	49165	92981	40277	59392	44289.6	9.455	9.455
sea anemone	791.25	0	305.42	275.83	0	0	938.75	2568.8	0	466.25	649.17	0	499.623	0.107	0.107
Nematode	346043	310120	331142	476654	537183	446750	388202	266743	572626	404405	401598	375286	404729	86.404	88.396
Oligochaete	18368	9877.1	5063.3	1578.8	3791.3	2964.2	1496.7	2239.6	4560.8	2234.6	5240	1877.1	4940.96	1.055	
polychaete	5618.8	1664.2	4519.2	2758.3	2752.1	3925	6774.6	5675.8	6557.5	4646.3	5390.8	1389.2	4305.98	0.919	
Tube poly	0	0	806.25	0	0	0	0	202.08	0	0	0	0	84.0275	0.018	
H. Copepod	263.75	1103.8	1	850	2375.8	459.17	1222.5	325.83	1	1133.8	1	1	644.888	0.138	0.328
Zoea	0	0	0	450.83	0	491.67	304.17	132.5	92.5	167.5	0	0	136.598	0.029	
Crust eggs	0	1237.5	0	0	0	0	0	0	0	0	0	0	103.125	0.022	
Larvae	263.75	888.33	272.5	2558.8	804.17	1437.9	232.5	0	0	0	1280.8	74.167	651.076	0.139	
Gastropod	1414.6	949.58	0	547.08	2340.4	1893.8	2032.5	4644.6	346.67	3813.3	5420.8	0	1950.28	0.416	0.923
Bivalve	441.67	0	0	4569.2	185.42	4963.3	3639.6	5826.7	1961.7	3780	2555.8	567.92	2374.28	0.507	
eggs	3958.3	2232.9	2832.5	2864.6	0	6477.9	11771	3437.5	3458.3	1507.1	3713.8	2227.9	3706.82	0.791	0.791
Total	386929	329092	359580	512358	555368	561084	491685	364056	638769	515135	466127	440815	468417	100.000	

Nematoda

The dominance of nematoda is a common feature observed in almost all ecosystems. Marine nematodes according to Hodda & Nicholas (1986) prove to be sensitive biological indicators of pollution because they are very diverse taxonomically and occur everywhere (Platt, 1984). Moreover, according to Moens *et al.* (1999), the meiofauna of marine and estuarine sediments are almost invariably dominated by nematodes, and they can reach densities up to several million individuals / m^2 (Moens & Vincx, 1997). However Lambshead (1983) stated that the nematode densities can vary quite unpredictably from place to place & study to study. In the present investigation nematodes varied from 0 to 2683200 no/m^2 (av. 404729 no/m^2) (Table Me-5) and were evenly distributed in the entire creek except the unusual minimum value recorded at station 10 in December, when the meiofauna was low in the entire creek. The high density of Nematodes in Thane creek can be attributed to three main factors described by Bouwman (1983) viz. (1) The burrowing capacity in combination with their small and slender shape, allowing the occupation of interstitial spaces in coarse grained sediments as well as the invasion of soft sediments. (2) their tolerance, as a taxon, to a variety of environmental stresses, (3) the diversification in buccal structures, enabling nematodes to exploit a broad range of food items present in the benthos.

Table Me-5: Monthly variations in the Nematode density (no/m^2) at different stations.

	Stn.1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn10	Stn 11	Stn 12	Average
May-99	942525	173400	744950	1938475	1824700	676500	286200	404800	1915520	1623600	329180	429000	940738
June	320650	482625	323730	327305	429000	445450	191625	107525	216450	140700	932950	719950	386497
July	475600	624000	436800	211950	163625	277065	393900	480180	458725	127655	528000	510300	390650
Aug	359975	605550	241150	138910	173250	206125	133200	29175	196875	193750	604200	173550	254643
Sept	514800	536400	282205	448800	105875	420475	278080	66165	249150	196350	134200	325875	296531
Oct	137280	145530	185900	85085	170775	237490	63800	69960	292820	19825	339020	186250	161145
Nov	51375	87945	385440	139370	33440	27115	2725	168080	37950	343440	79200	230100	132182
Dec	117480	171875	43120	79230	14300	80850	168795	19875	19500	**0**	94875	92400	75192
Jan-00	57060	345730	425700	583440	73425	326700	770715	298650	984060	351120	378180	128700	393623
Feb	174075	252450	160600	76560	55000	88275	30195	162525	192115	80520	87120	387860	145608
Mar	18300	9495	41210	635000	719600	1735650	1486800	1100550	980870	42300	1058750	585200	701144
Apr	983400	286440	702900	1055725	**2683200**	839300	852390	293425	1327480	1733600	253495	734250	978800
Avg	346043	310120	331142	476654	537183	446750	388202	266743	572626	404405	401598	375286	**404729**
Min	18300	9495	41210	76560	14300	27115	2725	19875	19500	**0**	79200	92400	75191.7
Max	983400	624000	744950	1938475	**2683200**	1735650	1486800	1100550	1915520	1733600	1058750	734250	978800
SD	331836	208140	225679	547810	846118	472153	439532	302093	596175	606106	326311	224371	308805

Foraminifera

Benthic foraminifera are heterotrophic, amoeboid protozoa, characterized by the presence of granulo reticulose pseudopodia and a test (shell) with one or more chambers (Moodley *et al.*, 2000) Foraminifera are prevalent members of the benthic meiofauna (Yingst, 1978). They are widespread and have colonized a wide range of habitats since their first appearance in the Cambrian. Because of the fossilization potential of foraminifera, most of the studies have been carried by geologist, leading to a vast literature on shell taxonomy and broad-scale distribution patterns (Boltovskoy & Wright, 1976; Murray, 1991). In recent years, foraminifera have been increasingly found to be dominant members of benthic communities in both shallow and deep sea environment (Widbom, 1988; Alongi, 1992; Moodley *et al.*, 2000). According to Moodley & Hess (1992) foraminifera live at the oxic-anoxic boundary throughout the sediment and occur epiphytically, epizooically, epifaunally and infaunally. Further among the meiofauna, foraminifera appear most resistant to hypoxia (Josefson & Widbom, 1988) and prolonged anoxic conditions (Moodley *et al*., 1997). Boltovskoy *et al*. (2000) have shown the use of foraminifera as indicators of currents and water masses, thus contributing significantly to describe the main features of surface-layer circulation. Foraminifera are highly pollution tolerant (Rao & Rao, 1979) and are important in evaluating the impact of industrial effluents. In the present study in Thane creek, foraminifera were the second most dominant meiofauna. The density varied between 0 to 456000 no/m^2 (av. 44290 no/m^2) and was abundant at the seaward end and much less at the riverine end (Table Me-6). The low density at the riverine end can be attributed to the freshwater influence affecting the occurrence of foraminifera, corroborating with the inference of Annie Mathew (1989) for Thane creek and Nigam (1988) for the estuaries from west coast of India.

Table Me-6: Monthly variations in the foraminiferan density (no/m^2) at different stations

Months↓	Stn.1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn10	Stn 11	Stn 12	Average
May-99	15975	3400	0	14575	0	33000	40500	92000	58400	138600	21800	5200	35288
June	0	0	16350	13525	0	103250	36500	48875	33300	16750	79400	56100	33671
July	0	0	0	7850	0	63450	40400	79275	29500	31650	24000	9450	23798
Aug	0	0	0	0	0	48500	59200	58350	39375	31250	57000	17800	25956
Sept	0	0	18325	10200	9625	139000	126400	80200	60400	10500	12200	11850	39892
Oct	16640	8820	0	2210	5175	38100	14500	31800	12100	198250	13400	10000	29250
Nov	34250	0	0	36200	30400	49300	21800	76400	11500	95400	36000	47200	36538
Dec	0	0	19600	62550	3900	58800	13950	19875	0	63300	17250	24000	23602
Jan-00	31700	0	48375	14280	11125	16500	103800	27150	31950	79800	76400	2600	36973
Feb	0	0	73000	60900	11000	160500	36600	118200	99800	146400	28800	36900	64342
Mar	0	0	0	0	0	303050	259600	138000	84350	82250	43750	**456000**	113917
Apr	18625	0	0	8725	0	87200	147600	97000	129300	221625	73325	35600	68250
Stn Avg→	9766	1018	14638	19251	5935	91721	75071	72260	49165	92981	40277	59392	44290
Min	**0**	**0**	**0**	**0**	**0**	16500	13950	19875	**0**	10500	12200	2600	23602.1
Max	34250	8820	73000	62550	30400	303050	259600	138000	129300	221625	79400	**456000**	113917
SD	13186	2644	23520	22013	8948	79379	73007	36581	38935	70018	25256	126084	26218

Oligochaetes.

The oligochaetes followed the foraminifera in abundance and varied between 0 to 62220 no/m^2 (av. 4941 no/m^2) (Table Me-7). The oligochaetes are known to feed on detritus and microalgae and in turn form food for the small demersal fishery. Their occurrence and abundance is mainly influenced by the presence of other detritus feeding microfauna, meiofauna and macrofauna like gastropods and crabs.

Table Me-7: Monthly variations in the Oligochaete density (no/m^2) at different stations

Months↓	Stn.1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn10	Stn 11	Stn 12	Average
May-99	15975	8500	3170	0	12850	3300	0	0	0	0	6540	1040	4281
June	13250	2925	0	8115	13000	0	0	3910	6660	1340	35730	11220	8013
July	8700	0	0	4710	0	0	0	11325	0	2110	12000	5670	3710
Aug	8925	0	0	0	7875	0	14800	0	1575	6250	0	0	3285
Sept	7800	3725	0	0	0	0	3160	0	7550	3150	0	3555	2412
Oct	0	0	21125	0	3450	2540	0	0	605	0	0	0	2310
Nov	0	0	4380	0	0	0	0	5730	0	0	0	0	843
Dec	60520	0	0	0	0	0	0	0	0	0	0	0	5043
Jan-00	0	49390	22575	6120	0	0	0	0	38340	13965	5730	1040	11430
Feb	9495	0	0	0	0	0	0	5910	0	0	2880	0	1524
Mar	**62220**	47475	9510	0	0	27550	0	0	0	0	0	0	12230
Apr	33525	6510	0	0	8320	2180	0	0	0	0	0	0	4211

Stn Avg→	18368	9877	5063	1579	3791	2964	1497	2240	4561	2235	5240	1877	**4941**
Min	0	0	0	0	0	0	0	0	0	0	0	0	842.5
Max	**62220**	49390	22575	8115	13000	27550	14800	11325	38340	13965	35730	11220	12229.6
SD	22047	18240	8355	2948	5264	7837	4287	3706	10973	4160	10335	3445	3714

Table Me-8: Monthly variations in the Polychaete density (no/m^2) at different stations

Months↓	Stn.1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn 9	Stn10	Stn 11	Stn 12	Average
May-99	**28755**	0	15850	0	0	0	6750	20700	5840	7920	13080	1040	8328
June	0	2925	0	5410	23400	14750	5475	9775	8880	3350	15880	1870	7643
July	0	4000	4160	0	9625	0	0	0	7375	1055	2400	0	2385
Aug	0	3670	3710	4790	0	0	26640	9725	7875	11250	0	1780	5787
Sept	0	0	0	0	0	0	3160	0	13590	5250	4270	2370	2387
Oct	0	0	12675	0	0	12700	4350	0	3630	7930	2010	500	3650
Nov	0	0	8760	0	0	0	0	9550	0	7155	0	2360	2319
Dec	10680	9375	5880	0	0	1470	0	2650	0	0	0	0	2505
Jan-00	0	0	0	10200	0	1650	20760	10860	0	1995	9550	780	4650
Feb	9495	0	0	0	0	0	0	0	4990	0	0	0	1207
Mar	7320	0	0	12700	0	16530	14160	0	26510	0	17500	1520	8020
Apr	11175	0	3195	0	0	0	0	4850	0	9850	0	4450	2793
Stn Avg→	5619	1664	4519	2758	2752	3925	6775	5676	6558	4646	5391	1389	**4306**
Min	0	0	0	0	0	0	0	0	0	0	0	0	1207.08
Max	**28755**	9375	15850	12700	23400	16530	26640	20700	26510	11250	17500	4450	8327.92
SD	8690	2903	5388	4535	7067	6551	9020	6549	7621	4103	6742	1305	2528

Polychaeta.

The polychaete density in the meiobenthos varied from 0 to 28755 no/m^2 (av. 4306 no/m^2) (Table Me-8). Although the maximum density was recorded in May 99 from station 1, the abundance was more prevalent in the lower seaward stretches of the creek. According to Omori *et al*. (1994), meiobenthic abundance of polychaetes is an indication of pollution, largely due to domestic sewage.

Others.

The eggs followed the polychaetes in abundance. The stationwise annual average (Table Me-4) ranged from 1 to 11771 no/m^2 (av.3707 no/m^2). The eggs were observed in large numbers during the monsoon season and gradually declined during the nonmonsoon months. The occurrence of eggs during monsoon indicates the use of the creek as breeding ground during that season. The bivalves and gastropods were dominant in the lower stretches of the creek following a similar trend as that of polychaetes and eggs. The density of bivalves and gastropods varied between 0 to 5827 no/m^2 (av. 2374 no/m^2) and 0 to 5421 no/m^2 (av. 1950 no/m^2) respectively. The other groups were sporadic or rare and insignificant in their occurrence. The most significant of these groups was the harpacticoid copepods that ranged between 0 to 2376 no/m^2 (av. 645 no/m^2). According to Warwick (1981), the copepods are more sensitive to environmental stress and their abundance decreases with organic enrichment. In the present study, the harpacticoid copepods were prevalent during the monsoon and fairly abundant from the mid to the lower stretches of the creek. Their absence in the upper stretches (riverine end) of the creek highlights the polluted condition of the region, corroborating with the above observation.

The distribution and abundance of meiofauna according to Suresh *et al.* (1992), are a direct result of the prevailing environmental conditions. However studies on the ecology and distribution of meiofauna in sediments of shallow areas in the world, where wide fluctuations occur in water quality characteristics, are fragmentary (Sunitha rao & Ramasarma, 1990). Moreover according to Ingole & Parulekar (1998), physical parameters to which a species is exposed have a significant impact on its physiology but the correlation analysis between faunal density and environmental variables are rare. The correlation analysis between meiofauna and environmental variables for Thane creek is presented in Table Me-9.

Temperature is considered to be an important factor controlling the meiofauna (Ingole & Parulekar, 1998). Muus and Barnutt (1970) have stressed the importance of temperature in controlling the copepod population and reproduction, though the sensitivity to temperature differs among the species as observed by Verenberg & Coull(1975). In the intertidal sandy beaches according to Harkantra (1984), temperature & photoperiod play an important role in the vertical migration of meiofauna. Bouman *et al.* (1984) related the striking increase in the density of nematodes and oligochaetes to temperature. In the present study, water temperature showed significant positive correlation with total abundance and biomass of meiofauna, it also governed nematode and polychaete density.

Table Me-9 : Simple correlation coefficients of meiobenthos with environmental parameters.

	Total no	T. biomass	Nematode	Foraminifera	Oligochaete	Polychaete	Gastropod	Bivalve	eggs	H.copepoda
Air Temperature	0.5232	0.4926	0.5246	0.1356	0.0034	0.2369	0.0817	0.0078	-0.1419	0.1338
Water temperature	0.5149	0.3802	0.4857	0.0097	-0.0411	0.1995	0.0866	0.1108	-0.0249	0.1577
Suspended Solids	0.0145	0.0236	0.0714	-0.0256	-0.0843	-0.0569	-0.0682	-0.1115	-0.0177	0.0636
pH	0.5128	0.0572	0.1249	-0.0191	-0.2441	-0.1005	-0.0767	-0.1193	-0.0204	0.0186
Salinity	0.2819	0.2445	0.1858	0.2548	*-0.0256*	*0.0465*	*-0.0573*	-0.2235	-0.1928	-0.0279
Dissolved Oxygen	-0.0751	0.0106	-0.0147	0.0083	0.0089	-0.0331	0.1347	0.3521	0.1729	-0.0335
PO4-P	0.1699	0.0409	0.1149	-0.0745	0.1158	-0.0896	-0.1938	-0.1092	-0.583	0.1515
NO3-N	0.1219	0.1153	0.0925	0.1146	0.0391	0.0789	-0.0637	-0.1724	-0.1128	0.0014
SiO3-Si	0.0505	-0.1023	-0.0497	-0.0741	0.074	-0.2033	-0.1852	-0.3031	-0.1428	0.0038
Soil Parameters										
pH	0.3968	0.1745	*0.1327*	0.1811	*0.1521*	*-0.0961*	*-0.0047*	-0.1577	-0.1676	0.0396
Chlorides	0.1835	0.1669	0.1183	0.1989	-0.0356	0.0351	-0.037	-0.1875	-0.1501	-0.0077
Total Nitrogen	0.1093	-0.0338	0.0567	-0.1346	0.1547	-0.1722	-0.0441	-0.2146	-0.0795	0.086
Total Phosphorus	-0.1042	-0.0751	-0.0305	-0.0589	-0.0251	-0.0972	-0.1474	-0.0801	0.0005	-0.0295
Available Phosphorus	0.2568	0.0043	0.0851	-0.0687	-0.043	-0.1915	-0.1357	-0.0869	-0.1041	0.0218
Organic Carbon	-0.281	-0.3135	-0.1724	-0.3978	0.1196	-0.1005	-0.0422	-0.1414	-0.0109	0.0097
Moisture Content	0.0129	-0.0638	-0.0931	0.0132	-0.0465	0.0294	0.0228	-0.0141	0.0162	-0.0105
Sand	-0.1335	-0.171	-0.1048	-0.1935	0.0045	0.0302	-0.0568	-0.1836	-0.0203	-0.051
Silt	0.0926	0.0682	0.1207	-0.0118	-0.0976	-0.133	0.1602	-0.0497	0.0006	0.0769
Clay	-0.0039	-0.0159	-0.0877	0.0917	0.0426	0.0785	-0.154	0.0322	0.0708	-0.0167
Phytoplankton	-0.1278	-0.159	-0.1452	-0.1265	-0.0009	0.1162	-0.0558	0.0096	-0.0669	-0.0063
Zooplankton	-0.3007	-0.5347	-0.5152	-0.2832	-0.2936	-0.3899	-0.3798	-0.2439	0.3528	-0.5703
Phytobenthos	-0.0973	-0.1222	-0.0456	-0.1759	0.058	-0.0585	-0.0349	-0.1903	-0.0765	-0.0221
Macrobenthos	0.054	0.215	0.0809	0.3362	0.037	0.0668	-0.0722	-0.0469	-0.0246	0.0359

All values above ± 0.1623 significant at 5% level of significance except zooplankton which are significant above ± 0.5673.

In tropical estuarine environment, salinity variations greatly influence the distribution and abundance of meiofauna (Ingole & Parulekar, 1998). Sanders *et al.* (1965) however have indicated that salinity variations depend on the type of estuary studied. In fluctuating tidal estuaries salinity changes are regular and of short duration. In gradient estuary salinity changes are unpredictable and of longer duration. There appears to be a distinct relationship between salinity and the meiofaunal assemblage (Kinne, 1971); the relation is reflected in density, species composition & diversity. Bilio (1967) observed a decrease in number of species from high to low salinity. Reid (1979) noted increase in benthic copepod species with increasing salinity. In the present study the density of meiobenthos increased with the increasing salinity but the number of animal groups (nematodes, oligochaetes, polychaetes, copepods, etc.) was almost constant in the entire creek. The total meiofauna along with nematode, polychaete and foraminifera showed a positive correlation with salinity where as oligochaete, gastropods, bivalves, eggs & harpacticoid copepods showed a negative correlation with both water and soil salinity.

Depletion of dissolved oxygen according to Tietjen (1969), may present serious problems to many benthic organisms, as he observed death of harpacticoid copepods & ostracods in anoxic conditions. But Wieser & Knaweisher (1961) have reported nematodes and turbellarians to withstand anoxic conditions. In the present study only gastropods, bivalves & fish eggs showed moderately positive correlation with oxygen while all the other groups had insignificant influence of oxygen.

According to Chatterji *et al.* (1995) the availability of food is also an important limiting factor in controlling meiofaunal abundance. These animals feed actively on diatoms, bacteria, protozoans, detritus and dissolved organic carbon (Moens *et al.*, 1999). In the present study except for harpacticoid copepods, the meiobenthos had insignificant negative correlation with zooplankton, phytoplankton in the water and soil. This is contrary to the observations of Vanhove *et al.* (2000) who reported a positive correlation between the planktonic food and meiobenthos at Signy island. Organic carbon from the soil forms another important component in deciding the occurrence of meiobenthos. Mare (1942) observed that the difference in the density and distribution of the meiobenthos correlated with the levels of organic matter in the sediment. Kondalarao (1984) found maximum density of benthic copepods in the sediment having high organic matter. However Varshney *et al.* (1981) did not find any relation between meiofaunal density and sediment organic carbon. Ansari (1988) also observed inconsistent pattern between the horizontal distribution of meiobenthos and organic carbon. In the present study the meiobenthos showed a negative correlation with organic carbon except for harpacticoid copepods and oligochaetes.

According to Ansari (1988), organisms are important in controlling sediment fabrics by their burrowing and feeding activity. It is not unreasonable to expect a strong biological influence on sediment porosity, water content, cohesion and compaction. Medium size particles play an important role in the distribution of meiobenthos. Certain taxa, genera and species are restricted to a particular sediment type. Preference of different species & taxa to different grainsize has been confirmed experimentally (Fricks & Flemming, 1983). Sediment with medium particle diameters less than 125μm is dominated by burrowing meiofauna (Tita *et al.*, 1999). Small differences in grain size composition alters the porosity & permeability of sediment which in turn affects the oxygen content & animals that live in (Nair & Govindakutty, 1972). Thus Jansson (1967) regards the grain size composition as the 'super parameter' for sediment living fauna. In the present study on Thane creek, the meiofauna was mostly seen to prefer silty substratum as compared to sand; clay however did not show significant correlation with any of meiofauna corroborating with the observation of Annie Mathew (1989) for Thane creek. Chatterji *et al.* (1998) recorded similar characteristic of meiofauna in the tropical beach at Balramgari.

Nutrients also seem to have a controlling influence on the faunal development and lack of nutrients according to Subbarao & Venkatarao (1976) is responsible for small size of the populations. Thane creek is a nutrient enriched creek, hence nutrients do not form a limiting factor for the growth and occurrence of meiofauna and in general a positive correlation was observed between the meiofaunal abundance and available nutrients (except a few insignificant negative correlations). Further Bell and Coull (1978) suggested that meiofauna may serve as food at higher trophic level and their density is controlled by macrofaunal community. In the present study however the macrofauna had insignificant influence on the meiofauna as most of the groups showed a positive correlation with macrofauna suggesting poor prey-predator relation with macrofauna.

The study of population density, biomass and species number in relation with environment and pollution, according to Athalye (1988), are crude ways of assessing the benthic community. This is because the vast information inherent in this data with various interpretations lacks the brevity and precision, hence making it necessary to use the statistical and biological indices. Fig. Me-3 shows the diagrammatic presentation of the stationwise variations in meiofaunal groups respectively, wherein N 0 indicates the total number of groups at each station. Though total 13 groups were recorded during the study, at each station only 7 to 11 groups were present. Stations 3, 5, 9 & 12 had less number of groups compared to the other stations. N 1 & N2 illustrate the dominant and most dominant groups respectively at different stations revealing that stations 6, 7 & 8 had maximum (i.e. approximately 2) groups dominant or most dominant. Hence it may be inferred that the conditions at these stations were favourable for meiobenthos. The poor dominance observed at stations 1 to 5, 9 & 12 indicate stress, which can be attributed to the higher sewage load at stations 1 to 5 & 9 and disturbance caused by stronger wave action at station 12.

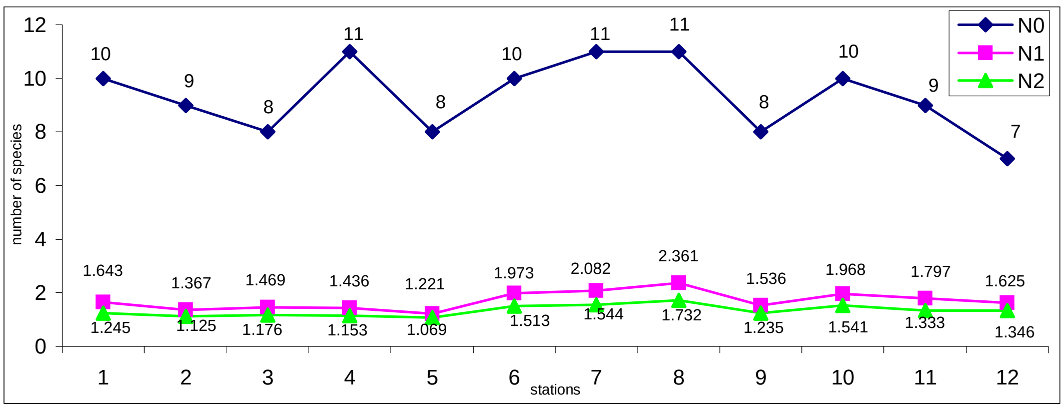


Fig. Me-3: Station wise variations in the total number of groups(N 0), number of dominant groups (N 1) and number of most dominant groups (N 2).

More or less a similar picture is given by the richness indices (R 1 & R 2) (Fig. Me- 4) which further specify the unfavourable conditions at stations 3, 5, 9 & 12 that show low richness. The Shannon-Weaver index (H'), Simpsons' index (λ) (Fig. Me-5) & Evenness index (E 5) (Fig. Me-6) also indicate low diversity at stations 1 to 5, 9 & 12 with highest adversity at station 5 which is in close proximity with a major sewage outlet of Thane city.

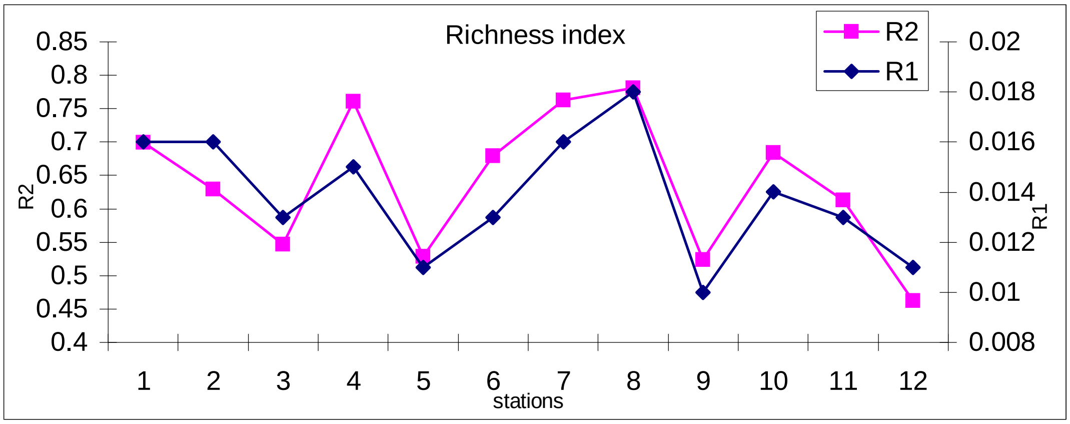
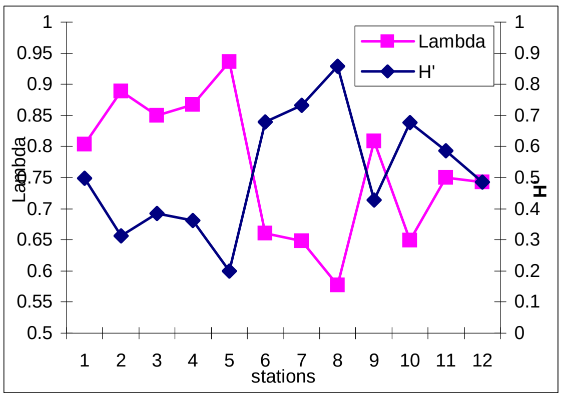


Fig.Me-4: Stationwise variations in the richness indices Margalefs' (R 1) and Menhinick (R 2).



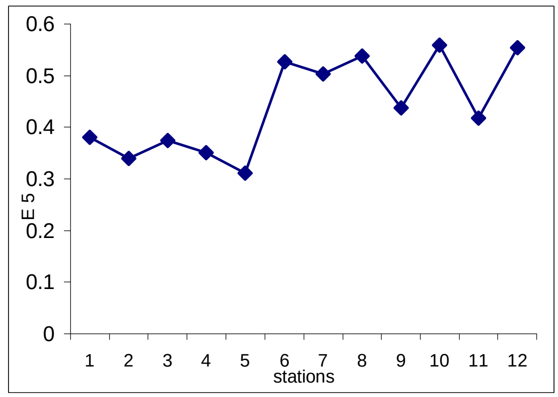


Fig. Me-5: Stationwise variations in the diversity indices (Shannon-Weaver H' and Simpsons index λ).

Fig. Me-6: Stationwise variations in the evenness index (E 5).

The abundance biomass curve (ABC curve) as suggested by Warwick (1986) is a simple method of detecting pollution. As explained in Chapter I (Fig I –1) when the abundance and biomass curves are placed wide apart, with the biomass curve lying over the abundance curve it indicates healthy conditions. While the opposite condition reveals gross pollution and when the curves are placed close to each other and even intersect each other it suggests moderate pollution. The ABC curve plotted for the meiobenthic groups of Thane creek reveals moderate pollution in the creek (Fig Me-7). According to Vidakovic (1983) pollution plays a major role in controlling density and distribution of meiofauna. He further added that sewage tends to increase density and decrease the diversity of meiofauna, which corroborates with the present study.

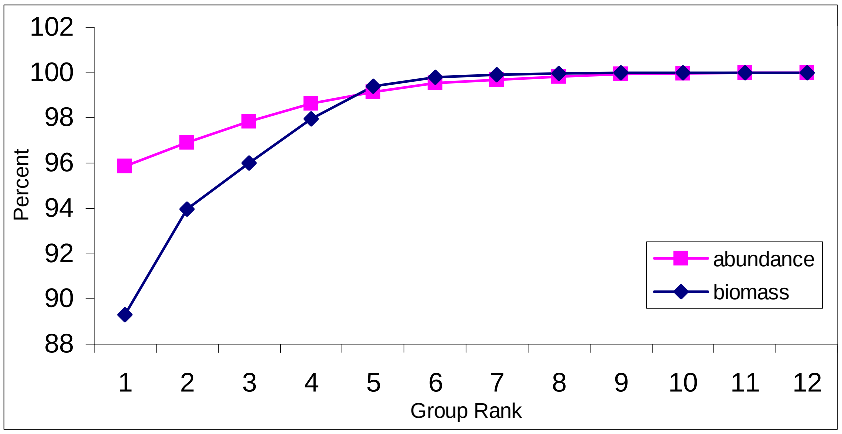


Fig. Me-7: ABC curves of the meiobenthic groups.

Rafaelli & Mason (1981) have proposed that the ratio of abundance of nematodes to copepods in marine sediments is a sensitive index of marine pollution. In this index the ratio of Nematode / copepod increases with increasing degree of pollution, due to reduction in the pollution sensitive copepod species. According to them the ratio values over 100 would indicate high organic pollution. This however has faced a lot of criticism from scientist like Coull *et al.* (1981) and Lambshead (1984) on grounds that the ratio oversimplifies a highly complex set of relationships and that nematode and copepod populations may react independently to a variety of environmental parameters of which pollution is one. On the contrary Warwick (1981) and Amjad & Gray (1983) are of the opinion that the index is useful in illustrating the trends of organic enrichment and forms an additional tool to the already available statistical indices. Keeping in mind the above argument, the nematode / copepod ratio for Thane creek was calculated. The values at all the stations (Table Me-10) varied widely and were above 100 indicating severe organic pollution in the creek. In my opinion it is difficult to rely on this ratio because as in the present case it indicates the environmental conditions at stations 2, 4 & 5 to be better as the ratio is low at these stations. This is contrary to the picture given by the earlier biological indices and also the observational facts. Hence the view point of Coull *et al.* (1981) and Lambshead (1984) seems to be correct.

Table Me-10: Stationwise variations in the nematode / copepod ratio.

	Stn. 1	Stn..2	Stn. 3	Stn. 4	Stn.5	Stn. 6	Stn.7	Stn. 8	Stn. 9	Stn.10	Stn.11	Stn.12	Average.
N/Cratio	1312.01	280.957	3311142	560.769	226.106	972.951	317.548	818.657	572626	356.681	401598	375266	627.597

A comparison of the present data with the past available data from the shallow region of Thane creek is shown in figure Me-8 which reveals that the meiofaunal density has reduced by 10 %. This reduction can be attributed to the excess organic pollution in the shallow region. This according to Warwick (1981) can be ascribed to the response of meiofauna to pollution much before it becomes obvious visually. Varshney *et al.* (1984) also reported low meiofaunal density at the creek station off Versova in comparison to the offshore region and attributed it to greater pollution stress with which corroborates the present observation.

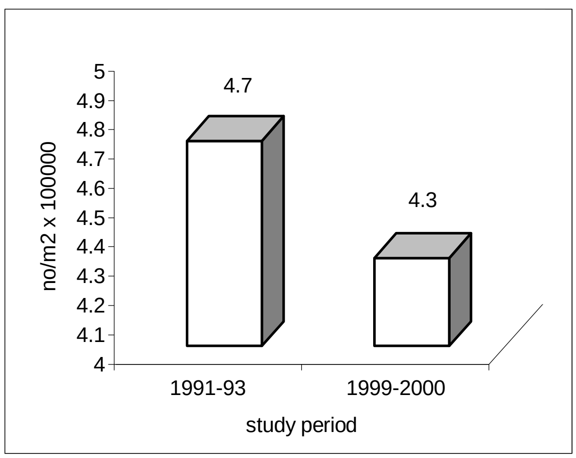


Fig. Me-8: comparison of meiobenthos with the past comparable data of the shallow region of Thane creek.

Summary:- In Thane creek 13 groups of meiobenthic organisms were recorded of which only Nematoda was the most dominant group followed by foraminifera. A 10 % reduction in the meiobenthic density as compared to 1991-93 was recorded. The meiobenthic groups showed varied correlation coefficients with different environmental parameters, hence it was difficult to specify any one particular parameter governing them. However the distribution of meiobenthos and the various indices like dominance,

diversity, richness, evenness, etc., indicated highly polluted state of the creek in the upstream region and moderate pollution in the downstream part. It also became evident that a detailed study identifying meiofauna up to the species level (rather than group level) is essential.

Macrobenthos

The intertidal benthic invertebrates are a major link in the energy flow between primary producers and larger consumers such as fish and shore birds (Edgar & Shaw 1995), and are of substantial commercial value (FAO, 1997). Hence according to Ricciardi & Bourget (1999), understanding the macro invertebrate variations has both fundamental and applied importance. Benthic fauna is a key element in any marine and estuarine monitoring programme. The information gained from monitoring benthic macro invertebrate communities has been used widely to measure the status and trends in the ecological condition of estuaries (Engle & Summers, 1999).

The benthic macro invertebrates are good indicators of estuarine condition because most benthic animals are sedentary and respond immediately to organic stress (Bilyard,1987). Short term disturbances such as hypoxia and long term disturbances such as accumulation of sediment contaminants affect the population and community dynamics of benthic macroinvertebrates (Rygg, 1986) Many of the effects of such disturbances include changes in benthic diversity, ratio of long lived to short lived species, biomass, abundance of opportunistic or pollution tolerant organisms, and the trophic or functional structure of the community (Pearson & Rosenberg, 1978; Gaston & Young, 1992 and Engle & Summers, 1999). In addition to the spatial variations caused by organic enrichment, other infaunal organisms have specific seasonal fluctuations, characterized by periodic recruitment, environmental disturbances, biological interactions and many human influenced changes (Rizzo & Amaral, 2000).

The estuaries are the major components of marine ecosystems due to their high nutrients and productivity. In the tropics the estuaries and creeks are lined by mangroves, the unique feature of which according to Jordan *et al*. (1989) is the shallowness, low wave energy and marginal or semienclosed nature of the ecosystem. The decomposition of plant litter is an important component of nutrient recycling in such ecosystems which in turn harbours a large number of diverse species. The studies on benthic animal communities have assumed greater importance with the increasing realization of the significant role they play in the trophic cycle (Pillai, 1977). According to Duda *et al.* (1982), macrobenthic fauna prey on all lower forms of life, help to process organic matter and they act as the principal source of food for most of the fishes. i.e. they play am important role in the food chain either at secondary level as feeders of detritius and plant matter or at tertiary level as food for predators like crabs and fishes, hence their study can act as an indicator of demersal fishery potential. (Varshney *et al*., 1988). Such coastal areas, in the opinion of Gopalakrishnan & Nair (1998) are extensively explored for marine resources, however some areas are also used for dumping industrial and domestic wastes causing environmental problems. According to Ansari *et al.* (1994), the disturbances are greater in estuaries and creeks adjacent to cities. Benthic fauna have a great potential to indirectly control the fate and subsequent bioavailability of sedimentary contaminants in their immediate environment (Sanders *et al*., 2000). However when the waste is released in quantities far exceeding their waste assimilating capacity, it results in marine pollution. This pollution often imbalances the ecosystem by imposing additional stress on the marine life. Since in the marine food chain, there exists a direct flow of energy from one trophic level to the next, any alteration at a particular level is bound to affect the entire ecosystem. The assessment of pollution is often done by traditional method of monitoring water, which is inadequate and time consuming. Moreover it fails to notice sudden unpredictable changes in water quality inspite of frequent and continuous monitoring (Annie Mathew, 1989). Hence Wilhelmi (1961) suggested the use of marine invertebrate animal or population as an indicator of pollution. The benthic fauna because of its constant presence, relatively long life span, sedentary or sluggish habits and differing tolerance to stress are regarded as the best indicators of organic pollution (Govindan *et al*., 1976). The pollutants are known to kill the more sensitive organisms, there by eliminating the competition of more stress tolerant species, which inturn increase in number. If the amount of waste discharged is increased the species diversity is further reduced. Therefore, knowledge of species present is of paramount importance in evaluating the effect of pollution. Bilyard (1987) emphasized the need to base all the environment management decisions on scientific information that exhibit three characteristics. viz., 1) the information should be quantitative and its inherent variability should be estimable, 2) It should be site specific to aid in defining impacts in space, time and attribution to individual sources of pollutants. 3) it should characterize at least one biological community. According to him, the benthic fauna holds all these three characteristics, therefore more suitable for assessing the marine pollution. In the earlier part of this chapter views of various authors on the importance of meiobenthic studies to evaluate pollution have been discussed. However Odum (1971), is of the opinion that larger species make better pollution indicators than smaller species, because larger and more stable biomass or standing crop can be supported with the given energy flow, whereas the turnover rate of small organisms may be so great that the particular species present at any one moment may not be very instructive as an ecological indicator. Hence vast information on the benthic fauna from almost every part of the world exists, but it mainly deals with the systematics. The idea of quantitative investigation of bottom fauna is rather recent. It was not until the early years of the 20th century that Peterson (1913) made extensive investigations in Danish waters, to study the bottom fauna in the marine economy. This initiated a number of other investigations on bottom fauna in different parts of the world. Peterson & Johnson (1911); Belegvad (1917 & 30), Sparck (1935); Jones (1950, 51 & 56); Sanders (1956 & 58); Thorson (1950 & 57) and Mulicki (1957) studied macrobenthos and evaluated their importance as food for demersal fish.

In India too the work on benthos was initiated in the early 20th century & was mainly concerned with the systematics. The significant contributions include the work done by Annandale (1907); Pannikar & Aiyar (1937); Seshappa (1953); Kurian (1955); Desai & Krishnankutty (1967 a & b) and Desai (1971). Though the ecological aspect in assessing the productivity of water gained importance much later. It has long been recognized that tropical regions, by and large support a more diverse fauna as it is easier to tolerate reduced salinities at high temperatures than at low temperature (Pannikar, 1940). As a result more marine forms are able to invade tropical estuaries than at higher altitude and the most diverse values are found among the tropical marine samples (Sanders, 1968).

Information on the bottom fauna of Bombay coast is scanty, despite more literature being available for the west coast than the east coast, and the data for Thane creek further limited. NIO (1975) conducted benthic studies in Thane region to indicate pollution.

Govindan *et al*. (1976) studied the fauna of Bombay harbour and Thane creek in relation to pollution. Shetty (1982) used foraminiferans as indicators of pollution in Thane creek. Varshney (1982) included Thane creek in his studies of the polluted & unpolluted environments of Bombay. Athalye (1988) studied the role of macrobenthos in the detritus food chain in the shallow region of Thane creek. Borgaonkar (1988) investigated the influence of ecological parameters on the benthic crab *Ilyoplax gangetica* from the shallow region of Thane creek. Annie Mathew (1989) conducted a study of the benthos of the coastal environments of Bombay. Mukherjee (1993) compared the macrobenthos from the shallow regions of Ulhas river and Thane creek. Gokhale & Athalye (1995) studied the effect of pollution on the fauna of the shallow region of Thane creek. Kotibhaskar (1998) analysed the habitats of some macrobenthos of the shallow region of Thane creek while Venkatachalam (1999) studied the influence of physico-chemical parameters on the macrobenthos of the shallow region of the creek.

From the above literature survey it was evident that the study of macrofauna from the intertidal zone / area of Thane creek was restricted to the shallow region of the creek. While the remaining studies dealt with the subtidal fauna, making it necessary to document the intertidal fauna of the entire 26 km stretch of Thane creek.

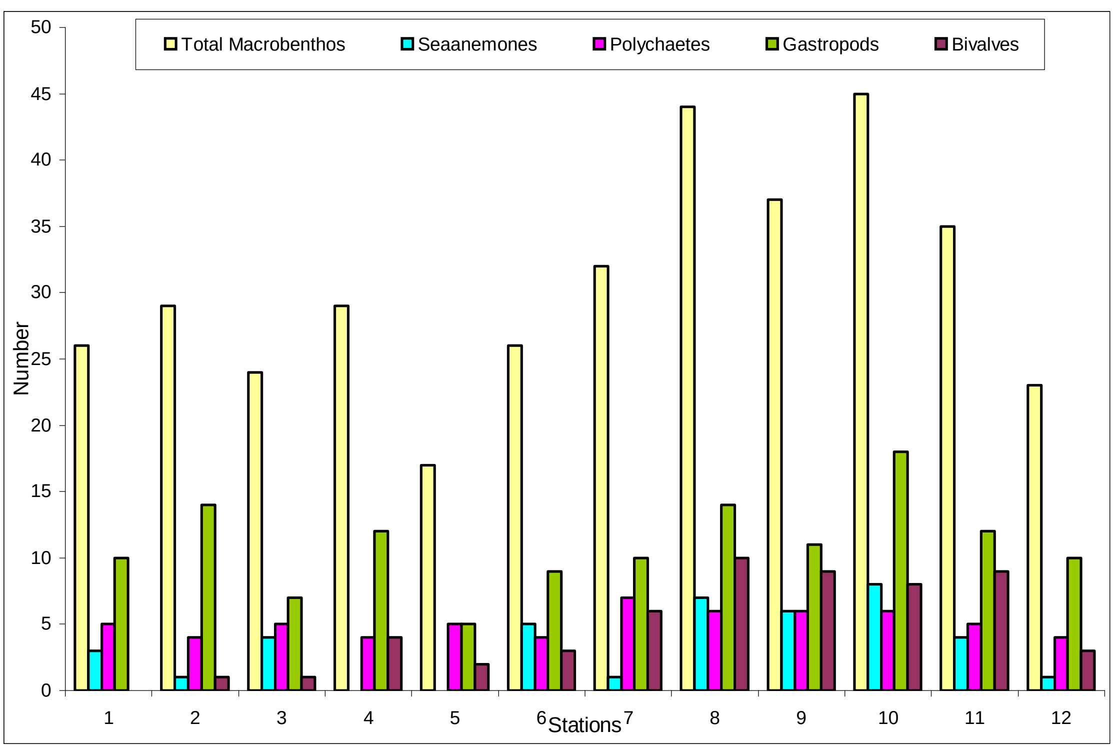


Fig. Ma-1: Stationwise variations in the number and types of macrofauna.

The estuarine fauna generally consist of marine, brackish water, freshwater and migratory forms (Pillai, 1977). In the present investigation 75 faunal types representing 12 major groups were recorded, maximum types (i.e. 45) were recorded at station 10 and minimum (i.e. 17) were observed at station 5 (Fig Ma-1). The overall macrofaunal density and biomass in the creek varied between 100 to 449280 no/m2 (av. 29583.5 no/m2) and 0.1 to 3666 gm/m2 (av. 286.27 gm/m2) respectively(Table Ma-1a & b). In comparison to the other marine ecosystems (Table Ma-2) the macrofaunal density and biomass of Thane creek is very high.

Table Ma-1a: Stationwise variations in the monthly macrofaunal density (no/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	2380	1180	920	2260	1140	3200	2180	3960	3600	34740	10320	540	5535.00
Jun	680	2680	5820	8580	100	2620	13580	11940	6700	9780	9300	3160	6245.00
Jul	1480	3940	1560	1680	3860	6720	11140	15000	56160	15200	8540	1500	10565.0
Aug	1580	3880	3220	3260	5480	4760	17620	10300	25320	9360	11260	820	8071.67
Sept	1760	8000	2980	5940	4760	11520	19720	14260	21880	91380	20140	1900	17020.0
Oct	3360	460	1660	900	1880	3880	980	6560	52700	10940	12880	660	8071.67
Nov	1620	1660	3360	68360	1360	10400	27480	121520	189120	78120	167200	5640	56320.0
Dec	26520	11940	9620	67300	11660	35440	28820	34860	30720	18900	69600	1760	28928.3
Jan-00	1300	17840	4040	44800	3280	63280	20340	45180	78440	45400	17540	2860	28691.7
Feb	6360	18620	20280	96080	100	160300	449280	90380	101220	25580	15680	320	82016.7
Mar	6280	14780	23500	78720	140	402580	162280	52060	64080	58520	24040	2380	74113.3
Apr	51760	30880	18320	20880	560	23900	20040	66340	46200	24800	47320	2080	29423.3
Stn. Avg.→	8757	9655	7940	33230	2860	60717	64455	39363	56345	35227	34485	1968	29583.5
Max	680	460	920	900	100	2620	980	3960	3600	9360	8540	320	5535
Min	51760	30880	23500	96080	11660	402580	449280	121520	189120	91380	167200	5640	82016.7
SD	15290	9376	8101	35613	3346	116658	128540	37472	50777	27659	45591	1475	26995

Table Ma-1b: Stationwise variations in the monthly macrofaunal biomass (gm/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	80.9	27.9	12.4	43.3	32.6	127.7	55.3	90.0	230.0	261.6	330.0	2.4	107.8
Jun	8.3	85.7	173.1	153.2	0.3	61.3	98.2	135.6	221.2	216.2	225.3	8.5	115.6
Jul	17.3	18.2	29.6	92.1	36.7	274.4	244.4	181.0	872.2	136.7	903.2	25.7	236.0
Aug	9.0	36.8	60.1	65.8	20.7	199.1	121.7	212.5	634.4	115.5	578.5	19.6	172.8
Sept	29.5	47.2	43.0	13.1	23.6	136.8	197.3	167.1	450.4	771.9	586.5	19.5	207.2
Oct	31.6	25.0	41.8	2.8	12.4	34.4	77.8	143.2	458.2	100.0	308.9	29.3	105.4
Nov	25.7	42.6	51.2	136.8	10.2	215.9	191.0	417.9	916.5	757.0	998.0	33.7	316.4
Dec	86.0	85.4	90.9	247.0	33.0	202.8	287.7	265.9	301.8	251.6	902.4	15.1	230.8
Jan-00	78.6	170.1	88.6	428.8	26.6	338.7	133.0	299.4	449.3	1079.0	467.5	52.0	301.0
Feb	70.6	50.4	176.9	726.4	0.5	1283.0	2454.0	1134.0	805.2	242.8	878.3	7.3	652.4

Mar	93.7	52.2	445.8	791.9	0.1	3666.0	11.4	390.0	352.7	347.2	749.4	65.0	580.5
Apr	320.0	174.4	302.4	324.1	10.5	373.8	557.5	399.5	1261.0	379.2	757.9	53.0	409.4
Stn. Avg.→	70.9	68.0	126.3	252.1	17.3	576.2	369.1	319.7	579.4	388.2	640.5	27.6	286.3
Max	8.3	18.2	12.4	2.8	0.1	34.4	11.4	90.0	221.2	100.0	225.3	2.4	105.4
Min	320.0	174.4	445.8	791.9	36.7	3666.0	2454.0	1134.0	1261.0	1079.0	998.0	65.0	652.4
SD	84.7	53.0	130.4	269.5	13.4	1026.9	672.0	279.5	322.6	311.6	263.4	20.0	179.7

Table Ma-2 : Review of macrofaunal density (no/m2) and biomass (gm/m2 wet wt.).

Study area	**Density no/m2**	**Biomass gm/m2**	**Dominant fauna**	**Reference**
Swansea bay	50 –3174 (av. 787)	0.5 – 2190 (av. 116.65)	Polychaetes (44%) Mollusc (32 %)	Harkantra, 1982
Tropical island- Tahiti	Av. 222	Av. 1.54	Polychaetes	Frouin, 2000
Gulf of St. Lawrence	Av. 11223.8	Av. 8.8	Bivalves, Polychaetes	Bourget & Messier, 1983
Krishna river estuary	Total 90	Total 0.11	Polychaetes	Ansari *et al.*, 1982
Godavari river estuary	Total 4785	Total 13.64	Gammaraides, Scaphopoda, Polychaeta	
Mahanadi river estuary	Total 1062	Total 16.04	Polychaetes, Bivalves	
Hooghly river estuary	Total 177	Total 2.48	Bivalves, Polychaetes	
Narmada estuary	26 – 1085	0.052 – 325.1	Chaetopods (82.5 %)	Varshney *et al.*, 1981
Sandy beaches of Lakshadweep	71 – 3157	5.22 – 325.1	Polychaetes	Ansari *et al.*, 1990
Goa estuaries	504 –2533	0.075 – 301.3	Bivalves (50 %)	Parulekar & Dwivedi, 1974
Cochin backwaters	481 – 1100	37.33 – 106.32	Mollusc, Polychaetes	Ansari, 1977
Asthamudi Lake	150 – 195410	0.3 – 220.2	Polychaetes, Amphipods	Divakaran *et al.*, 1981
Off Cochin	30- 1200 (av. 304)	0.11 – 8.57 (av. 2.37)	Polychaetes (82.45 %)	Harkantra & Parulekar,1987
Shelf of NE Arabian sea	57323 – 12553	3.88 – 285.76	Polychaetes	Parulekar & Wagh, 1975
Vembanad Lake	347 – 793	50.5 – 285.76	Polychaetes	Ansari,1974
Rajapur bay	25 – 2657 (av. 445)	1.2 – 26.5 (av. 6.01)	Polychaetes (42 %), Mollusc (39 %)	Harkantra & Parulekar, 1994
Cochin backwaters	1100 – 8970	16.57 – 57.86	Polychaetes (51.44 %)	Sunil Kumar, 1995
NE Bay of Bengal	0 – 12572 (av. 839)	0 – 150.6 (av. 10.61)	Polychaetes, **&** Bivalve **&** Amphipoda (88 %)	Harkantra *et al.*, 1982
Kali estuary	25 – 650	0.125 –110.52	Bivalves (65 %)	Harkantra, 1975
Andaman sea	266 – 410	0.3 – 74.4	Polychaetes (76.8 %)	Parulekar & Ansari, 1981
Vashishti estuary	Av. 8008	Av. 3.9	Polychaetes, Mollusc, Crustaceans	Nair *et al.*, 1998
Off Versova	50 – 92550	0.06 – 29.42	Foraminifera, Polychaetes, Crustaceans	Varshney *et al.*, 1988
Marmugoa harbour	498 – 1107	2.54 – 46.02	Mollusc **&** Polychaetes	Ansari *et al.*, 1994
Mangalore coast	20 – 45680	1 – 1100	Bivalve (59 %), Polychaetes (17 %)	Gopalakrishnan & Nair, 1998
Roskilde estuary	Av. 5580	Av. AFDW 36.8	Mollusk	Josefson & Rasmussen, 2000
Vejle estuary	Av. 4910	Av. AFDW 80.1	Mollusc	
Horsens estuary	Av. 2300	Av. AFDW 46.7	Mollusc	
Kolding estuary	Av. 5800	Av. AFDW 55.5	Mollusk	
Nakskov estuary	Av. 7890	Av. AFDW 16.8	Mollusc	
Stege Bugt estuary	Av. 9510	Av. AFDW 6.1	Mollusk	
Randerseste estuary	Av. 6740	Av. AFDW 18.2	Polychaetes	
Arhus Bugtesu	Av. 3460	Av. AFDW 23.7	Mollusk	
Norsminde estuary	Av. 8650	Av. AFDW 59.7	Mollusk	
Odense estuary	Av. 7760	Av. AFDW 115.6	Mollusk	
Helnaes Bbryt estuary	Av. 2210	Av. AFDW 14.4	Mollusk	
Isefjord estuary	Av. 1500	Av. AFDW 32.2	Mollusc	
Halkaer Bredning estuary	Av. 2570	Av. AFDW 98.2	Polychaete	
Flensborg estuary	Av. 2440	Av. AFDW 30.9	Echinoderm	
Thane creek	63 – 18543	0.048 – 27.215	Bivalve	Govindan *et al.*, 1976

	50 – 32950	0.058 – 100.449	Foraminifera, Polychaete	Varshney, 1982
	2030 – 57720	27.03 – 227.5	Mollusk, Polychaete	Athalye, 1988
	24 – 5118	0.1 – 230.1	Polychaete, Mollusk	Annie Mathew, 1989
	40 – 2120	1.7 – 110.68	Polychaete	Mukherji, 1993
	Av. 5814.73	Av. 182.7	Polychaete	Gokhale & Athalye, 1995
	100 – 449280 (av. 29583.5)	0.1 – 3666 (Av. 286.27)	Polychaete	Present study. 1999-2000.

AFDW – Ash Free Dry weight, Dominant fauna as per order of occurrence, **&** indicates codominance.

However the comparison of density & biomass results with literature values must be done with caution, since the sampling methods, units and scales are often incompatible; moreover, the diversity of habitats in tropical & subtropical ecosystems is high (Chardy & Clavier, 1988; Alongi, 1990). Alongi (1990) also mentioned that the density of benthic fauna in tropical & subtropical shallow soft bottoms is variable, with mean values between 100 no/m2 and 7505 no/m2. According to Reish (1980), if the amount of waste discharged into open oceanic waters is less than 18 mld. then a biological enhancement is noted with an increase in biomass, number of specimens and diversity. If the amount exceeds 40 – 180 mld., then the biomass and population counts increased but the number of species, diversity and richness is decreased. Varshney (1982) and Annie Mathew (1989), observed increased population and biomass with a decreased diversity of macrofauna in the polluted creek regions of Bombay. In Thane creek, according to TMC-ES report (2000), the waste discharged is more than 200 mld., justifying the high density and biomass of macrofauna in Thane creek observed during the present study. Ansari *et al* (1986), found that the benthic population and biomass were significantly higher at the site of organic enrichment due to waste discharges, when compared to a site having normal organic enrichment in Goa estuaries. Varshney *et al.* (1986), in their report on the polluted and unpolluted regions off Versova, noticed a higher benthic population and biomass in the polluted nearshore regions as compared to the unpolluted off shore regions. Further according to Harkantra and Parulekar (1987), the spatial variations in the distribution and abundance of benthic fauna, are attributed to the impact of localized environmental factors.

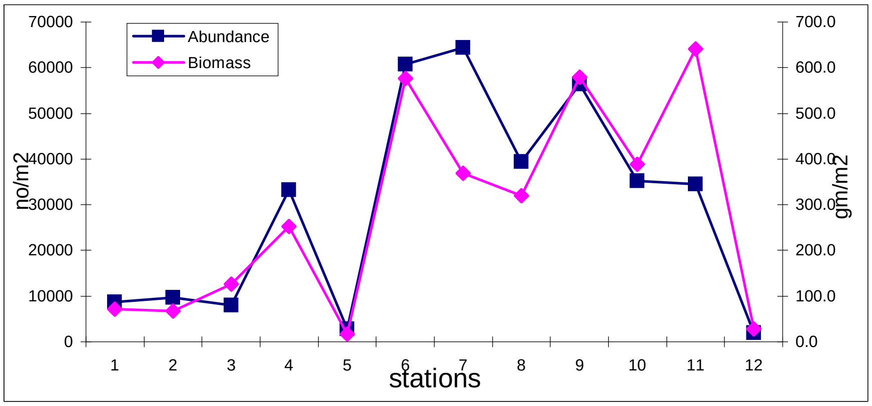


Fig Ma-2: Stationwise variations in the annual average abundance (no/m2) and biomass (gm/m2).

A spatial comparison of the macrobenthic abundance and biomass (Fig.Ma-2)in the present study in general indicated lower values on the riverine end and higher on the seaward end. Similar trend was reported from Vashishti estuary, Narmada estuary, Kali estuary, Goa estuaries and Vembanad lake by Nair *et al.* (1998); Varshney *et al.* (1981); Bhat & Neelkantan (1988); Ansari *et al.* (1986) and Ansari (1974) respectively. This decreasing trend from sea to river was mainly attributed to the salinity gradient, which is also observed to a minor extent in Thane creek. However it is interesting to note the low abundance and biomass at station 12, the seaward end that has high human influence. This station being close to open sea, experiences stronger wave action causing disturbance. According to Berkenbusch (2000), susceptibility of benthos to sediment disturbance reflects on the benthic composition. Thom & Chew (1980-81) while studying the effect of combined sewage overflow on the subtidal benthos reported that fauna of the stations very close to the discharge were acutely affected. Menon *et al.* (1979) observed the same sublethal effects of prolonged effluent release on the intertidal zone of the near shore environment of Arabian sea at Kochuveli, Trivandrum. In the present study, minimum abundance and biomass was obtained at station 5 which was in close proximity to a major sewage outlet from Thane city. Similar observation was also reported from Visakhapatnam harbour by Raman & Ganapati (1983). According to Tsutsumi (1990), the benthic communities of organically enriched locations are frequently affected by catastrophic environmental actions and vary seasonally. Bhat & Neelkantan (1988), ascribed the environmental characteristics of an estuary to fluctuate periodically depending on the 3 seasons, i.e. the premonsoon, monsoon & post monsoon. While the premonsoon season is identified by high temperature and salinity, the monsoon season is characterized by heavy rainfall, greater riverine discharge and consequent dilution of the estuarine water. The post monsoon season is known for stable environmental conditions and an increasing benthic production. Parulekar *et al*. (1980) have expressed a similar view, and stated that the greater environmental stress prevailing in an estuarine environment results in distinct seasonal changes in the distribution of dominant species. It is characterized by a depletion during monsoon, initial colonization during post monsoon, followed by secondary colonization, growth and structural development of benthic communities in the premonsoon season. In the present study the seasonal variations in abundance and biomass followed a similar pattern as depicted in Fig Ma-3., except for a drop in values during the month of October, December, January & April. The drops in October and April could be due to high temperature leading to desiccation of the mudflats, whereas the lowering in December –January could be due to low temperature reducing the production in general.

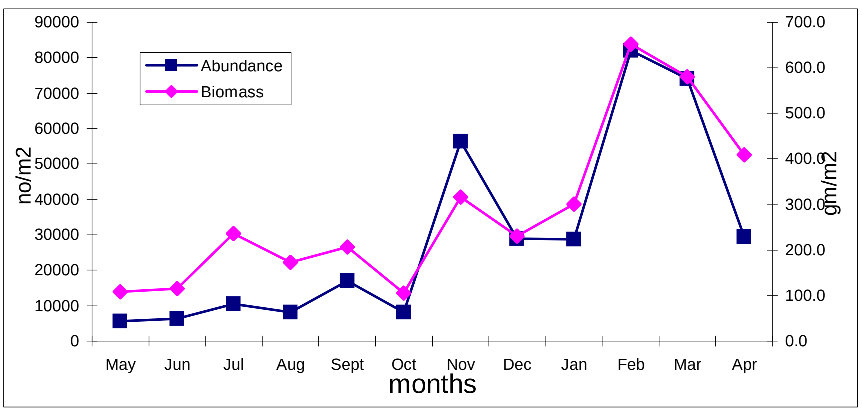


Fig Ma-3: Monthly variations in the annual average abundance (no/m2) and biomass (gm/m2).

The macrobenthos of Indian estuaries, in the view of Chandran *et al*. (1982) unusually consist of polychaetes, bivalves, gastropods and crustaceans. However, according to Parulekar and Dwivedi (1974) the faunal composition is determined by several mutually independent parameters, having a limited influence on the number of species. In Thane creek during the present study the macrobenthos abundance had the following decreasing order Polychaetes **à** Bivalves **à** Gastropods **à** Insect Larvae **à** Oligochaetes **à** Crustaceans **à** Sea anemones **à** Tubepolychaetes **à** Balanus **à** Planaria **à** other arthropods **à** gammarus (Table Ma –2 a & b).

Polychaetes

Polychaetes are one of the most characteristic groups of soft bottom macrofauna, in terms of species and individuals (Muniz & Pires, 2000), forming an important group as a descriptor of environmental conditions (Simboura *et al.*, 2000). According to Paiva (1993), polychaetes play a key role in macrobenthic secondary production. Moreover, polychaetes are one of the most abundant food items in the diet of commercially important demersal fishes and large epibenthic invertebrates (Simenstad & Cailliet, 1986). In Indian estuaries the predominance of polychaetes have been reported by various scientists (Mukherjee, 1993). According to Unnithan *et al* (1975), polychaetes are a considerably tolerant group of animals and dominate in number in the polluted zones (Pearson & Rosenberg, 1976), and their growth is enhanced due to sewage input (Ansari *et al.*, 1986).

Table Ma 2 a: Stationwise occurrence of different macrofaunal organisms (no/m^2).

	St.1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St.10	St.11	St.12	Average	Percent	Tot gr. Percent.
Planaria	3	0	0	0	0	0	2	27	0	0	0	0	2.64	0.0089	0.0089
Sea anemones															0.239
Edwardsia athalyei	0	0	0	0	0	0	0	0	0	2	0	0	0.14	0.0005	
Cerianthids	0	0	0	0	0	53	0	47	0	0	3	0	8.61	0.0291	
Pelocoetes spp.	0	0	53	0	0	0	2	10	10	10	0	0	7.08	0.0239	
Pelocoetes exul	0	0	0	0	0	2	0	15	2	42	5	0	5.42	0.0183	
Phytocoetes gangeticus	10	0	0	0	0	0	0	0	0	2	3	0	1.25	0.0042	
Stephensonactis ornata	0	0	0	0	0	0	0	8	0	0	0	0	0.69	0.0023	
S-1 Unidentified	0	0	0	0	0	0	0	10	3	2	3	0	1.53	0.0052	
S-2 Unidentified	0	0	0	0	0	0	0	0	18	22	0	2	3.47	0.0117	
S-3 Unidentified	7	17	98	0	0	15	0	0	0	5	0	0	11.81	0.0399	
S-4 Unidentified	0	0	63	0	0	27	0	43	2	0	0	0	11.25	0.038	
S-5 Unidentified	30	0	12	0	0	95	0	67	8	22	0	0	19.44	0.0657	
Polychaetes															50.9293
Boccardia tricuspa	0	0	385	0	0	0	127	40	0	0	0	0	45.97	0.1554	
Dendronereis heteropoda	10	157	252	812	120	7	142	33	0	0	0	7	128.19	0.4333	
Glycera alba	0	0	0	0	0	0	0	0	0	2	0	0	0.14	0.0005	
Lycastis ouanaryensis	6970	2128	2175	15553	1052	6815	17790	0	87	18	17	0	4383.75	14.8182	
Lycastis indica	375	482	748	0	58	6760	13	0	28	5	0	0	705.83	2.3859	
Nereis glandicincta	0	0	0	0	0	2133	0	1733	860	107	595	0	452.36	1.5291	
Nereis (ceratonereis) spp.	128	53	2772	13775	1078	28895	27930	8410	2433	4128	42	427	7505.97	25.3722	
Polydora tentaculata	120	0	0	0	0	0	6940	1480	290	498	5417	210	1246.25	4.2127	
Capitella capitata	0	0	0	0	15	0	0	0	0	0	0	0	1.25	0.0042	
Sigambra bassi	0	0	0	186.67	0	0	133.33	53.33	4498.33	0	2098.33	193.33	596.94	2.0178	
Tube polychaetes	0	13.33	206.67	106.67	0	0	0	26.67	105	6.67	0	0	38.75	0.131	0.131
Oligochaete	30	2668	20	1007	263	0	17	0	47	0	0	0	337.64	1.1413	1.1413
Gastropods															22.168
Assiminea brevicula	263	197	148	15	70	467	275	70	3232	1017	938	120	567.64	1.9188	

Auricula elongata	2	7	5	0	0	0	0	108	205	5	142	0	39.44	0.1333	
Auricula spp.	15	2	7	0	7	0	0	0	0	0	0	0	2.5	0.0085	
Cerethidea (Cerethideopsis)	0	0	0	12	0	205	357	237	563	135	488	2	166.53	0.5629	
Drupa spp.	0	3	0	0	0	0	0	0	0	2	0	0	0.42	0.0014	
Fairbank bombayana	0	0	0	0	0	0	0	7	0	12	0	10	2.36	0.008	
Haminea crocata	8	0	0	2	0	15	8	5	0	2	0	100	11.67	0.0394	
Littorina ventricosa	0	0	0	27	0	35	215	902	7622	2987	2865	2	1221.11	4.1277	
Melampus ceylonicus	0	20	0	0	0	0	0	0	0	0	0	0	1.67	0.0056	
Melampus singaporensis	58	3	0	0	0	0	0	0	0	0	0	2	5.28	0.0178	
Melanoides tuberculata	0	2	0	2	0	0	0	0	0	3	0	0	0.56	0.0019	
Mitra amphorell	0	0	0	0	0	0	0	2	328	0	47	0	31.39	0.1061	
Nassarius ornatus	0	0	0	0	0	0	7	7	143	28	97	0	23.47	0.0793	
Nassarius spp.	0	0	0	0	0	0	0	0	38	27	115	0	15	0.0507	
Nerita (Dostia) violacea	0	2	2	0	0	0	0	18	0	5	0	0	2.22	0.0075	
Neritina spp.	8	0	0	27	0	0	0	0	0	2	0	0	3.06	0.0103	
Onchidium verruculatum	0	13	0	2	0	7	0	0	0	0	0	0	1.81	0.0061	
Stenothyra minima	0	2	0	7	7	180	543	2258	2508	1053	6157	0	1059.58	3.5817	
Salinater burmana	0	12	0	2	0	88	50	8	18	5	43	22	20.69	0.0699	
Stenothyra deltae	180	5	141.7	56.67	8.33	480	2298.33	4088.33	10155	9391.67	12216.7	51.67	3256.11	11.0065	
Thiara spp.	35	0	0	3.33	0	0	18.33	143.33	326.67	473.33	88.33	0	90.69	0.3066	
Turbinicola nux	60	35	13.33	8.33	13.33	101.67	0	0	0	106.67	0	13.33	29.31	0.0991	
Turitella cerea	13.33	15	3.33	0	0	0	13.3333	0	0	1.67	5	1.67	4.44	0.015	
Calcareous tubes	0	0	0	0	0	0	0	13	0	0	0	0	1.11	0.0038	
Bivalves															23.1942
Cuspidaria cochinensis	0	0	0	60	0	255	1743	578	4617	788	760	2	733.61	2.4798	
Katelysia marmorata	0	0	0	0	0	0	0	17	72	30	163	0	23.47	0.0793	
Katelysia opima	0	0	0	0	0	0	3	58	417	97	333	0	75.69	0.2559	
Microbivalve	0	0	0	1307	2	12593	4353	17065	15593	7202	1233	33	4948.47	16.7271	
Glauconome cerea	0	0	3	222	2	705	935	943	1367	1808	415	3	533.61	1.8037	
Dosinia pubescens	0	0	0	0	0	0	0	348	522	252	17	0	94.86	0.3207	
Cardium asiaticum	0	0	0	0	0	0	2	2	38	0	142	0	15.28	0.0517	
Brachyodontes karachiensis	0	2	0	0	0	0	0	173	0	3263	0	0	286.53	0.9685	
unidentified bivalve	0	0	0	2	0	0	12	3	70	1600	10	0	141.39	0.4779	
unidentified razor clam	0	0	0	0	0	0	0	5	95	0	5	0	8.75	0.0296	
Crustaceans															0.4906
Uca sp.	0	0	0	3	0	0	0	0	0	0	0	0	0.28	0.0009	
Illyoplax gangetica	235	233	525	15	10	288	73	232	0	58	0	35	142.08	0.4803	
Prawn	0	0	0	2	0	0	2	0	0	0	0	7	0.83	0.0028	
Hermit crab	0	0	0	0	0	0	2	12	3	2	5	0	1.94	0.0066	
Gamarus	0	0	0	0	0	0	0	0	0	0	3	0	0.28	0.0009	0.0009
Balanus amphitrite	0	0	2	0	0	0	22	32	15	22	2	0	7.78	0.0263	0.0263
Larvae (insect)															1.6648
Larva-1 Unidentified	90	650	302	13	68	490	55	7	0	0	5	343	168.61	0.5699	
Larva-2 Unidentified	100	2422	0	2	68	2	373	0	0	0	0	375	278.47	0.9413	
Larva-3 Unidentified	0	508	2	2	0	0	0	0	2	0	0	10	43.61	0.1474	
Larva-4 Unidentified	0	2	0	0	20	0	0	0	0	0	0	0	1.81	0.0061	
Arthropods															0.0061
Lethoceros spp.	0	2	0	0	0	0	0	0	0	0	0	0	0.14	0.0005	

Ant	0	0	2	0	0	0	0	2	0	0	0	0	0.28	0.0009	
Red insect	0	2	0	0	0	2	0	0	0	0	0	0	0.28	0.0009	
2 insect	0	0	0	2	0	0	0	0	0	0	0	0	0.14	0.0005	
Stick insect	2	0	0	0	0	0	0	0	0	0	0	0	0.14	0.0005	
Beetle	2	0	0	0	0	0	0	0	0	2	5	0	0.69	0.0023	
Other Arthropods	2	0	0	0	0	0	0	0	0	0	0	0	0.14	0.0005	
Total Abundance	8756.67	9655	7940	33230	2860	60716.7	64455	39363.3	56345	35226.7	34485	1968.33	29583.5	100	

Table Ma 2 a: Stationwise occurrence of different macrofaunal organisms (gm/m2 wet wt.).

	St.1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St.10	St.11	St. 2	Average	%	Tot gr. %
Planaria	0.033	0	0	0	0	0	0.005	0.250	0	0	0	0	0.024	0.0082	0.0084
Sea anemones															1.8146
Edwardsia athalyei	0	0	0	0	0	0	0	0	0	0.090	0	0	0.008	0.0027	
Cerianthids	0	0	0	0	0	0.658	0	0.800	0	0	1.767	0	0.2688	0.0915	
Pelocoetes spp.	0	0	0.258	0	0	0	0.158	0.315	1.153	0.138	0	0	0.1686	0.0574	
Pelocoetes exul	0	0	0	0	0	0.267	0	3.242	0.65	3.392	3.292	0	0.9035	0.3077	
Phytocoetes gangeticus	0.137	0	0	0	0	0	0	0	0	0.057	0.055	0	0.0207	0.007	
Stephensonactis ornata	0	0	0	0	0	0	0	0.127	0	0	0	0	0.0106	0.0036	
S-1 Unidentified	0	0	0	0	0	0	0	1.917	0.083	0.017	0.15	0	0.1806	0.0615	
S-2 Unidentified	0	0	0	0	0	0	0	0	0.497	32.70	0	0.317	2.7928	0.951	
S-3 Unidentified	0.125	0.197	1.278	0	0	0.087	0	0	0	0.298	0	0	0.1654	0.0563	
S-4 Unidentified	0	0	0.727	0	0	0.330	0	0.913	0.025	0	0	0	0.1663	0.0566	
S-5 Unidentified	0.425	0	0.227	0	0	1.142	0	4.232	0.088	1.613	0	0	0.6439	0.2193	
Polychaetes															41.4934
Boccardia tricuspa	0	0	3.780	0	0	0	0.490	0.130	0	0	0	0	0.370	0.126	
Dendronereis heteropoda	0.150	1.110	3.740	2.110	1.460	0.060	0.730	0.300	0	0	0	0.020	0.810	0.2758	
Glycera alba	0	0	0	0	0	0	0	0	0	0.460	0	0	0.040	0.0136	
Lycastis ouanaryensis	39.630	8.560	29.800	53.840	3.410	21.480	31.320	0	2.230	0.210	0.050	0	15.880	5.4075	
Lycastis indica	16.038	25.603	21.865	0	3.777	71.772	0.300	0	0.955	0.103	0	0	11.701	3.9845	
Nereis glandicincta	0	0	0	0	0	19.200	0	18.533	8.433	2.133	1.473	0	4.148	1.4124	
Nereis (ceratonereis) spp.	1.377	1.235	29.297	176.123	5.527	357.270	260.365	76.877	47.098	44.713	1.680	10.643	84.350	28.7233	
Polydora tentaculata	0.142	0	0	0	0	0	11.640	2.213	1.033	5.863	11.922	0.392	2.767	0.9423	
Capitella capitata	0	0	0	0	0.030	0	0	0	0	0	0	0	0.002	0.0007	
Sigambra bassi	0	0	0	0.600	0	0	1.067	0.517	13.415	0	5.500	0.300	1.783	0.6072	
Tube polychaetes	0	0.200	4.442	1.493	0	0	0	0.107	0.818	0.133	0	0	0.599	0.2041	0.2094
Oligochaete	0.037	2.733	0.050	1.64	0.3833	0	0.0333	0	0.05	0	0	0	0.411	0.1398	0.1434
Gastropods															22.4772
Assiminea brevicula	0.900	2.920	1.650	0.210	0.820	0.900	1.420	0.180	3.250	1.300	1.680	0.930	1.350	0.4597	
Auricula elongata	0.020	0.230	0.070	0	0	0	0	0.210	7.050	0.040	0.260	0	0.650	0.2213	
Auricula spp.	0.060	0.050	0.020	0	0.030	0	0	0	0	0	0	0	0.013	0.0044	
Cerethidea (Cerethideopsis)	0	0	0	5.210	0	72.290	114.100	62.850	146.120	32.370	138.270	0.910	47.680	16.2362	

Drupa spp.	0	0.330	0	0	0	0	0	0	0	0.030	0	0	0.030	0.0102	
Fairbank bombayana	0	0	0	0	0	0	0	0.020	0	0.030	0	0.020	0.010	0.0034	
Haminea crocata	0.830	0	0	0.36	0	5.190	3.640	3.040	0.000	0.270	0	7.130	1.700	0.5789	
Littorina ventricosa	0	0	0	0.017	0	0.038	0.282	0.980	8.533	2.612	3.382	0.010	1.3211	0.4499	
Melampus ceylonicus	0	0.067	0	0	0	0	0	0	0	0	0	0	0.0056	0.0019	
Melampus singaporensis	0.383	1.192	0	0	0	0	0	0	0	0	0	0.050	0.1354	0.0461	
Melanoides tuberculata	0	0.017	0	0.017	0	0	0	0	0	0.013	0	0	0.0039	0.0013	
Mitra amphorell	0	0	0	0	0	0	0	0.667	10.930	0	2.150	0	1.1456	0.3901	
Nassarius ornatus	0	0	0	0	0	0	1.093	2.000	13.465	2.738	11.863	0	2.5967	0.8842	
Nassarius spp.	0	0	0	0	0	0	0	0	0.722	0.183	0.513	0	0.1182	0.0402	
Nerita (Dostia) violacea	0	0.183	0.317	0	0	0	0	4.067	0	0.3	0	0	0.4056	0.1381	
Neritina spp.	0.013	0	0	0.133	0	0	0	0	0	0.003	0	0	0.0125	0.0043	
Onchidium verruculatum	0	4.042	0	3.892	0	3.358	0	0	0	0	0	0	0.941	0.3204	
Stenothyra minima	0	0.017	0	0.018	0.018	0.340	1.192	2.827	4.635	1.58	10.350	0	1.748	0.5952	
Salinater burmana	0	0.017	0	0.117	0	2.185	3.842	0.280	0.883	0.055	1.150	0.260	0.7324	0.2494	
Stenothyra deltae	0.327	0.005	0.2067	0.077	0.028	0.980	4.732	6.322	16.965	12.685	20.354	0.128	5.2341	1.7823	
Thiara spp.	0.073	0	0	0.035	0	0	0.027	0.187	0.12	0.424	0.095	0	0.08	0.0272	
Turbinicola nux	0.150	0.12	0.11	0.015	0.052	0.06	0	0	0	0.195	0	0.047	0.0624	0.0212	
Turitella cerea	0.022	0.095	0.038	0	0	0	0.020	0	0	0.017	0.075	0.003	0.0225	0.0077	
Calcareous tubes	0	0	0	0	0	0	0	0.080	0	0	0	0	0.01	0.0034	
Bivalves															30.7053
Cuspidaria cochinensis	0	0	0	0.410	0	0.720	6.390	7.460	21.260	8.570	4.000	0.030	4.07	1.3859	
Katelysia marmorata	0	0	0	0	0	0	0	6.380	6.880	15.990	48.160	0	6.45	2.1964	
Katelysia opima	0	0	0	0	0	0	0.13	18.400	39.330	67.110	113.320	0	19.86	6.7628	
Microbivalve	0	0	0	0.90	0	3.470	4.120	20.600	18.580	5.260	1.670	0.070	4.56	1.5528	
Glauconome cerea	0	0	0.010	0.440	0	1.430	2.720	4.730	5.010	10.960	0.630	0.020	2.16	0.7355	
Dosinia pubescens	0	0	0	0	0	0	0	16.310	12.360	53.480	1.750	0	6.99	2.3803	
Cardium asiaticum	0	0	0	0	0	0	0.01	1.260	139.870	0	249.250	0	32.53	11.0772	
Brachyodontes karachiensis	0	0.008	0	0	0	0	0	30.550	0	80.212	0	0	9.231	3.14337	
unidentified bivalve	0	0	0	0.260	0	0	2.640	0.710	3.090	30.010	3.020	0	3.31	1.12713	
unidentified razor clam	0	0	0	0	0	0	0	2.080	9.760	0	0.290	0	1.01	0.34393	
Crustaceans															2.5683
Uca sp.	0	0	0	0.150	0	0	0	0	0	0	0	0	0.01	0.00341	
Illyoplax gangetica	9.760	11.100	26.860	1.020	0.940	10.110	0.980	2.760	0	1.230	0	3.560	5.690	1.93758	
Prawn	0	0	0	0.227	0	0	0.317	0	0	0	0	0.203	0.062	0.02119	
Hermit crab	0	0	0	0	0	0	3.510	14.210	1.380	0.300	1.900	0	1.780	0.60613	
Gamarus	0	0	0	0	0	0	0	0	0	0	0.010	0	0.001	0.00034	0.0003
Balanus amphitrite	0	0	0.030	0	0	0	0.610	0.800	0.500	0.460	0.050	0	0.200	0.0681	0.0699
Larvae (insect)															0.50615
Larva-1 Unidentified	0.540	4.380	1.550	0.160	0.320	2.750	0.450	0.030	0	0	0.020	1.380	0.960	0.3269	
Larva-2 Unidentified	0.360	2.540	0	0.030	0.290	0.010	0.610	0	0	0	0	1.490	0.440	0.14983	
Larva-3 Unidentified	0	0.610	0.010	0.090	0	0	0	0	0.01	0	0	0.030	0.060	0.02043	
Larva-4 Unidentified	0	0.133	0	0	0.183	0	0	0	0	0	0	0	0.026	0.00899	
Arthropods															0.01447
Lethoceros spp.	0	0.3	0	0	0	0	0	0	0	0	0	0	0.030	0.01022	
Ant	0	0	0.008	0	0	0	0	0.018	0	0	0	0	0.002	0.00068	
Red insect	0	0.0	0	0	0	0.020	0	0	0	0	0	0	0.003	0.00102	

2 insect	0	0	0	0.002	0	0	0	0	0	0	0	0	0.000	3.4E-05	
Stick insect	0.002	0	0	0	0	0	0	0	0	0	0	0	0.000	3.4E-05	
Beetle	0.013	0	0	0	0	0	0	0	0	0.050	0.023	0	0.007	0.00238	
Other Arthropods	0.003	0	0	0	0	0	0	0	0	0	0	0	0.000	0.0001	
Total Biomass	70.94	67.989	126.322	252.108	17.268	576.156	458.942	319.675	547.233	420.399	640.124	27.943	293.666	100	100

During the present study the polychaetes were present throughout the creek and maintained a good consistency of occurrence with a frequency of 96.53 %. The polychaete abundance and biomass varied from 0 to 409700 no/m2 (av. 15066.7 no/m2) and 0 to 3501.6 gm/m2 (av. 121.84 gm/m2) respectively (Table 3a &b). The polychaetes formed 50.92 % and 41.49 % of the total macrobenthic abundance and biomass respectively in the creek, and followed the general pattern of the total fauna with increasing density and biomass during the pre monsoon season (Fig Ma 4a &b). During the monsoon the physiological stress exerted by the freshwater conditions resulted in the decreased population density (Athalye, 1988).

Table Ma-3a: Stationwise variations in the total polychaete density (no/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	1960	160	640	1240	240	2560	420	0	660	120	1860	60	826.667
Jun	220	780	3940	4900	0	2220	0	0	140	540	7780	2980	1958.33
Jul	1260	360	700	1380	3740	3580	5200	4720	8640	3560	840	1300	2940
Aug	520	440	3120	2800	3100	2960	14780	4240	3680	4080	6420	420	3880
Sept	960	1560	2880	5220	3520	4480	15600	4320	8640	6080	16500	440	5850
Oct	580	120	1380	380	1800	800	80	1120	1500	860	6700	200	1293.33
Nov	1280	820	1500	68320	940	9600	27280	3080	6240	5120	11800	560	11378.3
Dec	25940	4660	8240	55680	11520	20800	27200	17600	12160	4720	17920	940	17281.7
Jan-00	920	2800	1800	44800	2880	40960	19200	26560	29440	6400	5480	2380	15301.7
Feb	2200	18400	19200	96000	0	148480	409700	20800	11840	6400	4840	160	61501.7
Mar	4200	440	19540	65600	60	281600	113920	24000	8060	12820	6360	240	44736.7
Apr	51200	3300	13040	17600	80	17280	3520	34560	7360	6400	11520	360	13851.7
Stn. Avg.→	7603.33	2820	6331.67	30326.7	2323.33	44610	53075	11750	8196.67	4758.33	8168.33	836.667	15066.7
Min	220	120	640	380	**0**	800	**0**	**0**	140	120	840	60	826.667
Max	51200	18400	19540	96000	11520	281600	**409700**	34560	29440	12820	17920	2980	61501.7
SD	15470.1	5115.47	7065.65	33885.2	3253.1	85290.5	116534	12177.2	7816.99	3455.65	5303.28	937.029	19016.8

Table Ma-3b: Stationwise variations in the total polychaete biomass (gm/m2 wet wt.).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	79.36	0.72	10.7	11.02	24.9	79.76	15.1	0	2.36	2.4	2.88	0.48	19.14
Jun	1.86	63.22	144.56	112.58	0	35.5	0	0	0.6	7	12.2	7.5	32.09

Jul	15.2	5.6	10.4	81.2	36.5	51.9	92.7	36.8	313.6	64.66	17.5	22.9	62.39
Aug	5.66	19.58	59.18	61.94	14.82	53.68	68.52	48.4	53.7	38.8	17.74	4	37.17
Sept	16	24	41.6	11.92	17.8	38.92	64.2	51.2	29.32	129.7	31.9	2.6	38.26
Oct	14.52	7.3	34.28	1.66	11.02	19.8	0.48	37.02	3.7	11.5	10.12	1.78	12.77
Nov	11.5	13	31.76	136	7.36	43.6	110.7	76	25.78	36.8	29.66	8.84	44.25
Dec	73.3	33.26	51.42	195.52	31.9	64	51.32	99.2	20.8	26.1	19.3	10.24	56.36
Jan-00	57.9	111	25.5	428.8	25.04	249.6	56	122.2	138.28	35.2	15.1	48.9	109.46
Feb	34.1	30.8	148.5	716.8	0	1203	2248.72	222.4	142.8	22.4	24.2	3.2	399.74
Mar	58.6	13.9	331.64	761.92	0.06	3501.6	947.2	214.52	71.8	123.9	22.08	5.5	504.39
Apr	320	115.7	172.18	272.8	1	296	16	275.1	75.2	143.3	44.8	20.28	146.03
Stn. Avg.→	57.3333	36.5067	88.4767	232.68	14.2	469.78	305.912	98.57	73.1617	53.48	20.6233	11.3517	121.84
Min	1.86	0.72	10.4	1.66	**0**	19.8	**0**	**0**	0.6	2.4	2.88	0.48	12.77
Max	320	115.7	331.64	761.9	36.5	**3501.6**	2248.72	275.1	313.6	143.3	44.8	48.9	504.39
SD	87.1	39.5	95.1	266.8	13.1	1010.5	665.2	91.9	90.1	50.5	11.1	13.8	160.3

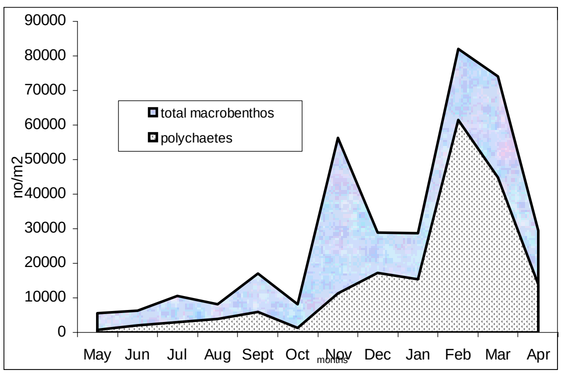


Fig. Ma.-4a: Monthly variations in the total macrobenthos and polychaete density (no/m2).

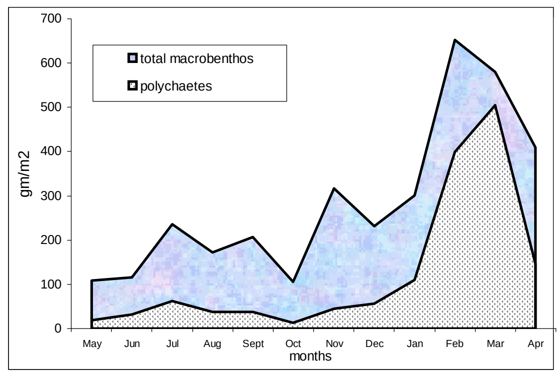


Fig. Ma.-4b: Monthly variations in the total macrobenthos and polychaete biomass (gm/m2).

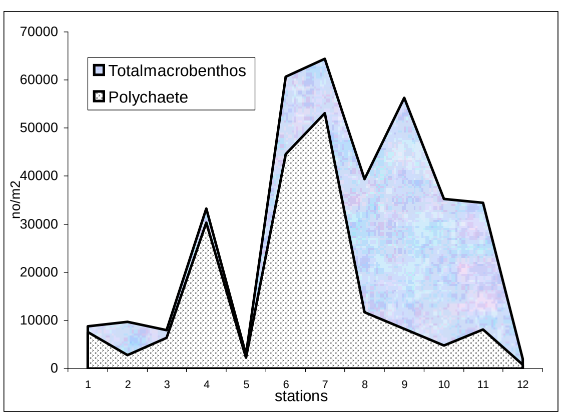


Fig. Ma.-5a: Stationwise variations in the total macrobenthos and polychaete density (no/m2).

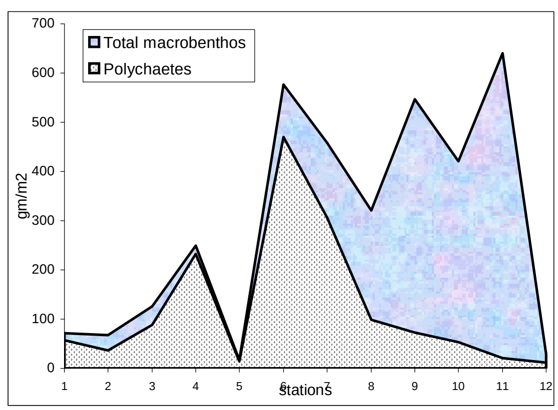


Fig. Ma.-5b: Stationwise variations in the total macrobenthos and polychaete biomass (gm/m2).

Comparison of abundance & biomass of the polychaetes in Fig.'s Ma- 4a & 4b also indicates the presence of juveniles during the period November to January and mature and large size polychaetes in March. A stationwise comparison (Fig Ma-5a &b) of polychaetes showed increasing abundance and biomass from station 1 to station4, followed by the lowest values at station 5. The occurrence of polychaetes was the highest at the middle stations 6 & 7 which tapered towards station 12. From the figures it is evident that on the riverine end upto station 5, polychaetes made for the entire abundance and biomass of the total macrobenthos. This according to Vijayakumari *et al.* (1991) could be due to the biostimulating effect caused by the organic effluents, fascilitating the growth of a particular group. Whereas in the lower reaches animals other than polychaetes probably successfully join the struggle for survival and reduce the number of polychaetes (Unnithan *et al.*, 1975). In the present study 10 different species of polychaetes were identified with the dominance of only one species in the entire creek and 3 other species co-dominant. However at the individual stations the species number varied between 4 to 7 only. A change in the species number according to Gray (1981) is a useful index in monitoring the environment and the number of species vary depending on the health of the ecosystem (Athalye 1988). Raman & Ganapati (1983), reported 1 to 50 species of polychaetes in the very polluted to healthy environments respectively of Visakhapatnam harbour. According to Unnithan *et al*. (1975), although polychaetes form the most tolerant group of benthic animals, they can be completely wiped off from the polluted zone due to anaerobic conditions.

The polychaetes during the present study occurred in the following order of abundance *Nereis (Ceratonereis) burmensis* (49.82 %), *Lycastis ounaryensis* (29.10 %), *Polydora tentaculata* (8.27 %), *Lycastis indica* (4.69 %), *Sigambra bassi* (3.96 %), *Nereis glandicinta* (3.002 %), *Dendronereis heteropoda* (0.85 %), *Boccardia tricuspa* (0.31 %), *Capitella capitata* (0.008 %) and *Glycera alba* (0.0009 %). According to Kristensen (1989), Nereid polychaetes form important component of most benthic communities in coastal marine environments and are known to have major impacts on benthic metabolism and nutrient dynamics. In the present study from the Nereid spp. recorded, *Nereis (Ceratoneris) burmensis* (av. 7505.97 no/m2 & 84.35 gm/m2) was the most dominant polychaete, it was observed throughout the creek and was highly dominant in the middle region of the creek (Fig. Ma-6a). Monthly trend of this species (Fig. Ma- 6b) showed December to March as favourable period for growth. The Abundance-Biomass trends indicated the probable breeding period for the polychaetes to be December, January & Feburary. The polychaete ***Nereis (Ceratonereis)burmensis*** was first reported by Mukherji (1993) in Thane creek region, its present abundance in the creek indicates its adaptability to stress. According to Huston (1979), a species begins to compete with other species after reaching certain population level which he described as competitive equilibrium. If one species grows faster and reaches the competitive equilibrium earlier, it excludes other species, reducing the diversity. Furthermore, under stress conditions the sensitive organisms will be eliminated and successful organisms increase in number to dominate the community (Remani *et al*., 1983).

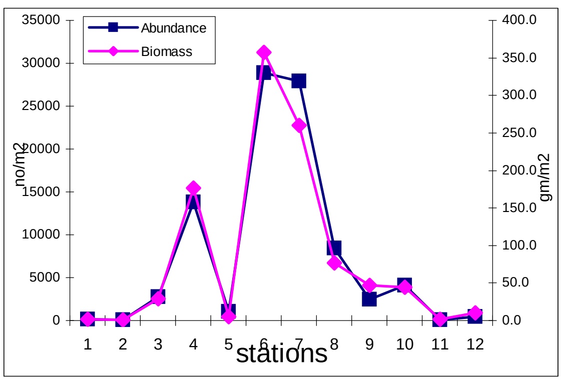


Fig Ma-6a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of polychaete *Nereis (Ceratonereis) burmensis*.

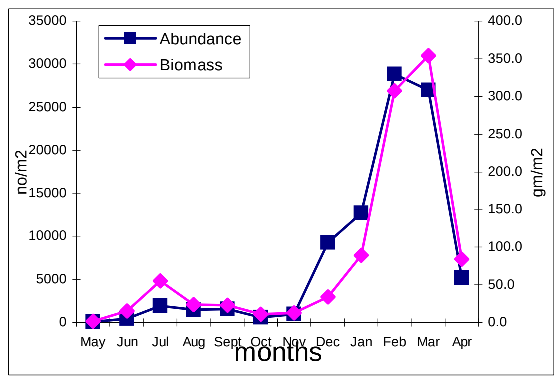


Fig Ma-6b: Monthly variations in the density (no/m2) and biomass (gm/m2) of polychaete *Nereis (Ceratonereis) burmensis*

The other Nereid species namely ***Nereis glandicincta*** (av. 452.36 no/m2 & 4.147 gm/m2) was recorded in August 99, and Feburary to April 2000 only and was restricted in its occurrence from the middle to the lower stretches of the creek (Fig. Ma-7a & b). However Athalye (1988) and Mishra *et al*. (1994) have reported the polychaete in significant number from the shallow region near Thane city i.e. the upper stretches of the creek. It is important to note its total absence from the region and shifting to the downstream stretches. Raman & Ganapati (1983) stated that though *Nereis glandicincta* is a sturdy pollution tolerant species it gets terminated as the stress increases.

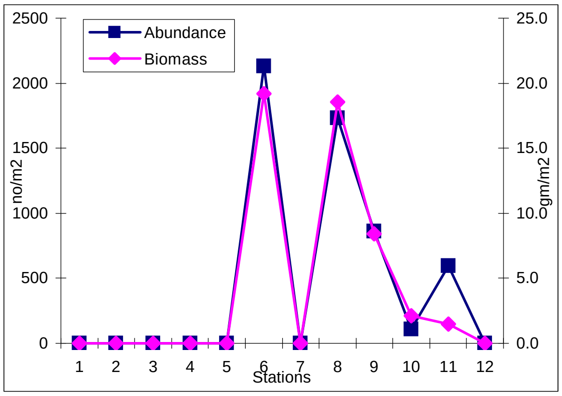


Fig Ma-7a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of polychaete ***Nereis glandicincta*.**

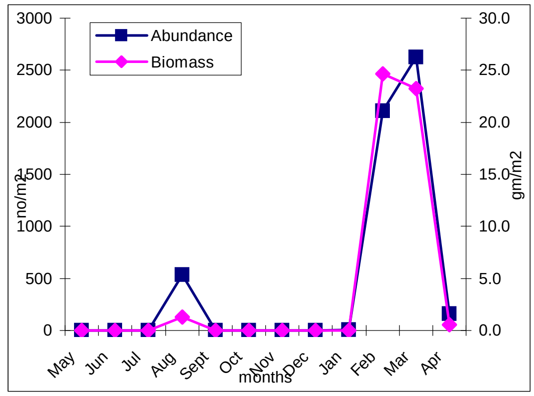


Fig Ma-7b: Monthly variations in the density (no/m2) and biomass (gm/m2) of polychaete *Nereis glandicincta.*

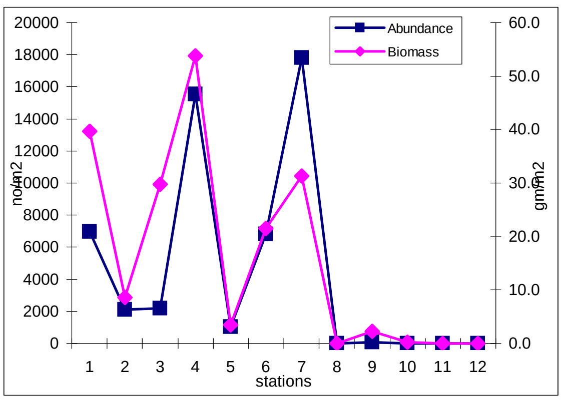


Fig Ma-8a: Stationwise variations in the density (no/m2)and biomass (gm/m2) of polychaete *Lycastis ouanaryensis*

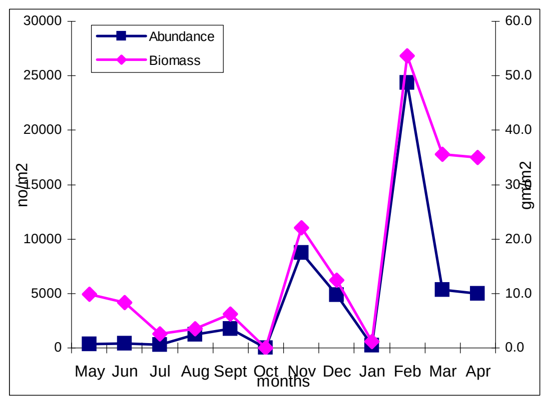


Fig Ma-8b: Monthly variations in the density (no/m2) and biomass (gm/m2) of polychaete ***Lycastis ouanaryensis*.**

Lycastis ouanaryensis (av. 4383.75 no/m2 & 15.88 gm/m2) is another polychaete which according to Athalye (1988) is sturdy and can withstand stress and competition. In the present study this was the 2nd dominant polychaete which occurred almost throughout the creek (Fig 8 a & b). However it preferred the upper stretch of the creek up to station 8 and post monsoon and pre monsoon seasons were favourable for its growth. The polychaete *Lycastis indica* (av. 705.83 no/m2 & 11.70 gm/m2) was also observed (Fig. Ma-9 a & b) and showed similar trend as that of *Lycastis ouanaryensis.* Mukherjee (1993) and Mishra *et al.* (1994) observed a prey-predator relationship between the *Lycastis spp.* and sea anemone in Thane creek. This could probably be the reason for lower density of *Lycastis spp.* in the lower stretches of the creek which had abundance of sea anemones. According to Sunilkumar (1997), *Nereis glandicincta & Dendronereis* *heteropoda* are insensitive to unfavourable conditions due to the presence of strong gills that help them in surviving and increasing their number.

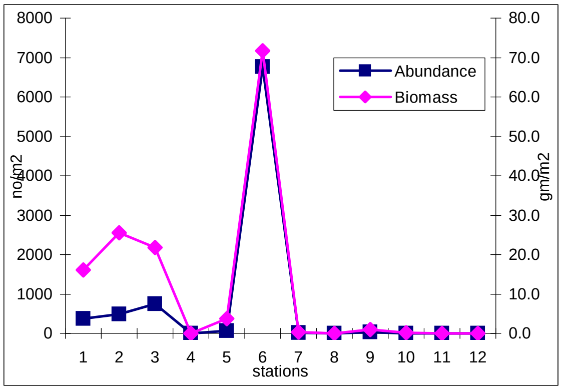


Fig Ma-9a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of polychaete *Lycastis indica.*

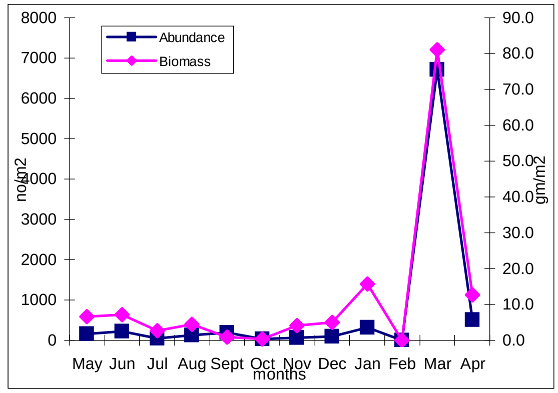
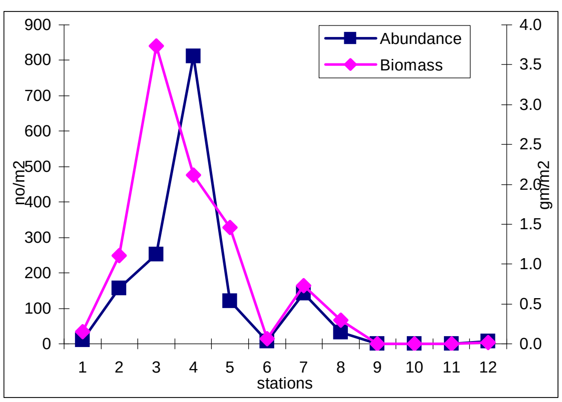


Fig Ma-9b: Monthly variations in the density (no/m2) and biomass (gm/m2) of polychaete *Lycastis indica*

The polychaete *Dendronereis heteropoda* has been reported to occur in Bombay & Thane (Athalye,1988; Mukherji, 1993; Gokhale & Athalye, 1995) with preference to low salinity(Athalye (1988). In the present study this polychaete (av. 128.19 no/m^2 & 0.81 gm/m2) was mostly restricted to the upper stretches of the creek and showed sporadic occurrence in the lower reaches (Fig. Ma- 10a). Small size organisms were observed mainly in pre-monsoon (Fig Ma-10b) which was probably its breeding season. Its lower occurrences in May – June, October, January and April suggest that the polychaete is sensitive to extreme temperatures.



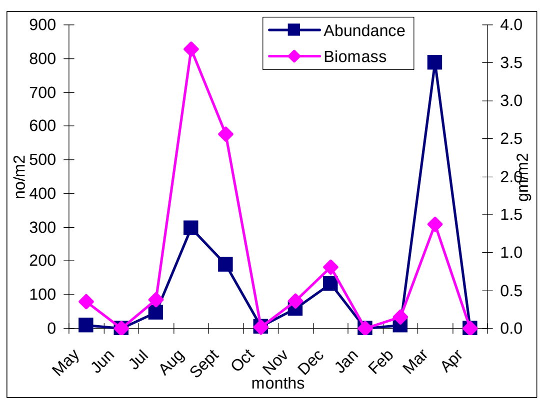


Fig Ma-10a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of polychaete *Dendronereis heteropoda.*

Fig Ma-10b: Monthly variations in the density (no/m2) and biomass (gm/m2) of polychaete *Dendronereis heteropoda*

The euryhaline species namely *Sigambra* and *Polydora* can withstand pollution to some extent (Rizzo & Amaral, 2000). Raman & Ganapati (1983) reported *Polydora ciliata* in the polluted region of Visakhapatnam harbour. In the present study *Polydora tentaculata* (av. 1246.25 no/m2 & 2.767 gm/m2) and *Sigambra bassi* (av. 596.94 no/m2 & 1.783 gm/m2) were observed only from stations 7 to 12. At station 4 *Sigambra bassi* was recorded only in the month of May 1999, when the salinity was high. During 1984 Athalye (1988) had observed *Polydora spp.* in the upper stretches of the creek which in the present study has descended down and restricted itself to the lower stretches of the creek. This means, the pollution in the upper stretches of the creek has grown beyond tolerance of *Polydora spp.* The polychaete *Boccardia tricuspa* (av. 45.97 no/m2 & 0.37 gm/m2) was sporadic in its occurrence and it did not show any definite pattern. Further, the polychaetes *Glycera alba* (av. 0.14 no/m2 & 0.04 gm/m2) and *Capitella capitata* (av. 1.25 no/m2 & 0.002 gm/m2) occurred only once during the entire study. The *Glycera spp.* is carnivores (Frouin, 2000) and its presence can modify the community structure mainly due to predator-prey relationship (Vizakat *et al.*, 1991). In the present study *Glycera alba* occurred only at station 10 during premonsoon. According to Frouin (2000), *Glycera spp.* can dominate in unpolluted and undisturbed sediments. Harkantra &Parulekar (1994) observed decline in the number of *Glycera alba* at Rajapur bay and attributed it to lack of physiological tolerance of the species, which holds true for the present study. Further the polychaete *Capitella capitata* according to Gamenick *et al*. (1998) is known as an indicator for organically polluted and disturbed marine environments. *C.capitata* dominates the macrobenthic community in areas which are highly eutrophicated by paper mills (Pearson & Rosenberg, 1978), fish farming (Tsutsumi, 1987) waste discharge (Chang *et al.*, 1992) or oil spills (Sanders *et al.*,1980). The population density, reproduction and growth rate of *C.capitata* are strongly correlated with the content of organic material (Bridges *et al.*, 1994). Moreover, *Capitella spp.* can substantially improve the physico-chemical properties of polluted sediments by enhancing degradation of hydrocarbons or associated organic contaminants (Gamenick *et al.,* 2000). Dominance of *C. capitata* was reported by Read *et al.*(1983) from the sewage polluted Frith of Froth, UK. Raman & Ganapati (1983) recorded *C. capitata* in the polluted and unpolluted regions of Visakhapatnam harbour but noticed its absence in highly polluted region. In the present study also the polychaete was observed only at station 5 in July 99.

According to Murugan & Ayyakkannu (1991), the distribution and abundance of polychaetes throughout the year may be due to their continuous breeding habits. Mukherjee (1993) observed the short life cycles and continuous breeding habits of polychaetes like *Nereis chingrighatensis, Nereis glandicincta, Lycastis indica, Lycastis merukensis* and *Dendronereis heteropoda*. In the present study the density of polychaetes like *Nereis glandicincta, Nereis (Ceratonereis)burmensis, Lycastis ounaryensis, Lycastis indica, Dendronereis spp. and Sigambra bassi* contained a mixture of juveniles and mature individuals corroborating with Mukherjee's view.

Bivalves

Polychaetes are reported to be the dominant group in Indian estuaries and according to Untawale & Parulekar (1976) are either followed by bivalves or Crustacea. In Thane creek during the present study bivalves (represented by 10 species) formed the second most dominant group. The bivalves showed 59.72 % frequency of annual occurrance with the density and biomass (shell free wet wt.) ranging between 0 to 113220 no/m2 (av. 6862 no/m2) and 0 to 1025.94 gm/m2 (av. 90gm/m2) respectively (Table Ma-4a &b). The bivalves contributed 23.19 % in abundance and 30.70 % in biomass to the total macrofauna.

A stationwise comparison of the abundance and biomass of the total bivalves (Fig. Ma-11a &b) revealed that the bivalves were restricted in their occurrence to the lower reaches of the creek, i.e. from station 6 to 12 and from stations 8 to 12 they form a major component of the total biomass. Parulekar & Dwivedi (1974) observed numerical and biomass superiority of bivalves over other faunal elements in certain pockets of Mandovi estuary. Further, it is important to note the absence or lack of bivalves at the riverine end of the creek. Vijaykumar *et al*. (1991), have also reported abundance of bivalves at the marine end in comparison to the backwaters in Kakinada bay. According to Unnithan *et al.* (1975), in the polluted and marginal zones bivalves are lesser in number than those in the healthy zones. This is because the mollusks mostly have a filter feeding habit & concentrate more pollutants than other animals. Hence in the polluted zones they are not able to tolerate the increase of pollutants beyond a level, and a consequent decrease in number results. This explains the absence of bivalves at the polluted riverine end during the present study. Furthermore, in 1976 Govindan *et al*. have reported the presence of the commercial bivalve *Meretrix ovum* in the riverine end of Thane creek, however in the present investigation the bivalve was not recorded throughout the total stretch of the creek indicating its elimination due to pollution.

The bivalves recorded in the study showed a marked seasonal variation in the creek (Fig Ma-12 a & b) with lower abundance and biomass during the monsoon resulting from land runoff and turbidity affecting their survival. However during the non-monsoon they bred and grew in numbers in the creek.

Table Ma-4a: Station wise variations in the total bivalve density (no/m2).

Months↓	St.1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10	St. 11	St. 12	AVG
May-99	0	0	0	520	0	40	660	3600	420	1780	340	0	613
Jun	0	0	0	3340	0	80	3700	7160	400	1880	400	0	1413
Jul	0	0	0	180	0	260	2480	7740	30480	8900	3580	0	4468
Aug	0	0	0	0	0	300	840	3620	16640	4500	140	0	2170
Sept	0	0	0	200	0	2280	1600	7460	1980	60920	1100	0	6295
Oct	0	0	0	120	0	1900	0	3580	4460	8720	660	0	1620
Nov	0	0	0	0	20	80	20	113220	103680	21540	16200	0	21230
Dec	0	0	0	0	0	11840	0	9060	1720	660	4860	40	2348.33
Jan-00	0	0	20	0	0	21240	320	10920	12780	19340	3520	320	5705
Feb	0	0	20	0	20	10240	28720	31460	47000	14900	2600	40	11250
Mar	0	0	0	11520	0	110700	46100	19220	37820	25620	1860	60	21075
Apr	0	20	0	3200	0	3680	140	13280	16100	11720	1680	0	4151.67
Stn. Avg.→	0	1.667	3.333	1590	3.333	13553.3	7048.33	19193.3	22790	15040	3078.33	38.33	6861.67
Min	0	0	0	0	0	40	0	3580	400	660	140	0	613.333
Max	0	20	20	11520	20	110700	46100	113220	103680	60920	16200	320	21230
SD	0	5.8	7.8	3359.2	7.8	31288.8	14701.8	30660.4	29866.1	16605.7	4395.6	91.2	7267.9

Table Ma-4b: Station wise variations in the total bivalve biomass (gm/m2 shell free wet wt.).

	St.1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10	St. 11	St. 12	AVG
May-99	0	0	0	2.18	0	0.5	7.296	4.54	142.54	164.6	246.9	0	47.38
Jun	0	0	0	7.98	0	0.22	29.16	47.54	120.9	142.88	139.24	0	40.66
Jul	0	0	0	0.26	0	0.34	20.58	13.16	432.08	20.32	302.82	0	65.80
Aug	0	0	0	0	0	0.46	10.06	18.3	363.84	10.76	322.58	0	60.50
Sept	0	0	0	0.34	0	3.22	8.92	30.54	45.72	591.52	367.5	0	87.31
Oct	0	0	0	0.14	0	3.46	0	10.42	202.1	41.2	45.46	0	25.23
Nov	0	0	0	0	0.04	0.4	0.06	195.7	295.58	535.3	657.2	0	140.36
Dec	0	0	0	0	0	20.58	0	87.9	63.88	202.6	593.3	0.22	80.71
Jan-00	0	0	0.06	0	0	5.51	0.46	131.58	140.28	1025.94	375.38	1.1	140.03
Feb	0	0	0.1	0	0.02	11.96	36.4	678.98	292.96	189.6	780.24	0.02	165.86
Mar	0	0	0	10.42	0	16.26	77.7	54.68	122.6	130.4	691.2	0.04	91.94
Apr	0	0.1	0	2.8	0	4.5	1.5	28.3	851.16	203.8	543.34	0	136.29
Avg	0	0.008	0.013	2.01	0.005	5.62	16.01	108.47	256.14	271.58	422.10	0.115	90.17

Min	0	0.000	0.000	0.00	0.000	0.22	0.00	4.54	45.72	10.76	45.46	0.000	25.23
Max	0	0.100	0.100	10.42	0.040	20.58	77.70	678.98	851.16	1025.94	780.24	1.100	165.86
SD	0	0.029	0.032	3.52	0.012	6.92	22.95	188.48	222.82	299.88	229.98	0.316	45.66

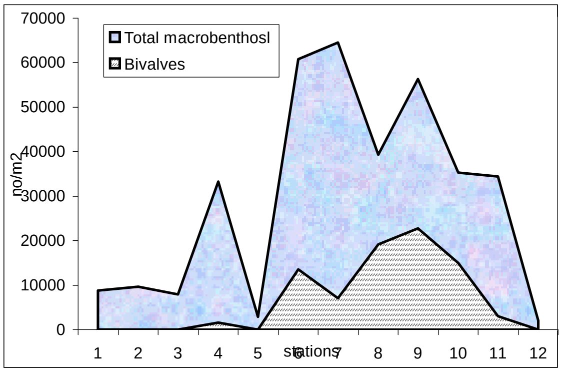


Fig Ma- 11a: Station wise variations in the total macrobenthos and bivalve density (no/m2)

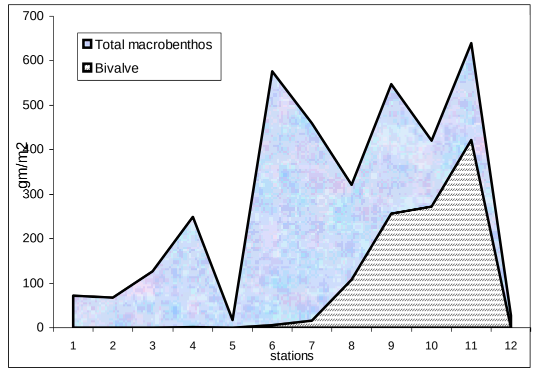


Fig Ma- 11a: Station wise variations in the total macrobenthos and bivalve biomass(gm/m2).

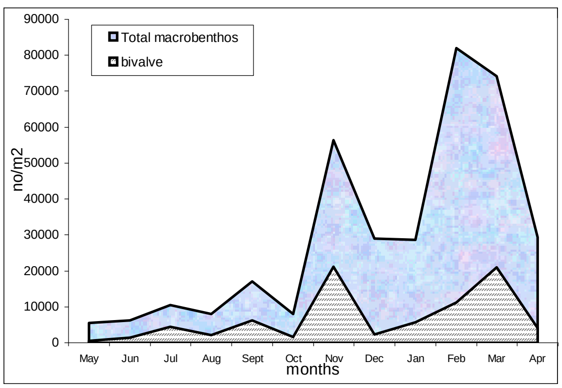


Fig Ma- 12a: Monthly variations in the total macrobenthos and bivalve density (no/m2)

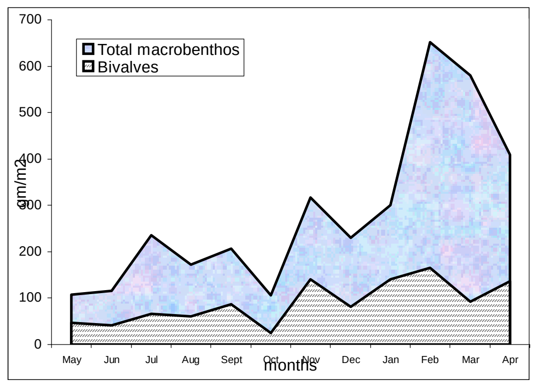


Fig Ma- 12b: Monthly variations in the total macrobenthos and bivalve biomass (gm/m2)

During the present study in Thane creek 10 species of bivalves were recorded occurring in the following decreasing order of abundance. Microbivalve (av. 4948.47no/m2) à *Cuspidaria cochinensis* (av. 733.61 no/m2) à *Glauconome cerea* (av. 533.61 no/m2) à *Brachyodontes karachiensis* (av. 286.53 no/m2) à unidentified bivalve (av. 141.39 no/m2) à *Dosinia pubescens* (av. 94.86 no/m2) à *Katelysia opima* (av. 75.69 no/m2) à *Katelysia marmorata* (av. 23.47 no/m2) à *Cardium asiaticum* (av. 15.28 no/m2) à unidentified razor clam (av. 8.75 no/m2). However when the biomass is considered the order changes to *Cardium asiaticum* (av. 32.53 gm/m2) à *Katelysia opima* (av. 19.86 gm/m2) à *Brachyodontes karachiensis* (av. 9.23 gm/m2) à *Dosinia pubescens* (av. 6.99 gm/m2) à *Katelysia marmorata* (av. 6.45 gm/m2) à Microbivalve (av. 4.56 gm/m2) à

Cuspidaria cochinensis (av. 4.07 gm/m2) à unidentified bivalve (av. 3.31 gm/m2) à *Glauconome cerea* (av. 2.16 gm/m2) à unidentified razor clam (av. 1.01 gm/m2).

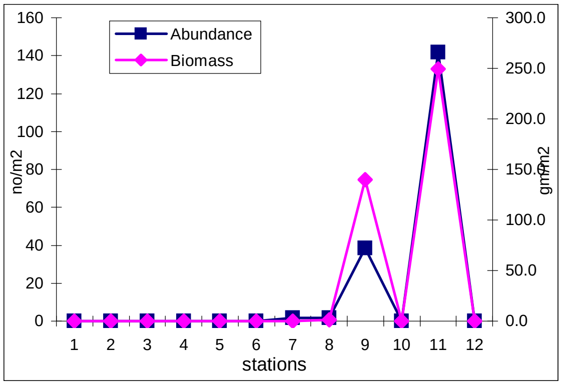


Fig Ma- 13a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of bivalve *Cardium asiaticum.*

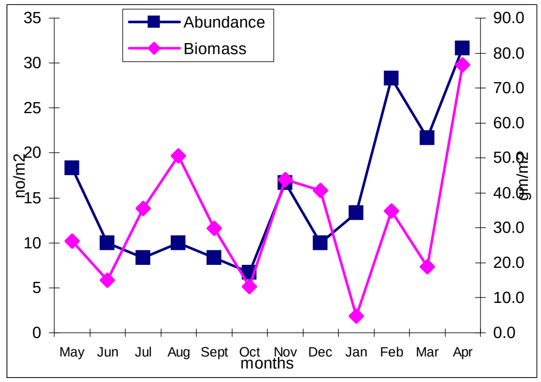


Fig Ma- 13b: Monthly variations in the density (no/m2) and biomass (gm/m2) of bivalve *Cardium asiaticum*

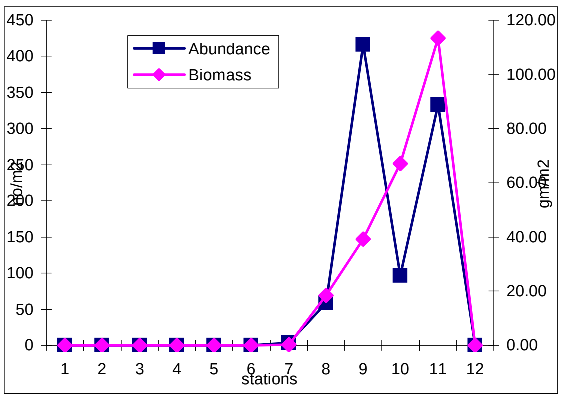


Fig Ma- 14a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of bivalve *Katelysia opima.*

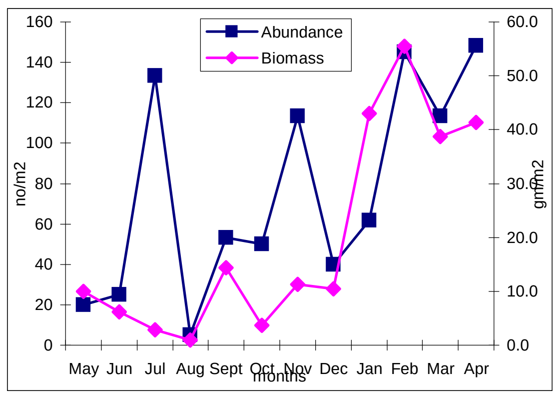


Fig Ma- 14b: Monthly variations in the density (no/m2) and biomass (gm/m2) of bivalve *Katelysia opima.*

The high biomass in the lower stretches of the creek was mainly due to the presence of edible big size bivalves like *Katelysia opima, Katelysia marmorata, Cardium asiaticum* and the inedible *Brachyodontes karachiensis.* The numerically abundant microbivalve had a maximum size of 2 mm and hence failed to influence the biomass. The edible bivalves were present only at stations 8 to 11and their occurrence at these stations can be attributed to the calm conditions (Annie Mathew, 1989) The edible bivalve *Cardium asiaticum* was observed only at station 9 and 11 through out the year (Fig.Ma –13 a & b). During the monsoon period growth was observed in these bivalves, while breeding could be noticed during the premonsoon season i.e. January to April. The other two edible bivalves namely *Katelysia opima* and *K. marmorata* were also observed through out the year at stations 8 to 11. *K. opima* was seen to be breeding from June to December

(Fig.Ma-14b) and showed growth from January to May during the study. *K. marmorata* occurred from station 7 to 12 throughout the year except monsoon (Fig.Ma -15).

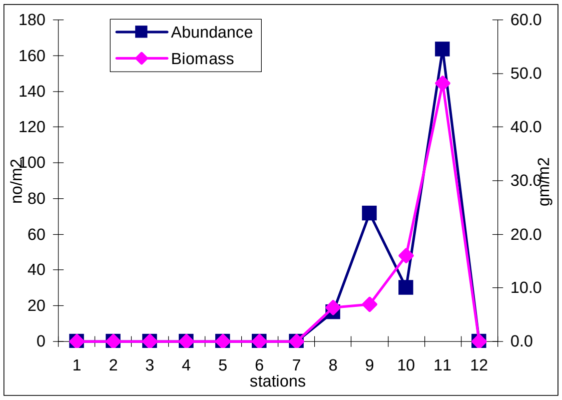


Fig Ma- 15a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of bivalve *Katelysia marmorata.*

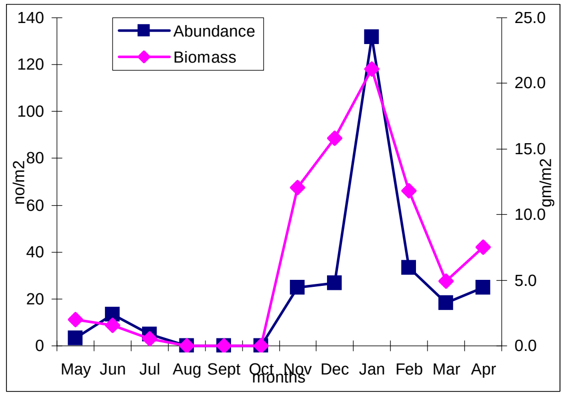


Fig Ma- 15b: Monthly variations in the density (no/m2) and biomass (gm/m2) of bivalve *Katelysia marmorata.*

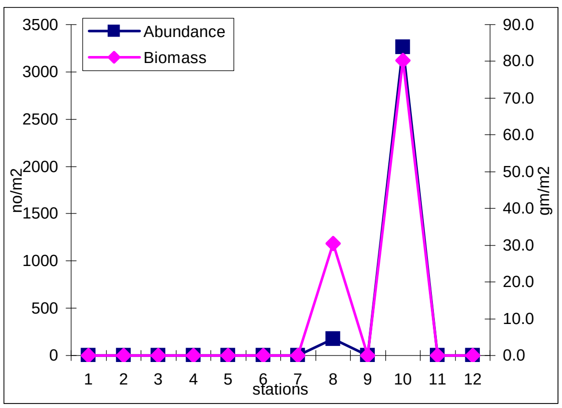


Fig Ma- 16a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of bivalve *Brachyodontes karachiensis.*

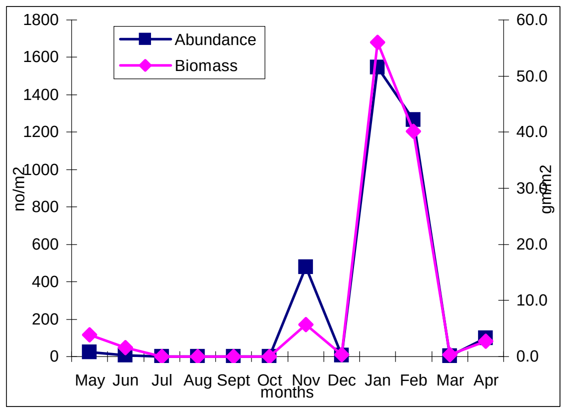


Fig Ma- 16b: Monthly variations in the density (no/m2) and biomass (gm/m2) of bivalve *Brachyodontes karachiensis*

Among the non-edible bivalves restricted to the saline region of the creek, *Brachyodontes karachiensis* was reported only at station 8 and 10 (Fig. Ma-16a). At station 10 mats of this bivalve were observed as it formed a major component of the macrobenthos. These stations have extensive mudflats with a gradual slope, probably favouring the growth of the bivalve, as juveniles were recorded in October, December and March with successive growth of bivalves. However during monsoon these bivalves totally avoided the creek. The bivalve *Dosinia pubesens* was observed during the entire study period (Fig Ma-17 a & b) but was restricted in its occurrence to the stations 8 to 11 only in monsoon probably favoured its breeding. The unidentified bivalve was seen to be dominant during the monsoon indicating its preference to intermediate salinity. While the unidentified razor clam was abundant in the post monsoon season.

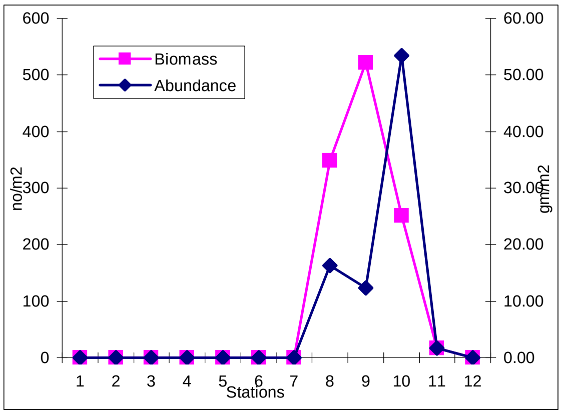


Fig Ma- 17a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of bivalve *Dosinia pubesens*

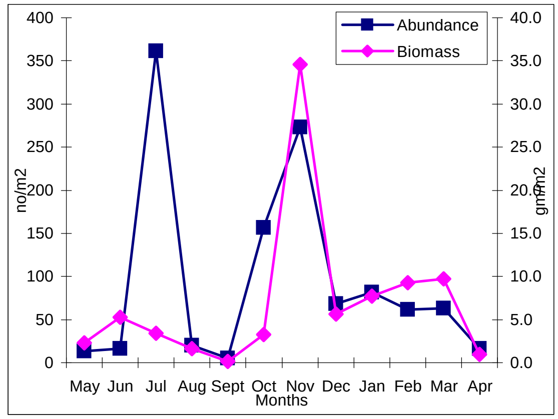


Fig Ma- 17b: Monthly variations in the density (no/m2) and biomass (gm/m2) of bivalve *Dosinia pubesence*

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The remaining bivalves namely *Cuspidaria cochinensis, Glauconome cerea* and microbivalve (Fig Plates given at the end of the text) were observed almost throughout the creek and throughout the study period. The abundance and biomass of these bivalves showed wide fluctuations with time and space but they remained concentrated mainly to the lower stretches of the creek. The overall abundance of bivalves at the seaward region of the creek can be attributed to the large water mass and topography favourable for their settlement and proliferation. As according to Frechette & Bourgett (1985), increased exposure to wave action results in increased food availability and feeding time for suspension feeders, which demonstrate higher growth potential.

Gastropods

The gastropods followed polychaetes and bivalves in abundance and biomass during the present study in Thane creek and showed the maximum frequency of 97.22 %. The total gastropod density and biomass (shell free wet wt.) varied between 0 to 139200 no/m2 (av. 6558 no/m2) and 0 to 541.4 gm/m2 (av. 66 gm/m2) respectively (Table Ma- 5a & b). Annie Mathew (1989) attributed the high abundance and biomass of gastropods to the slow currents and sluggish circulation in Thane creek. A stationwise comparison revealed dominance of gastropods from stations 6 to 12 with high values at stations 9 & 11. This difference can be attributed to the concentration of pollutants in the narrow and shallow upper stretches of the creek which get comparatively diluted in the lower marine stretch of the creek. Harkantra & Parulekar (1974) observed numerical superiority of molluscan faunal elements in the Mandovi estuary; out numbering the other faunal groups. In Thane creek a similar feature was noticed in the lower stretches of the creek as earlier studies by Govindan *et al* (1976), Varshney (1982), Annie Mathew (1989) have reported mollusk to be a major contributor towards biomass in Thane creek corroborating with the present study. The month wise comparison (Fig.Ma –18 a &b) indicated that the gastropods reduced in number during the monsoon while the density increased during the postmonsoon and premonsoon. Breeding was also noticed during the monsoon as mature gastropods were recorded during that period, with abundance of juveniles during the post monsoon and premonsoon.

Table Ma -5a: Stationwise variations in the total gastropod density (no/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	320	1000	140	320	500	360	1040	180	2500	32820	8120	40	3945
Jun	180	520	220	240	80	180	9840	4620	6040	7260	1100	140	2535
Jul	60	180	40	60	120	1520	3280	2320	17000	2620	3960	160	2610
Aug	760	780	60	240	120	580	1780	2300	4900	780	4680	240	1435
Sept	340	320	100	400	100	4340	2520	2460	10580	24360	2540	460	4043
Oct	2660	200	100	260	80	1000	880	1840	46740	1320	5520	280	5073
Nov	240	140	40	20	100	600	180	4360	79020	50560	139200	680	22928
Dec	20	160	40	0	80	2780	1540	7460	16840	13480	46740	20	7430
Jan-00	20	280	80	0	0	600	800	7460	36220	19580	8500	120	6138
Feb	2400	40	440	20	20	1440	10740	37660	41260	4220	8200	80	8877
Mar	340	100	240	320	0	4140	280	6660	17900	19460	15760	900	5508
Apr	380	80	2340	60	60	1400	12540	17080	22680	6600	34100	760	8173
Stn. Avg.→	643	317	320	162	105	1578	3785	7867	25140	15255	23202	323	6558
Min	20	40	40	0	0	180	180	180	2500	780	1100	20	1435
Max	2660	1000	2340	400	500	4340	12540	37660	79020	50560	139200	900	22928
SD	905	300	647	148	131	1426	4500	10373	22248	15080	39073	303	5652

Table Ma –5b: Stationwise variations in the total gastropod biomass (gm/m2 shell free wet wt.).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	0.64	26.9	1.4	27.46	4.49	41.82	32.46	80.54	84.78	93.52	80.26	0.2	39.54
Jun	0.52	4.06	1.46	30.36	0.24	24.34	53.72	85.22	96.04	63.38	73.52	0.876	36.14
Jul	0.1	4.04	0.4	8.86	0.2	186.3	130.72	85.88	118.3	49.86	541.4	1.1	93.93
Aug	2.86	5	0.82	0.32	1.92	109.66	38.9	94.18	215.8	65.94	237.62	13.58	65.55
Sept	1.9	6.66	1.4	0.46	1.5	88.58	124.2	85.12	221.8	47.1	187.06	2.94	64.06
Oct	9.32	5.2	0.6	0.4	1.42	8.55	77.22	95.62	252.42	43.82	253.312	2.14	62.50
Nov	3.34	15.3	0.22	0.32	0.4	170.26	38.2	76.9	506.22	151.34	311.1	3.66	106.44
Dec	0.06	2.74	4	0	0.5	118.08	235.2	61.82	217.1	21.5	266.88	0.44	77.36
Jan-00	0.12	37.1	0.2	0	0	77.4	76.48	38.84	170.78	17.38	73.2	0.4	40.99
Feb	3.26	0.86	4.98	4.3	0.28	58.06	164.56	168.26	187.96	14.14	52.7	3.9	55.27
Mar	5.6	0.6	2.08	1.6	0	109.3	75.3	63.2	158.08	66.8	35.88	54.58	47.75
Apr	5.44	2.8	11.28	47.1	0.4	31.74	517.22	68.7	322.8	30.3	169.44	29.88	103.09
Stn. Avg.→	2.76	9.27	2.40	10.10	0.95	85.34	130.35	83.69	212.67	55.42	190.20	9.47	66.05
Min	0.06	0.6	0.2	0	0	8.55	32.46	38.84	84.78	14.14	35.88	0.2	36.14
Max	9.32	37.1	11.28	47.1	4.49	186.3	517.22	168.26	506.22	151.34	541.4	54.58	106.44

SD	2.87	11.47	3.17	15.87	1.28	56.28	135.83	31.05	114.50	38.28	145.42	16.58	24.50

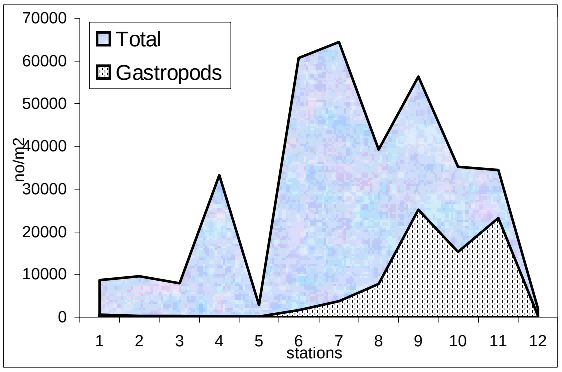


Fig. Ma.-18a: Stationwise variations in the total gastropod density (no/m2).

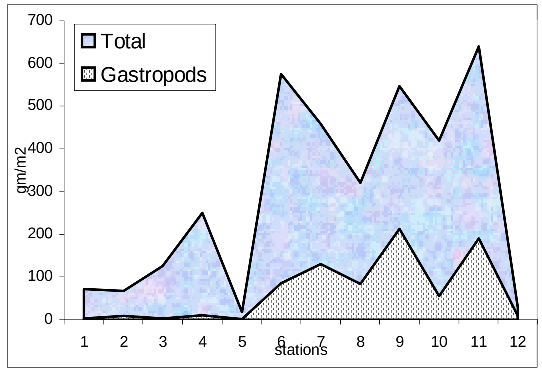


Fig. Ma.-18b: Stationwise variations in the total gastropod biomass (gm/m2).

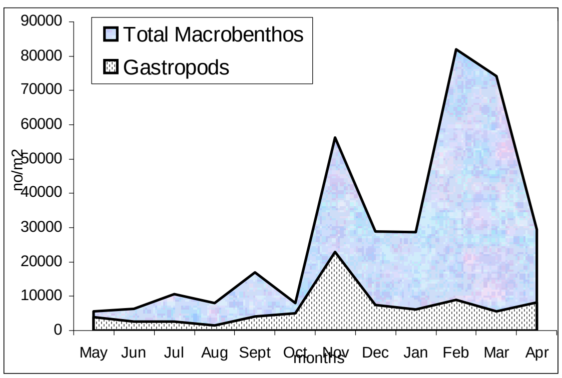


Fig. Ma.-19a: Monthly variations in the total gastropod density (no/m2).

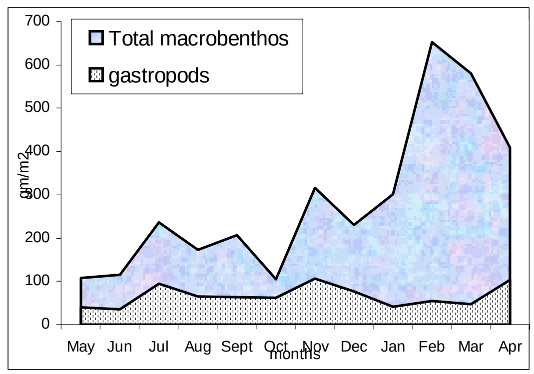


Fig. Ma.-19b: Monthly variations in the total gastropod biomass (gm/m2).

Govindan *et al.* (1976), observed uneven distribution of gastropods in Thane creek while Mukherji (1993) reported the gastropods to be opportunistic, making erratic appearance only under favourable conditions. During the present study a total of 24 gastropod species were recorded (Table Ma-2a &b). However only 6 species were dominant in terms of abundance viz., *Stenothyra deltae* (av. 3256 no/m2 & 5.234gm/m2), *Littorina vernuculatum* (av.1221no/m2 & 1.321gm/m2), *Stenothyra minima* (av. 1059.58 no/m2 & 1.748 gm/m2), *Assiminea brevicula* (av. 567.6no/m2 & 1.35 gm/m2), *Cerethidea cingulata* (av.166.53 no/m2 & 47.68 gm/m2) and *Thiara spp.* (av. 90.69 no/m2 & 0.08 gm/m2) of these only 3 species were observed throughout the creek i.e., *Stenothyra deltae, Stenothyra minima* and *Assiminea breviculla.* The gastropods that significantly contributed to the biomass were *Cerethidea cingulata, Stenothyra deltae*, *Nassarius oronatus* (av. 23.47 no/m2 & 2.597gm/m2), *S. minima*, *Hamminea crocata* (av. 11.67 no/m2 & 1.7 gm/m2) and *Assiminea brevicula* (Fig. Plates given at the end of the text.). Kashinath and Shanmugam (1985) while studying the molluscan fauna of Pitchavaram mangroves observed the abundance and distribution of gastropods to be controlled by the environmental conditions, In the present study *Cerethidea cingulata* showed marked environmental influence. This gastropod was obtained from mudflats with soft sediment and flourished in regions that were located away from the polluting source. Athalye (1988) had reported the same gastropod as *Cerethideopsilla djadjaviaensis*, according to him the gastropod has burrowing habit and is absent in anoxic mudflats hence he described it a pollution indicator. Govindan & Natrajan (1972) ascribed *Dostia violaceae* as a marine gastropod that was well acclimatized for wide salinity range. In the present study most of the gastropods including *Dostia violaceae* were observed to show fluctuations with salinity. However *Auricula spp., Mitra amphorel, Nassarius oronatus & Nassarius spp.* were limited by the salinity gradient, as the *Auricula spp.* was recorded only at the riverine end and the other 3 were restricted to the higher saline lower stations. Radhakrishna & Janakiram, (1975) have reported the gastropods *Assiminea brevicula & Melampus singaporensis* to prefer drier situations and grow abundant towards the land. However in Thane creek *A. brevicula* was observed throughout the creek and grew abundantly even on the soft sediment. But *Melampus singaporensis* and *M. ceylonicus* were restricted to the stations which had small mudflats and proximity to the mangrove vegetation.

Insects Larvae

Table Ma- 6a: Stationwise variations in the total insect larval density (no/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	0	0	40	0	360	20	60	0	0	0	0	440	77
Jun	20	600	240	0	20	20	20	0	0	0	0	20	78
Jul	0	80	60	0	0	160	180	0	0	0	60	20	47
Aug	100	0	40	40	260	100	0	0	0	0	0	120	55
Sept	60	300	0	40	0	40	0	0	0	0	0	840	107
Oct	0	60	80	60	0	60	20	0	0	0	0	100	32
Nov	0	60	260	20	280	60	0	80	0	0	0	4360	427
Dec	200	6360	400	40	40	0	60	0	0	0	0	720	652
Jan-00	40	14260	440	0	400	0	0	0	0	0	0	20	1263
Feb	1440	40	100	0	60	0	0	0	20	0	0	40	142
Mar	260	6880	1280	0	80	5120	1280	0	0	0	0	1160	1338
Apr	160	14340	700	0	380	320	3520	0	0	0	0	900	1693
Stn. Avg.→	190	3582	303	17	157	492	428	7	2	0	5	728	493

Min	0	0	0	0	0	0	0	0	0	0	0	20	31.7
Max	1440	14340	1280	60	400	5120	3520	80	20	0	60	4360	1693.3
SD	403	5586	372	22	164	1460	1039	23	6	0	17	1215	603

Table Ma- 6b: Stationwise variations in the total insect larval biomass (gm/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	0	0	0.1	0	2.98	0.2	0.4	0	0	0	0	1.74	0.452
Jun	0.06	3.6	1.8	0	0.04	0.14	0.2	0	0	0	0	0.04	0.490
Jul	0	0.84	0.3	0	0	1.98	0.4	0	0	0	0.2	1.6	0.443
Aug	0.3	0	0.12	0.56	1.52	0.92	0	0	0	0	0	0.2	0.302
Sept	0.6	8.7	0	0.36	0	0.3	0	0	0	0	0	2.2	1.013
Oct	0	3.24	0.32	0.5	0	0.3	0.1	0	0	0	0	0.14	0.383
Nov	0	4.04	1.74	0.44	2.3	0.7	0	0.3	0	0	0	18.7	2.352
Dec	1.6	13.2	3.8	1.46	0.16	0	0.86	0	0	0	0	3.14	2.018
Jan-00	0.3	2.28	4.2	0	1.6	0	0	0	0	0	0	0.8	0.765
Feb	5.6	0.7	1.06	0	0.2	0	0	0	0.1	0	0	0.2	0.655
Mar	1.5	24.3	3.02	0	0.04	25.6	2.56	0	0	0	0	4.3	5.110
Apr	0.8	31	2.24	0	0.7	3	8.2	0	0	0	0	1.6	3.962
Stn. Avg.→	0.90	7.66	1.56	0.28	0.80	2.76	1.06	0.03	0.01	0.00	0.02	2.89	1.50
Min	0	0	0	0	0	0	0	0	0	0	0	0.04	0.302
Max	5.6	31	4.2	1.46	2.98	25.6	8.2	0.3	0.1	0	0.2	18.7	5.11
SD	1.59	10.20	1.50	0.44	1.05	7.25	2.36	0.09	0.03	0.00	0.06	5.15	1.58

The insect larvae was the next most numerically abundant faunal group with a frequency of 51.39 % a total of 4 different types of larvae (unidentified) were recorded. The density and biomass ranged from 0 to 14340 no/m2 (av. 493 no/m2) and 0 to 31 gm/m2 (av. 1.50 gm/m2) (Table Ma-6a &b). All the larvae were observed throughout the creek and year but were dominant during the dry season (Fig.Ma-20a & b). The larvae were abundant at stations 1 to 7 & 12 and could withstand pollution stress& human influence, hence probably proliferated at these stations. Among the 4 larvae, a maggot type larva showed extreme tolerance as it survived for 15 days in 10 % formalin solution.

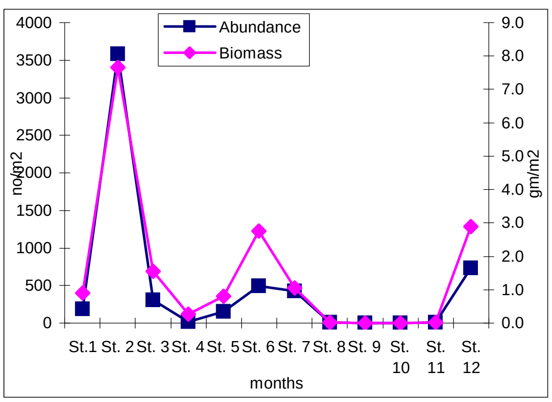


Fig. Ma.-20a: Stationwise variations in the total insect larval density (no/m2).

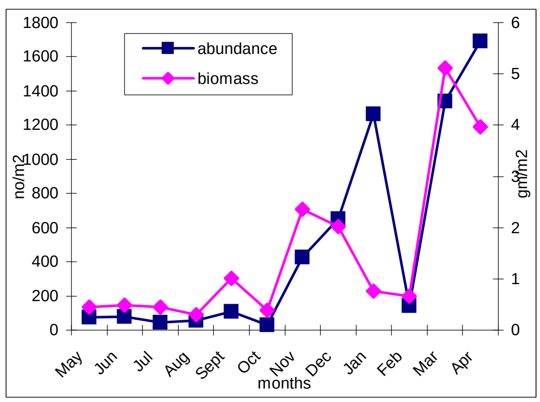


Fig. Ma.-20b: Monthly variations in the total insect larval biomass (gm/m2).

Oligochaetes

Oligochaetes is another faunal group that can tolerate anoxic conditions and prefer sewage polluted locations (Subbarao & Venkateshwara Rao, 1980) and are commonly used as indicators of organic pollution (Pearson & Rosenberg, 1978). Oligochaetes showed 15.28 % frequency of occurrence in Thane creek with the density and biomass varying between 0 to 12800 no/m2 (av. 338 no/m2) and 0 to 19.04 gm/m2 (av. 0.411 gm/m2) respectively (Table Ma- 7a & b). The oligochaetes were predominant during monsoon at stations 1 to 5. According to Srivastava (1962) presence of oligochaetes is an indication of gross pollution. Parker (1980) while studying the effect of pollution upon the benthos of Belfast Lough observed the polychaetes *Nereis spp. Polydora ciliata* and *Capitella capitata* at an anaerobic and anthropogenically disturbed site. In Thane creek during the present study all the 3 genera of polychaetes were recorded along with the oilgochaetes.

Fig Ma-7a: Stationwise variations in the oligochaete density (no/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	0	0	100	160	0	0	0	0	0	0	0	0	21.7
Jun	0	480	140	80	0	0	0	0	0	0	0	0	58.3
Jul	60	3200	0	0	0	0	0	0	0	0	0	0	271.7
Aug	200	2500	0	160	2000	0	200	0	0	0	0	0	421.7
Sept	100	5760	0	80	1120	0	0	0	560	0	0	0	635.0
Oct	0	0	0	80	0	0	0	0	0	0	0	0	6.7
Nov	0	0	0	0	40	0	0	0	0	0	0	0	3.3
Dec	0	0	0	11520	0	0	0	0	0	0	0	0	960.0
Jan-00	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Mar	0	7280	0	0	0	0	0	0	0	0	0	0	606.7
Apr	0	12800	0	0	0	0	0	0	0	0	0	0	1066.7
Stn. Avg.→	30	2668	20	1007	263	0	17	0	47	0	0	0	337.6
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	200	12800	140	11520	2000	0	200	0	560	0	0	0	1067
SD	62	4060	47	3311	634	0	58	0	162	0	0	0	395

Fig Ma-7b: Stationwise variations in the oligochaete biomass (gm/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	0	0	0.2	0.2	0	0	0	0	0	0	0	0	0.03
Jun	0	0.2	0.4	0.06	0	0	0	0	0	0	0	0	0.06
Jul	0.04	1.2	0	0	0	0	0	0	0	0	0	0	0.10
Aug	0.2	2.7	0	0.24	2.42	0	0.4	0	0	0	0	0	0.50
Sept	0.2	6.3	0	0.04	2.08	0	0	0	0.6	0	0	0	0.77
Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.01
Nov	0	0	0	0	0.1	0	0	0	0	0	0	0	0.01
Dec	0	0	0	19.04	0	0	0	0	0	0	0	0	1.59
Jan-00	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Mar	0	9.6	0	0	0	0	0	0	0	0	0	0	0.80
Apr	0	12.8	0	0	0	0	0	0	0	0	0	0	1.07
Stn. Avg.→	0.04	2.73	0.05	1.64	0.38	0.00	0.03	0.00	0.05	0.00	0.00	0.00	0.41
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	0.2	12.8	0.4	19.04	2.42	0	0.4	0	0.6	0	0	0	1.587
SD	0	4	0	5	1	0	0	0	0	0	0	0	1

Crustaceans

The crustaceans consisting of Brachyuran crab, *Illyoplax gangetica*, *Uca spp.* Anumoran Hermit crab; shrimp and the gammarid amphipod formed the next numerically abundant group showing a frequency of occurrence 61.11 %. The crustacean density and biomass varied from 0 to 1440 no/m2 (av. 145 no/m2) and 0 to 97 gm/m2 (av. 7.54 gm/m2) respectively (Table Ma 8a &b). The crustacean fauna showed wide annual fluctuations but recorded a peak in November 99 and March 2000 which were due to the crab population. According to Frusher *et al*. (1994) crabs are the dominant macrofaunal group within the tropical and tidal forest, in terms of both numbers and biomass. Within the Indo-Pacific mangrove forest over 40 species of crabs are found. Deshmukh (1990) reported 13 species of crabs from the Thane creek mangroves. However during the present investigation only 2 species of Brachyuran crabs and the Hermit crab were observed. Of the two brachyuran crabs *Illyoplax gangetica* (av. 142.08 no/m2 & 5.692 gm/m2) was the most dominant crustacean on the mudflats of Thane creek occurring at all sampling stations except station 9 & 11 where the mudflats were of sinking type (Fig Ma-21a). Borgaonkar (1988) while studying *Illyoplax gangetica* from Thane creek emphasised the importance of fine sand in distribution of the crab. However during the study the % of fine sand was negligible compared to silt. Probably the crabs have now adapted to the silty substratum. The crabs showed low density at stations 4, 5 & 7, probably due to prevalent pollution at these stations. Inspite of wide fluctuations in stationwise abundance, the crab in general showed decreasing trend towards station 12, thus showing its preference to brackish water or more sheltered mudflats away from the open sea. The monthly variations (Fig. Ma-21b) showed decline in the crab population during monsoon followed by increase up to premonsoon. Young crabs were observed mainly from November to January & March. The fiddler crab *Uca spp.* though was observed through out the creek, was collected from the intertidal mudflats only once at station 4. This crab is known to prefer hard sandy substratum (Chakraborty & Choudhury, 1985) may have accidently ventured onto the mudflats where it got trapped in the soft substratum.

Table Ma- 8a: Stationwise variations in the total crustacean density (no/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	0	0	0	20	40	120	0	80	0	0	0	0	21.7
Jun	140	160	100	20	0	40	0	40	0	0	0	20	43.3
Jul	100	40	120	40	0	980	0	40	0	20	0	20	113.3
Aug	0	160	0	20	0	820	20	140	0	0	0	40	100.0
Sept	300	60	0	0	20	240	0	20	0	20	0	160	68.3
Oct	120	80	100	0	0	120	0	20	0	0	0	80	43.3
Nov	100	640	1100	0	0	40	20	620	0	500	0	40	255.0
Dec	360	760	880	60	20	20	20	640	0	0	60	40	238.3
Jan-00	320	500	1440	0	0	160	0	20	0	60	0	20	210.0
Feb	320	140	360	60	0	140	0	120	40	0	0	0	98.3
Mar	1040	80	840	0	0	220	700	960	0	100	0	20	330.0
Apr	20	180	1360	20	40	560	160	220	0	20	0	60	220.0
Stn. Avg.→	235	233	525	20	10	288	77	243	3	60	5	41.6667	145.14
Min	0	0	0	0	0	20	0	20	0	0	0	0	21.67
Max	1040	760	1440	60	40	980	700	960	40	500	60	160	330
SD	285.7	253.2	561.6	22.6	16.0	320.8	201.4	316.0	11.5	141.9	17.3	43.9	100.8

Table Ma- 8b: Stationwise variations in the total crustacean biomass (gm/m2).

Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	0	0	0	2.4	0.26	5.04	0	1.62	0	0	0	0	0.78
Jun	4.5	12.6	9.52	2.18	0	0.4	0	14.02	0	0	0	0.06	3.61
Jul	2	2.6	15.4	1.8	0	29.96	0	43.7	0	0.6	0	0.1	8.01
Aug	0	9.5	0	2.72	0	34.38	3.8	51.6	0	0	0	1.8	8.65
Sept	10.8	1.5	0	0	2.2	3.7	0	0.2	0	3.6	0	11.8	2.82
Oct	7.8	9.22	6.6	0	0	2.26	0	0.12	0	0	0	25.2	4.27
Nov	10.9	10.3	15.52	0	0	0.9	42.1	67.8	0	12.3	0	2.5	13.53
Dec	11	36.24	30.9	0.96	0.4	0.18	0.3	13.76	0	0	22.8	1.1	9.80
Jan-00	20.3	19.8	52.6	0	0	2.24	0	0.76	0	0.7	0	0.8	8.10
Feb	27.6	18	19.3	5.3	0	9.7	0	6.4	16.6	0	0	0	8.58
Mar	21.4	3.8	75.5	0	0	5.1	1.6	0.6	0	0.8	0	0.6	9.12
Apr	0.8	9.6	97	1.4	8.4	27.5	9.8	3	0	0.3	0	1.24	13.25
Stn. Avg.→	9.76	11.10	26.86	1.40	0.94	10.11	4.8	16.97	1.38	1.53	1.9	3.77	7.54
Min	0	0	0	0	0	0.18	0	0.12	0	0	0	0	0.78
Max	27.6	36.24	97	5.3	8.4	34.38	42.1	67.8	16.6	12.3	22.8	25.2	13.53
SD	9.20	10.03	31.85	1.62	2.43	12.72	12.09	23.65	4.79	3.54	6.58	7.49	3.97

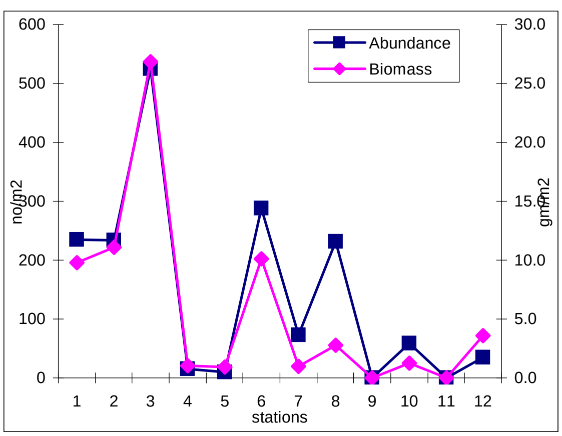


Fig. Ma.-21a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of the crab *Illyoplax gangetica.*

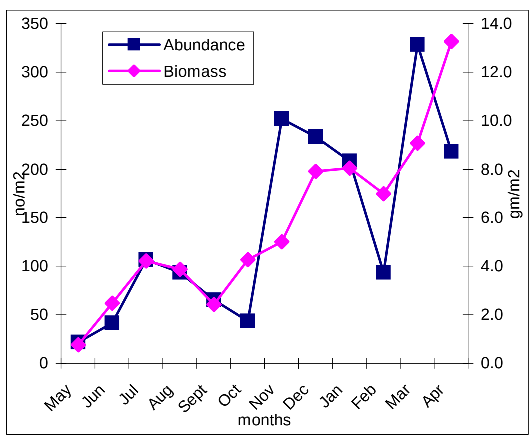


Fig. Ma.-21b: Monthly variations in the density (no/m2) and biomass (gm/m2) of the crab *Illyoplax gangetica.*

The anumoran hermit crab is also known to occur on hard substratum (Bertness, 1981a), was recorded only at station 8 and 10 where the mudflat was much compact & firm than the remaining creek. Further according to Bertness (1981), hermit crabs are predators, and though the food was in abundance in Thane creek, the hermit crab (av. 1.94 no/m2 & 1.78 gm/m2) was not recorded throughout the year and made its appearance sporadically. The other crustaceans viz., shrimps and gammarus were rare in their occurance and mostly restricted to the higher salinity region. Thus significant occurance of only one crab species and sporadic occurance of the other crustaceans in Thane creek can be attributed to the pollution load in the creek. According to Unnithan *et al.* (1975), crustaceans being heterotrophs in feeding habits, consume the polluted detritus available resulting in accelerated growth rate. However, accumulation of pollutants beyond the tolerance level affects the survival of the species and consequent reduction in the total number, which can be held true for Thane creek also.

Sea anemones

Table Ma-9a: Stationwise variations in the total sea anemone density (no/m2)

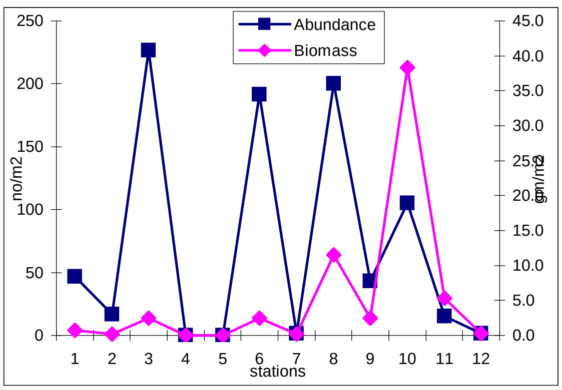
Months↓	Stn.1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7	Stn. 8	Stn. 9	Stn. 10	Stn. 11	Stn. 12	Average
May-99	40	0	0	0	0	100	0	0	20	20	0	0	15
Jun	80	140	1180	0	0	80	0	120	60	40	20	0	143
Jul	0	60	640	0	0	220	0	160	40	60	80	0	105
Aug	0	0	0	0	0	0	0	0	100	0	20	0	10
Sept	0	0	0	0	0	140	0	0	20	40	0	0	17
Oct	0	0	0	0	0	0	0	0	0	40	0	0	3
Nov	0	0	460	0	0	0	0	160	0	360	0	0	82
Dec	0	0	60	0	0	0	0	60	0	20	0	0	12
Jan-00	0	0	240	0	0	320	0	0	220	20	0	20	68
Feb	0	0	140	0	0	0	20	280	0	160	40	0	53
Mar	440	0	0	0	0	780	0	740	0	440	0	0	200
Apr	0	0	0	0	0	660	0	880	60	60	20	0	140
Stn. Avg.→	47	17	227	0	0	192	2	200	43	105	15	2	71
Min	0	0	0	0	0	0	0	0	0	0	0	0	3
Max	440	140	1180	0	0	780	20	880	220	440	80	20	200
SD	126	42	367	0	0	268	6	300	64	145	24	6	65

Table Ma-9b: Stationwise variations in the total sea anemone biomass (gm/m2)

	St.1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10	St. 11	St. 12	AVG
May-99	0.4	0	0	0	0	0.34	0	0	0.3	1.12	0	0	0.18
Jun	1.24	2	15.34	0	0	0.7	0	3.78	1.74	0.98	0.36	0	2.18
Jul	0	0.36	3.1	0	0	3.9	0	0.88	8.2	0.4	40.7	0	4.80
Aug	0	0	0	0	0	0	0	0	1.06	0	0.6	0	0.14
Sept	0	0	0	0	0	2.1	0	0	0.6	150.5	0	0	12.77
Oct	0	0	0	0	0	0	0	0	0	3.48	0	0	0.29
Nov	0	0	2	0	0	0	0	1.2	0	105.26	0	0	9.04
Dec	0	0	0.82	0	0	0	0	1.86	0	0.8	0	0	0.29
Jan-00	0	0	5.9	0	0	3.96	0	0	5.96	0.1	0	3.8	1.64
Feb	0	0	2.72	0	0	0	1.9	56.3	0	171.9	21.2	0	21.17
Mar	6.6	0	0	0	0	7.7	0	51.42	0	23.7	0	0	7.45
Apr	0	0	0	0	0	11.1	0	23.1	12.1	1.46	0.3	0	4.01

Avg	0.69	0.20	2.49	0	0	2.48	0.16	11.55	2.50	38.31	5.26	0.32	5.33
Min	0	0	0	0	0	0	0	0	0	0	0	0	0.14
Max	6.6	2	15.34	0	0	11.1	1.9	56.3	12.1	171.9	40.7	3.8	21.17
SD	1.90	0.58	4.45	0	0	3.62	0.55	20.82	4.03	64.84	12.70	1.10	6.43

The coelentrate group comprising the carnivorous sea anemones followed the crustaceans in numerical abundance showing 34.72 % frequency of occurrance. In all 11 species of sea anemones were recorded during the study of which 6 species were identified and 5 are pending identification. The 6 identified species include *Stephensonactis ornate* Panikkar, *Phytocoetes gangeticus, Pelocoetes exul, Pelocoetes spp., Edwardsia athalyei,* England, and Cerianthid spp. The sea anemones were recorded throughout the study period, but were totally absent at stations 4 & 5. This can be attributed to the excessive pollution load at these stations. The overall density and biomass of the sea anemones varied from 0 to 1180 no/m2 (av. 71 no/m2) and 0 to 171.9 gm/m2 (av. 5 gm/m2) (Table Ma-9a & b). The high biomass can be attributed to the cerianthid spp. that occurred at stations 8, 10 & 11. in Feburary 2000. Stationwise distribution (Fig. Ma-22a) of the anemones was not uniform. High abundance of small anemones was observed on riverine end at stations 1, 3 & 6. whereas in the lower stretches larger anemones were dominant. Month wise trend (Fig. Ma-22 b) showed fluctuations throughout the year.



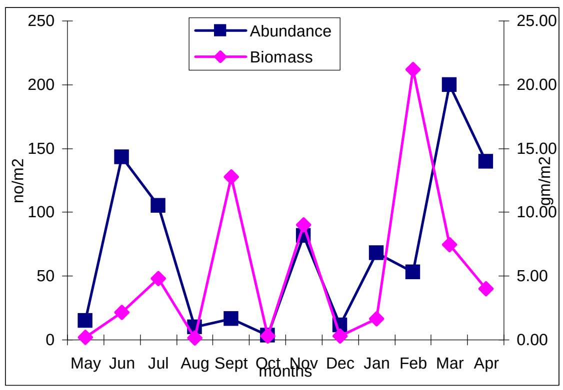


Fig. Ma.-22a: Stationwise variations in the density (no/m2) and biomass (gm/m2) of the Sea anemones.

Fig. Ma.-22b: Monthly variations in the density (no/m2) and biomass (gm/m2) of the Sea anemones.

Others

The other faunal elements that contributed to the macrofauna of the study region were tube polychaetes (av.38.75 no/m2 & 0.599 gm/m2) , 2 species of planaria (av. 2.64 no/m2 & .024 gm/m2), *Balanus amphitrite* (av. 7.78 no/m2 & 0.2 gm/m2), and other arthropods (av. 0.14 no/m2 & 0.0003 gm/m2). *Balanus amphitrite* showed a unique commensalism with gastropods like *Nereita (Dostia) violaceae*, *Cerethidea (Cerethideopsis) cingulata* and *Mitra amphorell.* Similar observations for *Balanus amphitrite* and *Dostia violaceae* were made by Athalye (1988) from the shallow region of Thane creek near Thane city. The other arthropods comprised of *Lethoceros spp.*, ant, stick insect, Beetle, 2 unidentified insects and an unidentified arthropod worm. These faunal components were sporadic & rare in their occurrence.

The distribution of species inhabiting estuaries is primarily determined by their responses to the highly variable physical and chemical environment indicative of the system (Attrill & Power, 2000). While most research effort has concentrated on physiological and behavioral responses to tidal fluctuations in environmental variables (particularly salinity), the ultimate spatial extent of organism distribution within estuaries is determined by the degree of freshwater entering from major tributaries coupled with the physiological tolerance to low salinity conditions (Remane & Schlieper, 1971). Seasonal cycles of precipitation and river flow also contribute to spatial and temporal variability in the structure of estuarine invertebrate assemblages (Attrill, 1998). Further according to Kerr & Corfield (1998), the distribution and abundance of benthic organisms are largely determined by abiotic aspects of their environment. Sediment characteristics such as grainsize distribution and organic matter content, are particularly important in determining the make up of benthic communities (Pearson & Rosenberg, 1978; Dewilde, 1991). The relationship of the benthic communities with the environmental aspects in the form of simple correlations is presented in Table Ma-10 a & b.

Table Ma-10a: Simple correlation coefficients of dominant macrofaunal species with the water parameters.

	Water parameters						
Macrofauna ↓	Temperature	SS	Salinity	DO	PO4-P	NO3-N	SiO3-Si
Planaria	-0.0014	-0.0386	0.0391	-0.0738	-0.0545	0.0363	0.0102
Seaanemone	-0.0013	0.1073	0.0285	-0.0348	-0.0122	-0.0041	-0.1099
Polychaete	-0.1920	0.0055	0.1494	0.0009	0.1875	0.0551	0.1651
Boccardia tricuspa	0.0790	-0.0197	0.0459	-0.0095	0.1261	0.0015	0.0589
Dendronereis heteropoda	0.0056	-0.0385	-0.0901	0.0595	0.2149	0.0367	0.0689

Lycastis ounaryensis	-0.2269	-0.0379	0.0820	-0.0324	0.1999	0.0268	0.2073
Lycastis indica	0.0264	0.0032	0.0244	0.0004	0.1292	0.0306	0.0223
Nereis glandicinta	-0.0627	-0.0373	0.0994	-0.0069	0.0762	-0.0094	0.0205
Nereis (Ceratonereis) burmensis	-0.1659	0.0432	0.1555	0.0125	0.1653	0.0693	0.1464
Polydora tentaculata	-0.0707	-0.0061	0.1306	0.0343	-0.0128	-0.0036	0.0347
Sigambra bassi	-0.1570	-0.0320	0.1339	0.0090	-0.0744	0.0467	-0.0485
Oligochaete	0.0345	0.2173	-0.1032	-0.1760	0.3181	0.0984	0.2903
Gastropods	-0.0975	-0.0705	0.2558	-0.0642	-0.1087	0.2560	-0.1428
Stenothyra deltae	-0.1068	-0.0334	0.1848	-0.0640	-0.0924	0.2742	-0.1324
Stenothyra minima	-0.1019	-0.0724	0.2415	-0.0235	0.0118	0.1094	-0.0303
Assiminea brevicula	0.0206	-0.0389	0.1983	-0.1210	-0.0107	0.0901	-0.0065
Cerethidea (Cerethideopsis) cingulata	0.0242	-0.0636	0.0402	0.1474	-0.2418	-0.0509	-0.2214
Thiara	0.1187	0.0559	0.0530	0.1282	-0.0993	-0.0418	-0.1435
Littorina	-0.0320	-0.0898	0.1478	-0.0189	-0.1310	0.0898	-0.1185
Nassarius ornatus	0.1043	-0.0576	0.1288	0.0081	-0.0669	0.0530	-0.0793
Hamminea crocata	-0.0492	-0.0589	0.1568	0.0150	0.1016	0.0505	-0.0373
Bivalves	-0.1470	-0.0759	0.1466	-0.0471	-0.0032	0.1068	-0.0834
Cuspidaria cochinensis	-0.1186	-0.0804	0.1054	0.1031	-0.0739	0.0075	-0.0526
Microbivalve	-0.1221	-0.0684	0.1385	-0.0672	0.0274	0.1182	-0.0621
Glauconome cerea	-0.0449	0.0357	-0.0270	0.0385	-0.1289	-0.0215	-0.1344
Katelysia opima	-0.0235	-0.0939	0.1217	0.0969	-0.0885	0.0094	-0.1509
Katelysia marmorata	-0.1477	-0.0250	0.1976	-0.0269	-0.0457	0.1045	-0.0681
Dosinia pubescens	-0.0872	-0.0723	-0.0122	0.1165	-0.0798	-0.0432	-0.1523
Cardium asiaticum	0.0464	-0.0316	0.1808	0.0274	-0.0718	0.0549	-0.1192
Brachyodontes karachiensis	-0.1571	-0.0147	0.1504	-0.0738	-0.0108	0.0110	-0.0221
unidentified bivalve	0.0278	-0.0088	-0.1166	0.0313	-0.0529	-0.0781	-0.0599
Razor clam	-0.0526	-0.0484	0.0325	0.0268	-0.1441	0.0408	-0.0773
Crustaceans	-0.1591	0.0600	0.0765	-0.2799	0.2183	0.0933	0.2236
Illyoplax gangetica	-0.1549	0.0626	0.0763	-0.2798	0.2195	0.0944	0.2264
Larvae	-0.0151	-0.0383	0.0404	-0.1675	0.2907	0.1531	0.3060
Balanus amphitrite	0.0028	-0.0014	0.1766	-0.0127	-0.1089	-0.0039	-0.1028
Total	-0.2189	-0.0330	0.2292	-0.0433	0.1325	0.1541	0.0807

All Values above ± 0.1623 are significant at 5% level of significance,
except for zooplankton where values above± 0.5673 are significant.

Table Ma-10b: Simple correlation coefficients of dominant macrofaunal species with the soil parameters, plankton & benthos.

	Soil Parameters							Phytoplankton	Zooplankton	Microphytobenthos	Meiobenthos
Macrofauna ↓	OC	TN	TP	AP	Sand	Silt	Clay				
Planaria	-0.1419	0.0424	-0.0284	0.0081	-0.0449	0.0666	0.0065	-0.0353	-0.1767	0.0519	0.0319
Seaanemone	-0.1962	-0.0149	-0.1364	0.1300	0.1002	-0.1289	0.1774	-0.1262	-0.2631	-0.1227	0.1716
Polychaete	-0.0370	0.1266	0.0279	0.1675	-0.1390	-0.1058	0.1563	-0.0796	-0.0791	0.1490	0.0373
Boccardia tricuspa	-0.0011	0.1022	-0.0209	0.2137	0.2572	-0.1043	0.0130	-0.0340	-0.3300	0.2417	0.1079
Dendronereis heteropoda	0.0688	0.0470	0.0328	0.1337	0.0300	0.1674	-0.1325	0.0763	-0.0322	0.0492	-0.0367
Lycastis ounaryensis	0.0691	0.1557	0.0041	0.1795	-0.1033	-0.0847	0.0778	-0.5430	0.1025	0.1321	-0.0429
Lycastis indica	-0.0367	0.0431	0.0217	0.0355	-0.0290	-0.0523	-0.0806	-0.0216	-0.1661	0.0889	0.0984
Nereis glandicinta	-0.0839	0.0297	0.0035	0.0296	-0.0898	-0.0403	0.1066	-0.0027	-0.2778	0.0706	0.0653
Nereis (Ceratonereis) burmensis	-0.0632	0.1058	0.0493	0.1633	-0.1347	-0.0826	0.1560	-0.0771	-0.1671	0.1256	0.0510
Polydora tentaculata	-0.0888	0.0335	0.0014	0.0182	-0.0897	-0.0982	0.1378	-0.0619	-0.0684	0.0998	0.0482
Sigambra bassi	-0.1043	-0.0548	-0.1013	-0.0439	-0.1301	-0.1594	0.1259	-0.1233	0.3540	-0.0445	-0.0091
Oligochaete	0.3274	0.2718	0.1186	0.0926	0.0393	0.0376	0.0053	-0.0058	0.1787	0.0881	0.0698
Gastropods	-0.2357	-0.1516	-0.1448	0.0064	-0.1809	-0.1989	0.3143	-0.1285	0.6915	-0.0050	0.0378
Stenothyra deltae	-0.1652	-0.1322	-0.1198	0.0390	-0.1141	-0.2118	0.2819	-0.1071	0.7245	-0.0494	-0.0489
Stenothyra minima	-0.1747	-0.0509	-0.0892	-0.0495	-0.1650	-0.1357	0.2414	-0.1157	0.1016	0.0346	0.0561
Assiminea brevicula	-0.2024	-0.0505	-0.0314	0.0850	-0.1144	-0.0732	0.1247	-0.0907	0.1548	0.1548	0.2959
Cerethidea (Cerethideopsis) cingulata	-0.2917	-0.2053	0.0291	0.0046	-0.1905	-0.0683	0.0679	0.0223	0.1990	0.0098	0.1084
Thiara	-0.1349	-0.1031	-0.0658	-0.0740	-0.0591	-0.0510	0.1438	-0.0875	-0.4604	-0.0672	-0.0360
Littorina	-0.1537	-0.1167	-0.1184	-0.0796	-0.1512	-0.0373	0.1547	-0.0402	0.4009	0.0027	0.0482
Nassarius ornatus	-0.2189	-0.0472	-0.0757	0.1095	-0.1170	0.0193	0.0227	-0.0807	-0.0012	0.1706	0.3365
Hamminea crocata	-0.1679	-0.0203	-0.0400	-0.1018	-0.0918	0.1202	-0.1391	-0.0618	-0.1473	0.1530	0.1157
Bivalves	-0.2403	-0.0820	-0.0659	0.0352	-0.1592	0.1125	0.1715	-0.1132	0.3242	0.0393	0.0231
Cuspidaria cochinensis	-0.1752	-0.0535	-0.0111	0.0659	-0.0492	-0.1797	0.2132	-0.0562	-0.2773	0.0247	0.0298

Microbivalve	-0.1983	-0.0648	-0.0657	0.0327	-0.1510	-0.0609	0.1037	-0.1020	0.3544	0.0491	0.0310
Glauconome cerea	-0.1865	-0.1028	0.0363	0.0601	-0.0560	-0.1062	0.1897	-0.0751	0.3261	-0.0294	-0.0108
Katelysia opima	-0.2093	-0.0499	-0.1109	0.0446	-0.1325	0.0183	0.0838	-0.1204	-0.0564	0.0763	0.1449
Katelysia marmorata	-0.1822	-0.0482	-0.1211	-0.0812	-0.1389	-0.0615	0.0564	-0.1172	-0.0003	0.0133	0.0488
Dosinia pubescens	-0.1683	-0.1080	-0.0458	0.0681	0.0233	-0.0746	0.1045	-0.0662	0.2806	-0.0817	-0.0544
Cardium asiaticum	-0.1813	-0.0748	-0.1071	-0.1296	-0.1346	0.0206	-0.0176	-0.0790	-0.2194	0.0768	0.1336
Brachyodontes karachiensis	-0.1047	-0.0010	-0.1214	-0.0470	-0.0837	-0.1541	0.1869	-0.0617	-0.0190	-0.0652	-0.0326
unidentified bivalve	-0.0552	-0.0423	0.0790	-0.0054	-0.0397	-0.1004	0.1493	-0.0201	0.0728	-0.0455	-0.0378
Razor clam	-0.0223	-0.0817	-0.1238	-0.0600	-0.0767	0.0366	-0.0314	0.0593	0.3340	-0.0642	-0.0590
Crustaceans	-0.0156	0.1226	0.0421	0.2276	0.2292	-0.0326	-0.3528	-0.0403	0.4165	0.1920	0.0556
Illyoplax gangetica	-0.0100	0.1273	0.0389	0.2281	0.2331	-0.0208	0.0296	-0.0416	0.4142	0.1938	0.0579
Larvae	0.2914	0.3541	-0.0008	-0.0326	-0.0509	0.0752	-0.0722	-0.0842	-0.0224	0.2013	0.1533
Balanus amphitrite	-0.1666	-0.0149	-0.0192	0.0469	-0.1180	-0.1358	0.1328	-0.1199	0.1466	0.0941	0.0752
Total	-0.1489	0.0501	-0.0360	0.1442	-0.2035	-0.1674	0.2574	-0.1346	0.1785	0.1359	0.0540

All Values above ± 0.1623 are significant at 5% level of significance,
except for zooplankton where values above± 0.5673 are significant.

Jones (1950), stated that the significant factors which may influence the distribution of bottom fauna are temperature, salinity and the nature of the bottom deposit. However according to Kurian *et al.* (1975) in tropical estuaries, the effect of temperature as a limiting factor is only of secondary importance. This view was corroborated by Chandran *et al*. (1982) while studying the macrobenthos of Vellar estuary. During the present study temperature played significant role in the occurrence, distribution and abundance of the total macrofauna. The majority of the fauna showed a insignificant negative correlation except for significant values obtained for polychaetes *L. ouanaryensis* and *N. (Ceratonereis) burmensis*. The effect of temperature was evident in the month of October, as the sudden rise in temperature after the monsoon period lead to desiccation and mortality of the benthic fauna.

Suspension feeding organisms like bivalves and certain polychaetes are known to prefer adequate amount of suspended particles in the ambient waters, however excess suspended solids can lead to choking and death of the animal. Hence the importance of suspended solids cannot be undermined. In the present study high suspended solids were recorded in the entire creek. As a consequence the macrofauna had a negative influence of the suspended solids, with the exception of oligochaetes that preferred the turbid conditions of the creek.

Salinity is the most fluctuating factor, which influences the distribution and abundance of the bottom fauna (Pillai, 1977), a view corroborated by many researchers (Bhat & Neelkantan, 1998). In Thane creek the molluscan fauna was governed by salinity variations as most of the species had an affinity for high salinity. According to Taylor &

Eggleston (2000) severe oxygen deficiency in estuarine & coastal waters is one of the few environmental perturbations that lead to massive mortality of benthic organisms. Further species inhabiting oxygen-depleted waters vary considerably in their response to hypoxia. The benthic macrofaunal species that are most resistant to prolonged exposure to severe hypoxia are bivalves and gastropods, followed by polychaetes, echinoderms and crustaceans. (Diaz & Rosenberg, 1995). In Thane creek the crustaceans, insect larvae and oligochaetes showed a significant negative correlation with oxygen, whereas the remaining fauna had an insignificant influence with the overlying oxygen concentration. This in the opinion of Chandran *et al*. (1982) can be attributed to the shallow nature of the ecosystem, where in the flow of water is continuous and dissolved oxygen may not be a limiting factor for the benthic fauna.

It is well known that substrate organic matter represents a food source for deposit – feeding organisms (Mare, 1942), apart from its value as an indicator of pollution (Parrish & Mackenthun, 1968; Wade, 1976). Murugan & Ayyakkannu (1991) observed a positive correlation between the benthos & organic carbon. They further reported that in the coastal waters of east coast of India more than 6 % sediment organic carbon was anoxic to bottom fauna. Along the west coast of India, Harkantra *et al*. (1980), observed a decrease in benthic fauna when the organic carbon was more than 4 %. Harkantra (1982), further stated that very low & high values of organic carbon show poor fauna while medium values show rich fauna. According to Ganapati & Raman (1973) high values of organic carbon lead to anaerobic conditions. In the present study the organic carbon ranged between 1.21 to 4.43 % and had a significant negative influence on the abundance and distribution of the molluscan fauna balanus & sea anemones whereas the oligochaetes & insect larvae showed a significant positive correlation.

Eutrophication of the marine environment is usually defined as a complex set of phenomena ultimately triggered by the increase of limiting nutrients, especially nitrogen and phosphorus from terrestrial sources (Moodley, 1998). In short, increase in limiting nutrients leads to increased primary production and subsequently increased amounts of organic material can be deposited to the sediments. This may eventually lead to increase in benthic biomass and densities but also to hypoxic / anoxic conditions in the sediment that can result in massive reduction or die off of benthic animals (Heip, 1995). According to Pastorok & Bilyard (1985) moderate sewage inputs may mimic nutrient enrichments and promote rapid growth of benthic organisms and domination by benthic suspension feeders. Thane creek is an effluent enriched ecosystem. Wherein the pollution tolerant polychaetes, insect larvae, oligochaetes and crustaceans get benifited from the nutrient enrichment. The polychaeta was the most successful group as it showed dominance and continuous breeding in the creek. The molluscan fauna although dominant towards the marine zone had negative to insignificant influence of the organic enrichment. The most significant observation among the molluscan fauna was the strong negative correlation of gastropod *C.cingulata* with organic enrichment reconfirming the opinion of Athalye (1988) as a pollution sensitive gastropod.

The role of sediment type as a factor determining macrobenthic community structure has been emphasized by many authors (Sanders, 1958; Gray, 1974; Raman & Ganapati, 1983; Sunilkumar, 1995; Muniz & Pires, 2000). Correlations between infaunal species and sediment types have been well documented since the turn of the 20^{th} century (Dayton, 1984) and different functional groups have been defined in association with different substrate types (Muniz & Pires, 2000). In Thane creek also different faunal groups were seen to favour different sediment types (Table Ma-10b), eg. polychaetes showed positive relation with clay and negative with sand & silt, except for *Boccardia tricuspa* that had positive relation with sand and silt. Sea anemones showed significant positive relation with clay, The mollusks had a strong affinity for clayey substratum showing significant positive correlation with clay and negative relationship with sand and silt. On the other hand crustaceans reported a significant positive correlation with sand and negative relation with silt and clay. However the sediment of Thane creek was predominantly clayey-silt and it governed the density of various macrobenthos.

One of the important factors regulating the distribution of benthos is the availability of food (Humprey, 1972; Chandramohan & Chetty, 1988). The vertical food web from phytoplankton to benthos , produces a concentration of benthos higher near the coasts than the open sea. (Harkantra & Parulekar, 1987). According to Qasim & Reddy (1967) in tropical estuaries, high levels of primary food is available. In Thane creek however due to the availability of excess food its influence on the benthos was not much significant.

Significant positive relation with microphytobenthos were shown by crustaceans & insect larvae and with meiobenthos by gastropods *Assiminea spp*. and *Nassarius spp*.

Macrobenthos are considered a suitable group for detecting the effects of pollution (Warwick, 1993), and its response to organic enrichment is relatively well documented (Pearson & Rosenberg, 1978). It is generally assumed that a macrobenthic community under increased organic enrichment will exhibit a general reduction in species richness, biomass and bodysize and an increase in total number of individuals (opportunistic species). Based on these assumptions several methods have been proposed to assess the disturbance status of a community (Warwick & Clarke, 1991). The diversity indices calculated for the present study are presented in Figs. Ma-23 to 26. The indices giving the total number of species (N 0), dominant species (N 1) and the most dominant species (N 2) showed an increasing trend from the riverine to the seaward end. The lowest species number (N 0) was observed at station 5 which increased on either sides towards station 1 & station 12. Drops in the species number at station 3, 5, 9 and 12 could be related to environmental stress namely sewage pollution (Stations 3, 5 & 9) & strong wave action and anthropogenic activities (station12). The trend of N 1 & N 2 however did not match exactly with N 0 and had certain unexpected values like drops at station 1, 4 & 8. However the richness indices R 1 & R2 (Fig. Ma-24) showed low richness either at the middle stations 5 to 8 (R 1) or seaward stations 6 to 11 (R 2). At highly polluted station near sewage reach (station 5) R 1 was low & R 2 was high. Thus the fluctuations in R 1 & R 2 were not concurrent with actual pollution status of the station.

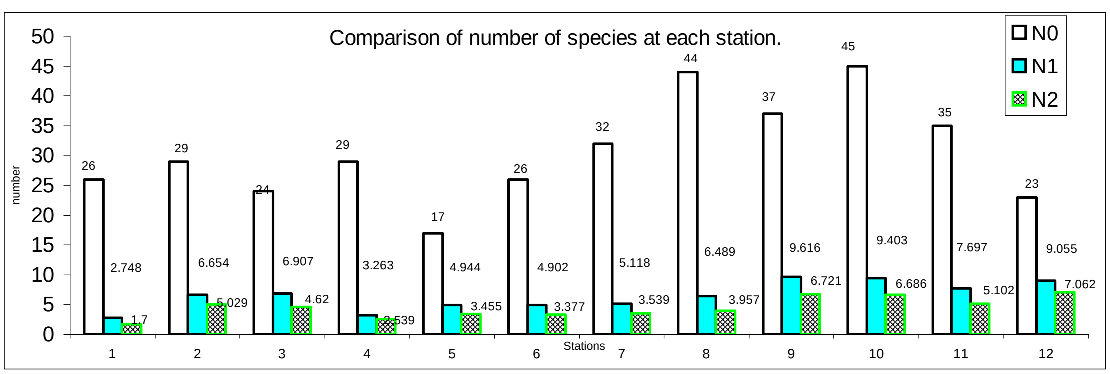


Fig. Ma-23: Stationwise variations in the total number of species (N 0), number of dominant species (N1) and number of most dominant species (N 2).

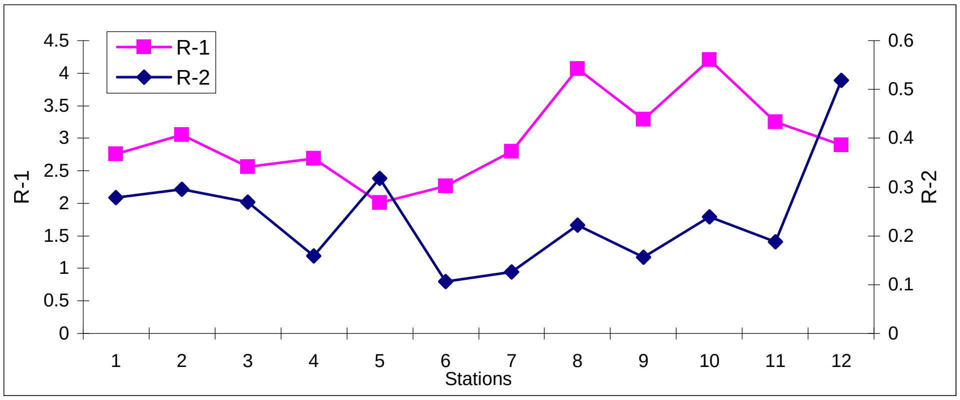


Fig. Ma-24: Station wise variations in the richness indices Margalefs' (R 1) and Menhinick (R 2).

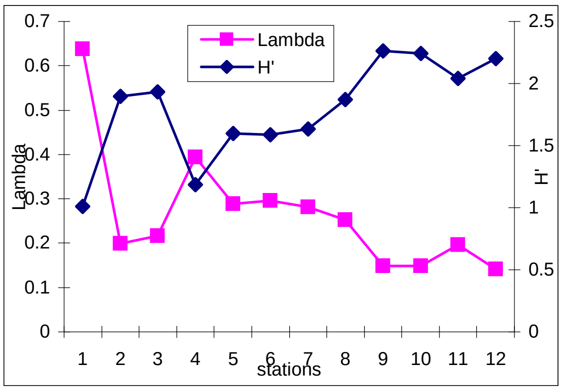


Fig. Ma-25: Stationwise variations in the diversity indices Shannon Weaver (H') & Simpsons (λ).

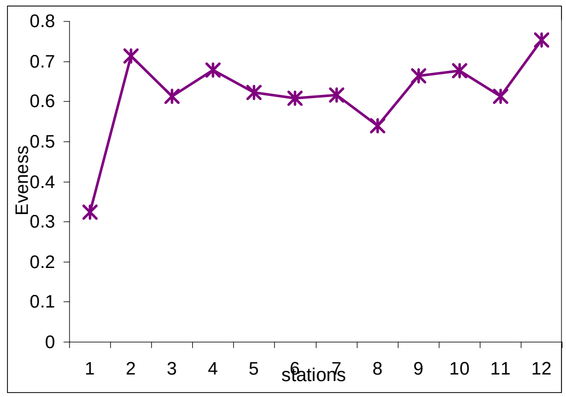


Fig. Ma-26: Stationwise variations in the evenness index (E 5).

Shannon Weaver's diversity index H' (Fig. Ma-25) unexpectedly showed high values in stressed region at station 2 & 3 and significant drops at stations 1 & 4. Increased diversity at station 5 & also station 12 seem to mislead regarding the pollution status of the stations. The Simpsons index (λ) (Fig. Ma-25) showed a trend inverse to H' as expected. Whereas evenness index E 5 showed a trend indifferent to pollution status (Fig. Ma-26). In earlier part of this chapter it was observed that these biological indices could rightly indicate the status of pollution at different stations, and were depicting similar pattern where as for macrobenthic data each index had a different trend and hence could not indicate pollution status.

According to Drake & Arias (1997), although the indices indicate the polluted state, they seem to be incapable of correctly detecting the level of stress on the ecosystem. Hence the ABC curves suggested by Warwick (1986) were tried. As already explained in chapter I, ABC curves are plotted by using the cumulative percentages of abundance and biomass. When the biomass and abundance curve lie wide apart, with biomass over the abundance curve it is assumed to be a healthy condition, whereas when the abundance curve is above the biomass curve it indicates gross pollution in the ecosystem. In case the curves lie close to each other and intersect at various points the ecosystem can be called as stressed. According to Warwick (1986), the ABC curves for higher taxa are better indicators than the species wise curves. Hence for the present study ABC curves were plotted using the groups for all the sampling stations, as well as the entire creek (Figs Ma.-27 to 40). All the plots indicate stressful conditions in the creek.

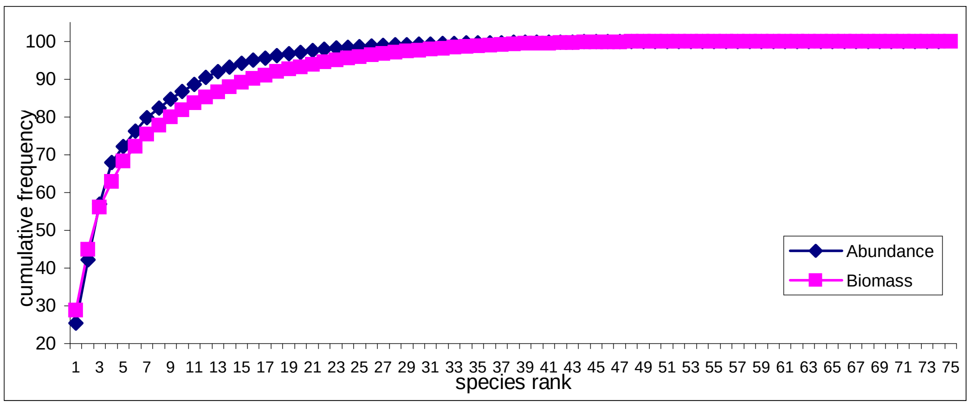


Fig. Ma-27: The ABC curves using the entire data of the present study

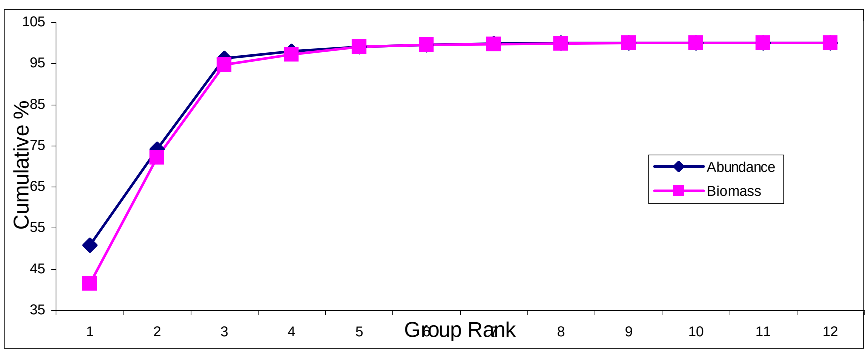


Fig Ma-28: The ABC curve for the entire creek.

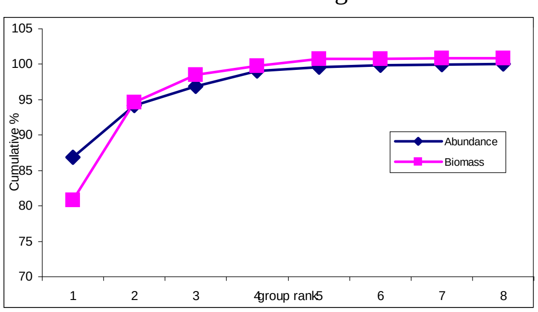


Fig. Ma-29: TheABC curve for Station 1.

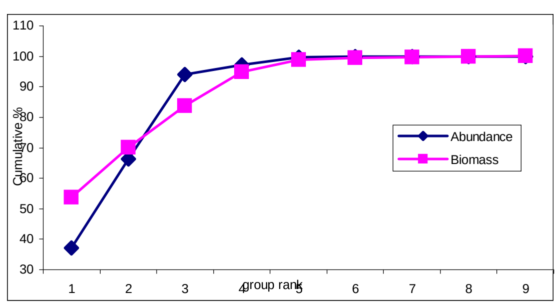


Fig. Ma-30: TheABC curve for Station 2.

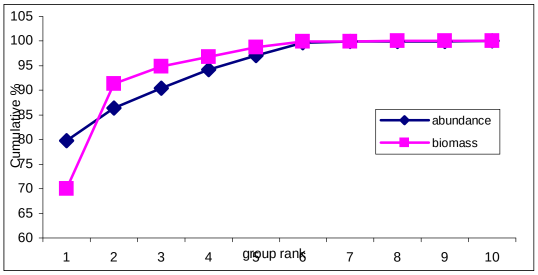


Fig. Ma-31: The ABC curve for Station 3.

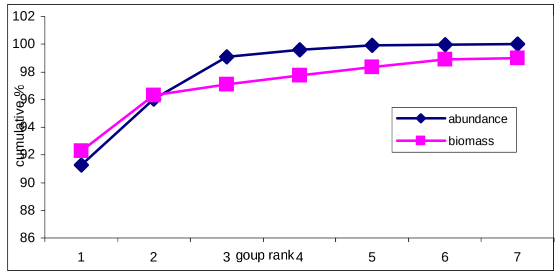


Fig. Ma-32: The ABC curve for Station 4.

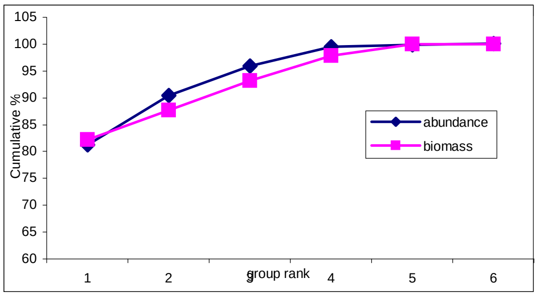


Fig. Ma-33: The ABC curve for Station 5.

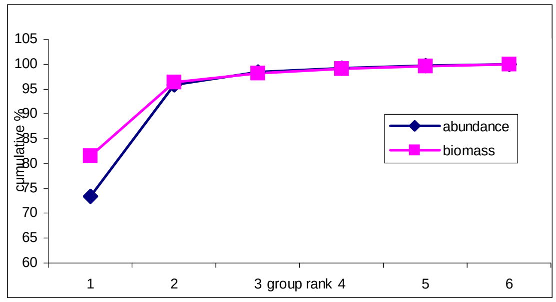


Fig. Ma-34: The ABC curve for Station 6.

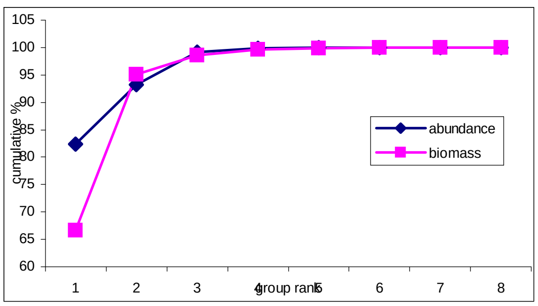


Fig. Ma-35: The ABC curve for Station 7.

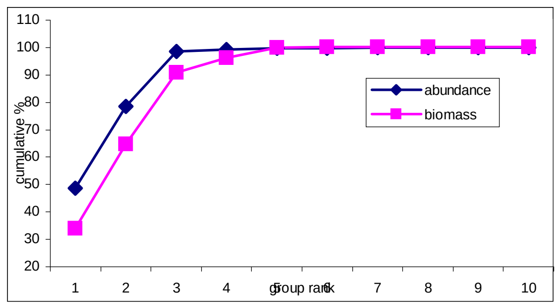


Fig. Ma-36: The ABC curve for Station 8.

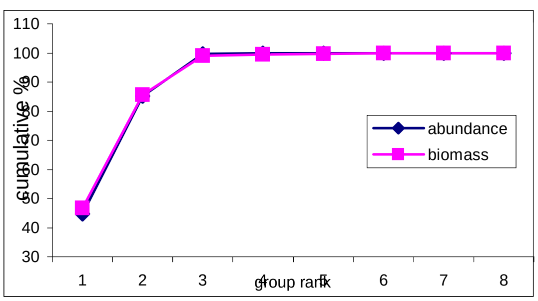


Fig. Ma-37: The ABC curve for Station 9.

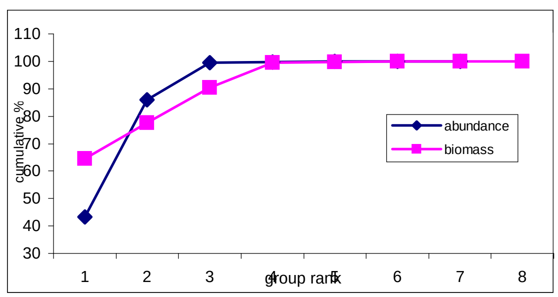
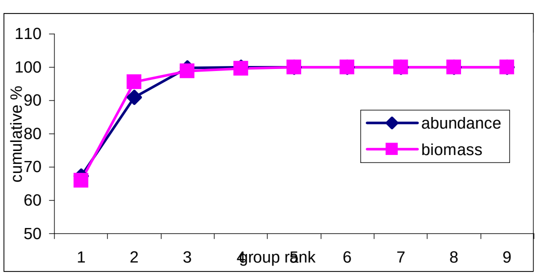


Fig. Ma-38: The ABC curve for Station 10.



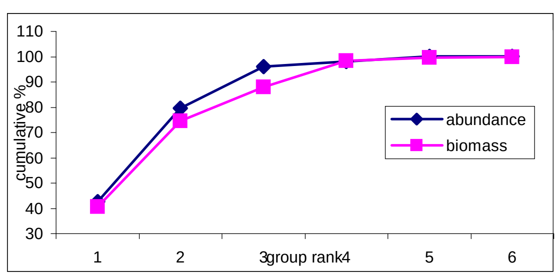


Fig. Ma-39: The ABC curve for Station 11.
Fig. Ma-40: The ABC curve for Station 12.

Summary

The macrobenthos showed wide variations in the creek, depending on the anthropogenic stress, sewage and effluent load. In all 75 different species were recorded, with dominance of polychaetes, bivalves, gastropods and sea anemones. However the number of dominant species were negligible (2 to 10) as mostly pollution tolerant species dominated the creek. The polychaetes dominated the riverine end of the creek which suffers a higher pollution stress while the bivalves were recorded from the seaward end where the pollutant load gets diluted creating healthier environment.

It is felt that certain species may be useful as pollution indicator species in estuarine environments. Presence of polychaetes *Nereis (Ceratonereis) burmensis, Lycastis ouanaryensis* and oligochaeta; whereas conspicuous absence of polychaetes *Polydora spp., Nereis glandicincta* and mollusks *Katelysia spp. & Cerethidea spp.* may be treated as indicator of heavy sewage pollution. In the present study macrobenthic species were governed by different environmental parameters and hence showed significant correlations accordingly. The biological indices calculated for macrobenthic data, so as to determine pollution status of the creek, revealed in general stressfull condition in the creek, but failed to accurately distinguish pollution intensity at different stations.

Detailed 3 dimensional diagrams to depict stationwise and monthly distribution of important macrobenthos species and their photo-plates are presented ahead for reference.

Miscellaneous notes

Fishery of Thane creek.

The coastal waters within the 30 meters of the continental shelf offer good feeding ground for many crustaceans and fishes, many of which spend a part of their life cycle in the creeks or in estuaries (Gajbhiye *et al.*, 1994). It is generally thought that the mangrove habitats surrounding these ecosystems are widely utilized by these marine fauna (Vose &

Bell, 1994). Many studies in various parts of the world have recogonised the importance of mangroves and sea grass beds as nurseries for fishes (Nagelkerken *et al.*, 2001).

Several hypothesis have been proposed to explain the high abundance of juvenile fishes in mangroves and sea grass beds. The hypothesis according to Nagelkerken *et al* (2000), are based on avoidance of predators, the abundance of food and interception of fish larvae. The hypothesis are (a) the structural complexity of these biotopes provide excellent shelter against predators (Parrish, 1989), (b) these biotopes are often located at a distance from the off shore waters and are therefore less frequented by predators (Shulman, 1985), (c) the relatively turbid waters of the bays and estuaries decrease the foraging efficiency of the predators (Blaber & Blaber, 1980) and (d) these biotopes provide a great abundance of food for fishes (Odum & Heald, 1972). But according to Nagelkerken (2001), the use of these biotopes as nurseries is not much apparent in the Indo-Pacific region.

In Hostens's (2000) opinion the distribution and abundance of fish in estuarine and coastal environments is dependant on physical, chemical & biotic factors. Increasing awareness of possible effects of man on the marine environment has led to a search for early warning indicators of any induced changes (McVicar *et al.*, 1988). The near shore waters of industrialized cities according to Gajbhiye *et al.* (1994) are prone to different types of pollution, which get build up from various sources (NIO, 1992). Further, with increasing development of shorelines and draining of mangrove swamps, it is vital that the importance of mangroves as fishery habitats be accurately defined, ascribed Vance *et al.* (1990), to provide useful advice for coastal management and alternative land use decisions.

Thane creek has apart from mangroves, industries, urban settlements and villages along both its banks. The inhabitants of these villages are mostly fishermen who depend upon the creek. However the heavy industrialization and urbanization along the creek has resulted in release of effluents in quantities far exceeding the assimilating capacity of the creek. According to Gajbhiye *et al.* (1994), high input of waste results in fluctuating trend in catch rate along with low species diversity. During the present study although the fish catch was not estimated, the different species of fish occurring in the creek were collected seasonally. It was observed that the fishing activity was mainly restricted to the lower stretches (marine end) of the creek, while at the riverine end fishing was an activity of the monsoon season only when the commercially important fishery would occur. During the investigation a total of 12 species of fish were recorded, consisting of 11 species of fin fish and 1 crustacean. The 11 fin fishes include *Mugil cephalus, Mystus gulio, Mystus shingala, Tilapia mossambica, Lates calcarifera, Elops saurs, Coilia dussimieri, Trichirus savala, Cleupia toli* and *Johnius spp.*, while the only crustacean was *Scylla serrata*. Among the above fishes only 5 species were dominant and occurred through out the year, namely *Mugil cephalus, Mystus gulio, Mystus shingala, Tilapia mossambica* and *Scylla serrata* where as the other fishes were rare in their occurrence.

All these 5 species occurred throughout the length of the creek, while the other species were restricted to the marine end of the creek. During the monsoon *Mugil cephalus, Mystus gulio* & *Mystus shingala* were reported in fairly large numbers from the upper stretches of the creek, later in the year their catch reduced significantly with occurrence of only *Tilapia mossambica* and *Scylla serrata*. However, Tandel (1984); Pejaver (1984) and Gokhale & Athalye (1995) had recorded fishery through out the year in the shallow region of the creek and observed greater abundance and species diversity during the monsoon, attributing the shallow region of the creek as a fairly sustainable nursing ground during the monsoon. Although the present observation corroborates their view, a significant reduction in the diversity is also noted, with the conspicuous absence of prawns from the entire stretch of the creek. Pejaver (1987), Gokhale & Athalye (1995) had reported the presence of *Metapenaeus monoceros, Macrobrachium rosenbergii, & Penaeus indicus* from the shallow region of the creek, while Krishnamurthy & Nair (1999) during their study in 1983, observed the presence of *Parapenaeopsis hardwickii, Macrobrachium rude, Metapenaeus brevicornis, Exopalaemon stylifera* and *Penaeus indicus* from the lower stretches of the creek. The absence of these species during the present study can be attributed to the increased pollutant load in the creek, which repelled most of the commercially important fish and crustacean species.

Gokhale & Athalye (1995) during their study in 1991-93, recorded 22 species of fish and 68% reduction in the fishery of the shallow region of Thane creek in comparison to the data of 1981 – 82. Although a quantitative data was not collected during the present study a comparison of the number of fish species indicated a substantial decline in the fishery of Thane creek. Further the local fishermen communicated an almost 75 % decline in the fishery in comparison to the fish catch obtained in the 1990's. The locals also informed about the gradual changes in occupation of the fishermen due to unsustaining yields, which have resulted with the rising effluent and sewage load. Moreover they complained that fish kill due to sudden release of harmful and toxic chemicals, were now a regular feature in the creek. In addition the perils of non-biodegradable matter loomed large in the creek, it had even succeeded in forcing the fishermen to change their fishing gears from the traditional dol nets to gill nets, with infrequent use of wall nets. This is because the dol nets would invariably get clogged with the non-biodegradable waste like thermocol, plastic bags etc., instead of the actual fish catch. With the fishery becoming obscure in Thane creek, commercial fishing in the creek was observed to be a dying occupation.

Birds.

The mangrove ecosystem is known to play an important role as nursery for a variety of marine and freshwater organisms. They present a much diverse structural habitat than most coastal ecosystems and harbour a great variety of bird life (Samant, 1985). Though the birds are not exactly aquatic creatures, a large number of birds are dependent solely on the aquatic environment for their survival (Mandal *et al*., 2001), and mostly use the mangrove ecosystem for feeding, roosting or transit purpose.

According to Samant (1985), the avian fauna in association with mangroves is a subject of regular study. In India very little information is available about the coastal birds associated with mangroves, except for the studies on the feeding habits of some water birds from the mangrove forests of Sunderbans (Mukherjee, 1969) and a checklist of birds around the mangroves of Ratnagari (Samant, 1985). The avian fauna of the Thane mangroves was first documented by Deshmukh (1990) who listed about 146 species of birds, later Kulkarni (1999) reported179 species from the same locality. Their listing includes birds; from the mangroves, mangrove associates and from the mudflat region.

During the present investigation the birds inhabiting the intertidal mudflats were observed, and are listed in Table B-1. A total of 61 species were recorded out of which Little egret, Cattle egret, Median egret, Curlew, Marsh sandpiper, Common Sandpiper, Little stint, Brown headed gull, Black headed gull, Indian river tern, little tern, White breasted kingfisher, House crow, Jungle crow & Small minivet occurred through out the entire stretch of the creek. The species diversity and number was higher on the west bank compared to the east bank, this can be attributed to less human interference due to the soft and sinking type of mudflats on the west bank compared to the east bank. However among all the sampling stations the birds species diversity was maximum at station 12, this could be due to the easy availability of food, as station12 is a landing site for the fish caught from the adjacent water body.

The birds like Osprey, Kingfisher and kites though never settled on the mudflats only were observed either fishing or resting on the permanent fishing poles / buoys / bamboos from the intertidal region of the lower stretches of the creek only. One of the most significant observations was that of the Flamingoes and Black winged stilts. The Black winged stilts were observed only in the upper stretches of the creek i.e. from station 1 to 6 and were totally absent in the lower marine end of the creek. Kulkarni (1999) while studying the birds in association with the mangroves of the same region had reported the roosting site of flamingoes in the off shore region of Bombay (Mumbai) harbour. In the present study, the flamingoes were recorded only along the west bank of the creek and were restricted to the lower stretches of the creek. i.e. Bhandup(Stn. 7) to Trombay (Stn 12). In the months of June to October the number of flamingoes varied from 5 to 25. November onwards the numbers gradually increased and showed peak abundance in February & March when a flock of almost 500 birds was observed. Although the flamingoes were never recorded in the upper stretches except for a lone injured bird in September 1999, the locals have noticed a northward migration of the birds with the onset of monsoon. The reason for the absence of flamingoes in the upper stretches of the creek can be attributed to excess pollution and anthropogenic activities.

Table B-1: List of birds observed from the intertidal mudflats of the Thane creek.

Common name	Scientific name
Cormorant	Phalcrocorax carbo
Little cormorant	*Phalacrocorx niger* Vieillot
Darter	*Anhinga rufa* Daudin
Little green bittern	*Butorides striatus* Linnaeus
Grey heron	*Ardea cinera* Linnaeus
Pond heron	*Ardeola grayii* Sykes
Night heron	*Nycticorax nycticorax* Linnaeus
Purple heron	*Ardeola purpurea* Linnaeus
Little egret	*Egretta garzetta Linnaeus*

Cattle egret	*Bubulcus ibis*Linnaeus
Large egret	*Ardea alba* Linnaeus
Median egret	*Egreta intermedia*
Open billed stork	*Anastomus oscitans* Boddaert
White stork	*Ciconia ciconia* Linnaeus
Lesser Flamingo	*Phoeniconaias minor* Geoffroy
Greater Flamingo	*Phoenicopterus roseus* Pallas
Spot billed duck	*Anas poecilorhyncha* J.R. Forster
Cotton teal	*Nettapus coromandelianus* Gmelin
Common teal	*Anas crecca* Linnaeus
Pintail	*Anas acuta* Linnaeus
Black shouldered kite	*Elanus caeruleus* Desfontaines
Pariah kite	*Milvus migrans govinda* Sykes
Brahminy kite	*Haliastur Indus* Boddaert
Sparrow Hawk	*Accipiter nisus*
Kestrel	*Falco tinnunculus* Linn
Lesser spotted eagle	*Aquila pomaiana*
Osprey	*Pandion haliaetus* Linnaeus
Jungle bush quail	*Perdicula asiatica* Latham
Red-wattled lapwing	*Vanellus indicus* Boddaert
Little ringed plover	*Charaerius Dubius* Scopoli
Whimbrel	*Numenius arquata* Linnaeus
Curlew	*Numenius arquata* Linnaeus
Red Shank	*Tringa tetanus*
Green Shank	*Tringa nebularia*
Marsh sandpiper	*Tringa stagnatilis*
Green sandpiper	*Tringa ochropus*
Wood sandpiper	*Tringa gareola* Linnaeus
Common sandpiper	*Tringa hypoleucos*Linnaeus
Little stint	*Calidris testacea*
Avocet	*Recurvirostra avocetta* Linnaeus
Black winged stilt	*Himantopus himantopus* Linnaeus
Lesser black backed gull	*Larus fuscus*
Brown headed gull	*Larus brunnicephalus* Jerdon
Black headed gull	*Larus ridibundus*
Herring gull	*Larus argentatus*
Indian whiskered tern	*Chlidonias hybrida* Pallas
Caspian tern	*Hydroprogne caspia* Pallas
Indian river tern	*Sterna aurantia* Gray
Little tern	*Sterna albifrons*
Gull billed tern	*Gelochelidon nilotica*
Small blue or common kingfisher	*Alcedo atthis* Linnaeus
White breasted kingfisher	*Halcyon smyrnensis* Linnaeus
Lesser pied kingfisher	*Cerylerudis*
Black Drongo	*Dicrurus adsimilis* Bechstein
Pied myna	*Sturnus contra* Linnaeus
Indian myna	*Acridotheres tristis* Linnaeus
House crow	*Corvus splendens* Vieillot
Jungle crow	*Corvus macrorhynchos* Wagler
Small minivet	*Pericrocatus cinnamomeus* Linnaeus.

Food & Feeding of different organisms

One of the most important factor regulating the distribution of fauna is the availability of food (Harkantra & Parulekar, 1987). According to Harkantra *et al*. (1982), the specificity of faunal density varies with the type of substratum and largely depends on the feeding habits. These feeding habits vary depending on niche occupied by the particular fauna. In the marine ecosystem the distribution and abundance of fauna is controlled by the primary producers which are limited by the presence of nutrients like phosphates & nitrates. In estuaries the secondary producers i.e. benthos along with the zooplankton, form an important link in demersal fishery (Varshney, 1982). Hence it becomes important to study the food and feeding behaviour of different organisms to estabilish the trophic links.

Sanders *et al*. (1962), studied the stomach contents of 234 individuals representing 36 species from Barnstable harbour, Massachusetts. Depending on the food observed in the gut they categorized the benthic fauna as follows.

(1) Suspension feeders:- those animals obtaining their food from particles in suspension.
(2) Deposit feeders:- organisms that feed on deposited material. Two subcategories can be included in this group. (a) Selective deposit feeders – animals that feed discriminately on the bottom sediments. (b) Non-Selective deposit feeders – animals that indiscriminately ingest the sediments.
(3) Scavengers:- the fauna that feed on dead animal remains.
(4) Carnivores:- the fauna that feed on living animals.
(5) Omnivores:- animals that obtain their food from two or more of the above categories, usually including the carnivorous mode of feeding.

During the present investigation the gut contents of a total of 1121 animals representing different macrofauna, meiofauna, fishes, crabs and the feacal matter of birds were studied. The total number of specimens & species, the type of food and its percent occurrence is presented in Table F-1. It was evident that with the exception of few animals the fauna of Thane creek predominantly fed on phytoplankton.

Table F-1: Gut contents of different animal groups.

Group	Number of species	Specimens observed	Type of food and its % occurrence in the specimens investigated..
Meiobenthos			
Nematodes	--	12	Phytoplankton [*Coscinodiscus* .(95 %), *Navicula* (64 %)], digested matter (70 %), soil (40 %)
Oligochaetes	--	12	Empty (100 %)
Macrobenthos			
Sea anemones	11	72	Gastropods (7 %), polychaete (35 %), nematodes (14 %), empty (56 %), digested matter (21 %)
Polychaetes	10	300	Phytoplankton [*Coscinodiscus.* (66 %), *Navicula* (49 %), *Nitzschia* (31%), *Thalassiosira* (35 %), *Euglina* (33 %), *Oscillatoria* (18 %), *Pleurosigma*

			(27 %), *Gyrosigma* (10%), *Skeletonema* (15 %), *Rivularia* (3.3 %)], digested matter (25 %), empty (16.5 %), soil (24 %), polychaete (3.3 %).
Bivalves	10	285	Phytoplankton [*Nitzschia* (36 %), *Navicula* (70 %), *Oscillatoria* (90 %), *Coscinodiscus* (68 %), *Pleurosigma* (15 %), *Skeletonema* (6%)], filamentous algae (18 %), soil (5 %), digested matter (34 %), empty (18 %)
Gastropods	24	525	Phytoplankton[*Navicula* (45 %), *Nitzschia* (43 %), *Rhizosolenia* (27 %), *Coscinodiscus* (49 %), *Gyrosigma* (14 %), *Pleurosigma* (19 %), *Thalassiosira* (12 %), *Rivularia* (7 %), *Chaetoceros* (18 %), *Leptocylindrus* (20 %), *Biddulphia* (5 %)], plant chloroplast (9 %), digested matter (45 %), nematodes (4 %), foraminifera (5 %), polychaete (7 %), oil globules (0.5 %), soil (40 %)
Crabs *Illyoplax gangetica.*	1	144	Phytoplankton [*Coscinodiscus* (5%), *Navicula* (5 %), *Nitzschia* (9 %), *Leptocylindrus* (3 %)] plant matter (35 %), polychaete (30 %), copepod appendages (25 %), eggs (12 %),digested matter (66 %), soil (38 %), empty (0.5 %)
Fishery			
Fin fishes	4	20	Phytoplankton [*Coscinodiscus* (40 %), *Navicula* (90 %), *Thalassiosira* (10 %), *Pleurosigma* (10 %)], polychaete (10 %), digested matter (20 %), oil globules (5 %), mud (20 %), empty (5 %)
Crab Scylla serrata	1	12	Crustacean appendages (8%), polychaete setae (24 %), nematode (16 %), oligochaete (16 %), plant fiber (42 %), digested matter (48 %), mud (32 %), empty (16 %)
Birds			
Flamingo Excreta studied	1	12	Phytoplankton [*Navicula* (40 %), Nitzschia (40 %), Gyrosigma (8 %), Coscinodiscus (32 %), Skeletonema (16 %), Chaetoceros (24 %)] mud (16 %), oil globules (16 %)
Black winged stilts Excreta studied.	1	12	Phytoplankton [Navicula (8 %), Nitzschia (8 %), Coscinodiscus (16 %), Leptocylindrus(16 %), Skeletonema (8 %)] polychaete (40 %), nematode (24 %), oligochaetes (24 %), crustacean appendages (24 %).

The sea anemones in the present study showed a predator-prey relationship with polychaetes, gastropods and nematodes. Similar predator-prey relationship was also reported by Mukherji (1993) & Mishra *et al.*(1994), who observed the sea anemone *Aconctiactis gokhaleae* to feed on various polychaetes belonging to *Lycastis spp.* According to Levinton (1982) the sea anemones are carnivores that trap their prey with their tentacles and usually feed on zooplankton, but larger anemones are known to consume and digest bivalves even 30 cm long.

The polychaetes showed omnivores feeding behaviour as all the species contained phytoplankton, digested plant matter and soil. Christensen *et al.* (2000) observed the feeding behaviour of suspension feeding polychaete *Nereis diversicolor* and deposit feeding polychaete *Nereis virens,* they reported that both the polychaetes showed omnivores behaviour as the suspension feeding polychaete would resort to deposit feeding in absence of adequate food in the overlying water. In the present study the polychaetes were mostly selective deposit feeding omnivores except for *Nereis (Ceratonereis) burmensis* that also showed a carnivores behaviour feeding on other smaller polychaetes as well.

The Bivalve mollusks are basically filter feeders feeding on algae as well as copepods, ostracods and other prey (Levinton, 1982). The bivalves in Thane creek also observed suspension feeding behaviour consuming suspended phytoplankton, but zooplankton or any other consumer organisms were never recorded in their gut.

Most of the gastropods are herbivores grazers that feed by scraping the substratum with a specialized feeding appendage called the radula (Thompson *et al.*, 1997). Further, the feeding activity of such grazers have considerable influence on the structure of intertidal communities by the removal of both microalgae and the propagules of macroalgae which have settled within the microalgal film. In the present study most of the gastropods showed non-selective deposit feeding except for *Nerita (Dostia) violaceae, Cerethidea (Cerethidiopsis) cingulata, Stenothyra deltae, Stenothyra minima, Haminnea crocata, Salinater burmana, Thiara spp.*& *Littorina ventricosa* which were omnivores in their feeding habits and fed on nematodes, polychaetes and occasionally on foraminifera. According to Levinton (1982), certain mollusks belonging to family Muricidae, Naticidae and Thaiidae are known to show predatory behaviour, and so it is not uncommon of gastropods to show carnivores habit.

Crustaceans are mostly considered as scavengers or omnivores (Sanders, 1962). In the present study, the feeding habit of the macrofaunal crab *Illyoplax gangetica* was observed to be omnivorous feeding on phytoplankton, detritus, polychaetes and copepods.

According to Moens *et al.* (1999), the meiobenthos has been considered a black box, receiving energy inputs from the lower trophic levels i.e. primary producers and microheterotrophs and later consumed by the macrobenthos. Further, among the meiobenthos the nematodes consume a variety of food sources including the detritus, bacteria, diatoms & other microalgae and other meiofauna by predation & scavenging. Wieser (1953) proposed a feeding type classification of marine nematodes on the basis of buccal morphology. In the present study the classification was not followed, but the nematodes were observed to be feeding on detritus, phytoplankton and soil. The oligochaetes according to Subbarao & Venkateshwararao (1980), are known to feed on detritus & microalgae. However in the present study the guts of all the oligochaetes examined were empty.

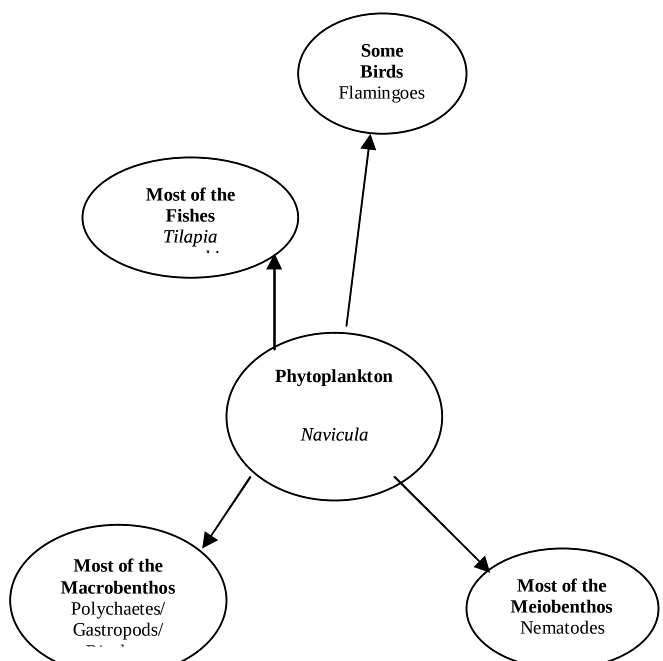
Interestingly, the benthic fauna was found to feed on pelagic plankton & not on benthic plankton species. Although both the benthic and the pelagic plankton types belonged to the same genera, the benthic plankton were larger (robust) in size, indicating different species (not identified). The total absence of benthic plankton in the gut of the benthic organisms, suggested their preference to suspension feeding.

The macrobenthos and meiobenthos are important food for larger crustaceans, fishes and birds (Varshney & Abidi, 1988). In the present investigation the gut contents of crab *Scylla serrata* and the dominant fishes i.e. *Mugil cephalus*, *Mystus gulio, Mystus shingala* & *Tilapia mossambica* revealed an omnivorous feeding habit with dominance of phytoplankton. Tandel *et al*. (1986) reported foodfeeding habit of *Mugil cephalus* in Thane creek. According to them, polychaetes formed the major component of *Mugils'* diet. As compared to this it is important to note the change in the feeding behaviour of the fishes in Thane creek, consuming phytoplankton (primary producers) as the main diet and sporadic or rare consumption of polychaetes (secondary producers). This change in diet can be attributed to either the increased turbidity of the water making it difficult for the fishes to detect and catch its prey, or the benthos could be accumulating the toxic heavy metals that repelled the fish. The second option could be true as Athalye *et al*. (2001 in press), have reported significant increase in toxic heavy metals in the polychaetes of Thane creek.

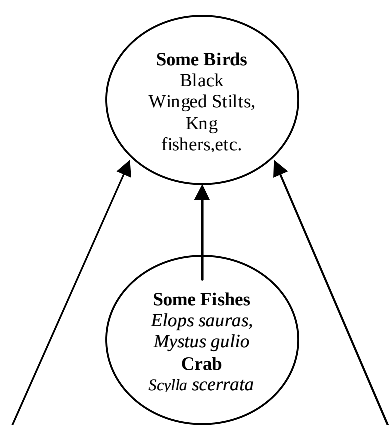
The faecal pellets of birds Flamingo and Black winged stilts were investigated, the diet of Flamingoes consisted only of phytoplankton and some oil globules. While the Black winged stilts showed a carnivores feeding habit with dominance of polychaets setae followed by nematodes & oligochaetes. Apart from establishing the trophic structure, Boersma (1986) is of the opinion that the analysis of the stomach contents of sea birds could be useful indicator of pollution, and the occurrence of oil would indicate pollution due to petroleum hydrocarbons. In the present study the oil globules were not only obtained in the gut of Flamingoes but also in the fish *Tilapia mossambica* and gastropod *Nereita (Dostia) violaceae.* This probably throws light on the presence of oil pollution in addition to organic and chemical pollution in the creek.

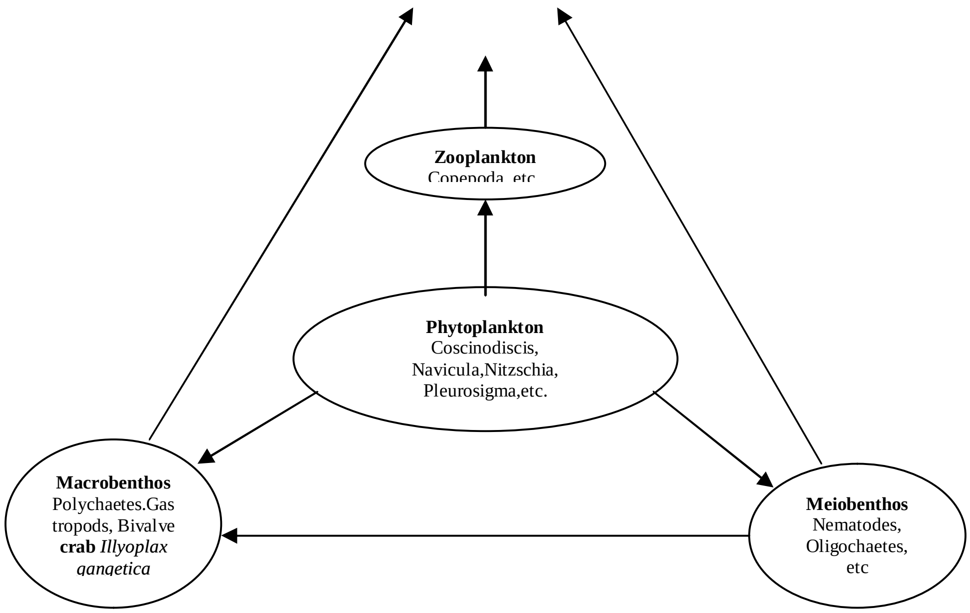
On the basis of the feeding habits, two kinds of food chain were observed in Thane creek (1) Simple (2) Complex which are shown below. The first one was dominant in Thane creek.

Simple Food Chain



Complex Food Chain





Productivity aspects.

Metabolic index

An important aspect of the ecological studies is the energetic role played by the organisms under investigation (Ansari, 1988). According to Giere (1993) the interactive relations of faunal elements and their contribution to the energy flux through the benthic ecosystem can be assessed by measuring numerical parameters such population density (abundance, biomass), production and for better comparison the turnover rate. Further Gerlach (1971), suggested the calculation of a metabolic index to get an idea of the food requirements of both the macrofauna and the meiofauna and hence the nutritional status. He attributed meiofauna to be 5 times metabolically more active than the macrofauna. Hence, for comparative purpose a rough metabolic index can be calculated by multiplying the meiobenthic biomass by 5 and adding it to the macrofaunal biomass (Elmgren, 1978). The sum (Σ) of macrobenthic and meiobenthic biomass (the metabolic index) thus calculated can indicate nutritional status of different stations or months. After calculating the metabolic indices one can find out the station or month with the lowest nutritional status and compare the status of other stations with it by finding a ratio of each stations metabolic index with metabolic index of station with the lowest nutritional status i.e. the minimum metabolic index.

$$\text{Ratio of a station or month} = \frac{\text{Metabolic index of the station or month}}{\text{The minimum metabolic index}}$$

The station wise and monthwise metabolic indices & the ratios for Thane creek are shown in Table Pr-1 & 2.

Table Pr-1: The Stationwise variations in benthic metabolic index for Thane creek.

Stations ↓	Actual biomass (g/m2 wet wt.)		Biomass calculated for metabolic index (gm/m2)		Metabolic index (Σ) (gm/m2)	Ratio to minimum metabolic index.
	Macrobenthic Biomass	Meiobenthic biomass	Macrobenthos x 1	Meiobenthos x 5	Macrobenthos + Meiobenthos	
Stn.1	70.900	25.08	70.900	125.38	196.28	1.2367
Stn.2	67.989	18.14	67.989	90.721	158.71	1.0000
Stn.3	126.322	22.81	126.322	114.031	240.35	1.5144
Stn.4	252.108	30.82	252.108	154.094	406.2	2.5594
Stn.5	17.268	31.26	17.268	156.276	173.54	1.0935
Stn.6	576.156	47.14	576.156	235.716	811.87	5.1154
Stn.7	369.107	41.21	369.107	206.038	575.14	3.6239
Stn.8	319.675	35.68	319.675	178.417	498.09	3.1384
Stn.9	579.408	43.58	579.408	217.914	797.32	5.0238
Stn.10	388.225	45.77	388.225	228.863	617.09	3.8881
Stn.11	640.492	33.92	640.492	169.603	810.09	5.1042
Stn.12	27.597	33.39	27.597	166.944	194.54	1.2258
Average	286.274	34.07	286.274	170.333	456.61	2.8776

From the Table Pr-1 it is evident that the benthic nutritional status in Thane creek was low at the riverine end and gradually increased towards the sea, with the maximum status at station 6 and the minimum at station 2. The monthly trend (Table Pr-2) showed fluctuations but indicated a declining trend in general, from June to December; there after it increased with peak values in March and April. Thus the metabolic indices indicated that, in general, the nutritional status (in other words productivity) in Thane creek was high in the downstream stretch and during the premonsoon months which corroborates with the findings in the earlier chapters.

Table Pr-2: The Monthly variations in benthic metabolic index for Thane creek.

Months↓	Actual biomass (g/m2 wet wt.)		Biomass calculated for metabolic index (gm/m2).		Metabolic index (Σ) (gm/m2)	Ratio to minimum metabolic index
	Macrobenthic Biomass	Meiobenthic biomass	Macrobenthos x 1	Meiobenthos x 5	Macrobenthos + Meiobenthos	
May-99	107.8	59.369	107.8	296.845	404.645	2.1174

Jun	115.6	35.104	115.6	175.52	291.12	1.5234
Jul	236	29.597	236	147.985	383.985	2.0093
Aug	172.8	22.51	172.8	112.55	285.35	1.4932
Sept	207.2	26.36	207.2	131.8	339	1.7739
Oct	105.4	17.141	105.4	85.705	191.105	1.0000
Nov	316.4	16.622	316.4	83.11	399.51	2.0905
Dec	230.8	11.766	230.8	58.83	289.63	1.5156
Jan-00	301	32.954	301	164.77	465.77	2.4372
Feb	652.4	23.272	652.4	116.36	768.76	4.0227
Mar	580.5	66.692	580.5	333.46	913.96	4.7825
Apr	409.4	67.412	409.4	337.06	746.46	3.9060
Average	286.275	34.0666	286.275	170.3329	456.608	2.3893

Annual production estimates.

Table Pr.3: Station wise annual production estimates (gm/m2 wet wt.)and percentage contribution of macrofauna and meiofauna.

	Macrofauna		Meiofauna		Total Annual Production Macro +Meio (gm/m2)	% Contribution	
	Actual Biomass gm/m2	Annual Production = biomass x 2.5 (gm/m2)	Actual Biomass gm/m2	Annual Production = biomass x 8 (gm/m2)		Macrofauna	Meiofauna
Stn 1	70.900	177.25	25.076	200.608	377.86	46.91	53.09
Stn 2	67.989	169.97	18.144	145.154	315.13	53.94	46.06
Stn 3	126.322	315.80	22.806	182.449	498.25	63.38	36.62
Stn4	252.108	630.27	30.819	246.551	876.82	71.88	28.12
Stn5	17.268	43.17	31.255	250.041	293.21	14.72	85.28
Stn6	576.156	1440.39	47.143	377.145	1817.53	79.25	20.75
Stn7	369.107	922.77	41.208	329.661	1252.43	73.68	26.32
Stn8	319.675	799.19	35.683	285.467	1084.65	73.68	26.32
Stn9	579.408	1448.52	43.583	348.663	1797.18	80.60	19.40
Stn10	388.225	970.56	45.773	366.181	1336.74	72.61	27.39
Stn11	640.492	1601.23	33.921	271.365	1872.59	85.51	14.49
Stn12	27.597	68.99	33.389	267.111	336.10	20.53	79.47
Average	286.274	715.68	34.067	272.533	988.22	72.42	27.58

To convert the total biomass to annual production estimates the meiofauna is multiplied with a factor 8 (Dye & Furstenberg, 1978) and the macrofauna with factor 2.5 (McLachlan, 1977). The total of both gives the annual production. The production estimates calculated for Thane creek are presented in Table Pr-3. from which it is evident that the overall annual contribution to the secondary production in the creek was more of macrofauna (72.42%) than the meiofauna (27.58 %). However stationwise variations reveal that the stations close to sewage out lets (station 5) or the ones that are highly disturbed (Station 12), the contribution of meiofauna surpassed that of macrofauna; corroborating with the observations of Quadros *et al.* (1996) for the shallow region of Thane creek. In general, the annual production was higher in the downstream stretches of the creek, as discussed earlier. Most workers have reported the significant role of macrofauna in annual production, but Ansari *et al.* (1990) observed dominance of meiofauna in the sandy beaches of Lakshadweep but of a smaller magnitude.

Demersal fishery potential estimate based on the average annual benthic production.

The above average annual total production of 988.22 g/m2/yr can be used to estimate the demersal fishery potential of the creek. Assuming that the average width of the mudflats of the creek was 100 m. (including both the banks) and the length as approximately 26 km, the total mudflat area is approximately 2600,000 m2. using this approximation the total production of the study area amounts to 2569372000 gm/yr i.e. 2569372 kg/yr. According to Slobodkin (1961) energy transfer from one trophic level to the next is of the order of 10 % (ecological efficiency). Using this generalization it can be concluded that the benthos in the study area can support an average fishery yield of atleast 256937.2 kg/year i.e. 21411.433 kg/month. This however is not fully utilized because the fishes were found to feed mostly on phytoplankton and the locals also reported very poor fishery catch in the creek.

A new Pollution Evaluator Index (PEI) based on environmental parameters.

Pollution is a major problem affecting the natural ecosystems around the world. Dybern (1973), defined pollutant as a substance which brings about negative changes in the natural environment. Since time immemorial, various methods are used to study the changes taking place in an ecosystem. Successively many scientists have even suggested different statistical and biological indices to conclusively state the extent of pollution. Some of the popular simple statistical tests & indices include correlation coefficients, average, standard deviation, ‘t & Z’ tests, graphical representations, etc., while the biological indices commonly used include Shannon-Weaver index, Margalef’s index, Menhinick’s index, Eveness index etc. However calculation and interpretation of the above would always require the biologists to seek help of a statistician or acquire adequate knowledge of the same. This problem has been tackled by some workers by evolving indices that can be easily used and interpreted by the biologists, which include Nygaards index, Palmers algal genus / species index, Raffaeli and Mason’s Nematode /

Copepod index, Lampshed's K-dominance curve, Warwick's ABC curve, etc. But for a non-biologist these indices would seem to be equally difficult as the statistical and biological indices. Hence in the present dissertation the author aims at evolving a simple Pollution Evaluator Index for assessing the health of an ecosystem. The tool is based on the standard pollution limits of aquatic ecosystem for different water & soil parameters, suggested by various researchers (Table Pe–1).

Table Pe-1: Pollution limits for water and soil parameters. (Mainly creeks and estuaries or coastal environments.)

Parameter	Reference	Pollution limits described
pH	Levinton (1982)	pH **8** indicates normal marine water; due to decomposition or respiration pH reduces to below 7.5; during photosynthesis it rises to over 9.
Dissolved oxygen	Laponite & Clark (1992)	In nutrient enriched waters dissolved oxygen below **2.5 mg/l** is considered as hypoxic.
PO_4-P	Ryther & Dunstan (1971)	**0.09 mg/l** PO_4-P is the maximum limit for unpolluted waters.
NO_3-N	Raman & Ganapati (1986)	**1.26 mg/l** NO_3-N is considered as semihealthy condition.
Soil Eh	Varshin & Rosanov (1983)	**Eh +200 mV** is considered as weakly reduced condition.
Soil Organic Carbon	Raman & Ganapari (1983)	Organic carbon below **1.22 %** in the sediment is considered as healthy condition.

Thane creek as already discussed in the dissertation is a much polluted ecosystem, where the extent of pollution has also been highlighted by using the different statistical and biological indices. And the pollution evaluator index not only substantiates the extent of pollution, but also succeeds in differentiating the degree of degradation.

The procedure for calculating the index is as follows:

1) The station wise annual average values of the parameters mentioned above are considered for calculating the index.
2) The pollution limit values shown in Table Pe-1 are treated as 100 % for the respective parameters.
3) On the basis of the pollution limits, the percent increase or decrease in the station wise averages of different parameters are calculated.
4) For a fixed percent increase or decrease from the pollution limit value, positive or negative points are assigned. The interval of percent increase or decrease, considered for giving points varies with the parameter as shown in (Table Pe- 2). For example, pH changes in a small range, while in case of PO_4-P or suspended

solids the fluctuations are usually large. Hence for every 1% variation in pH from the pollution limit, ±1 point is allotted; whereas the same ±1 point is assigned for every 25 % change in PO_4-P and 100 % change in suspended solids.

5) Positive points are allotted for the changes towards healthy conditions and negative points for the ones indicating more deterioration of the environment.
6) Finally the points assigned for all the parameters are totaled and depending on the final value the healthiness or pollution at a sampling station is evaluated. The station is said to be **Healthy** when the total of points for all the parameters is a positive number; **Stressed** when the total is zero and **Polluted** when the total is a negative number. Further, the magnitude of deviations from the zero value would indicate the extent of pollution or health.

Table Pe-2: Point assigning scheme based on percent change from pollution limit values of different parameters.

Parameter	Pollution limit considered φ	Decided percent interval for assigning points. φ	Point assigned per the percent increase or decrease from pollution limit.
pH *	8	1%	± 1 point
Suspended solids @	1.703 mg/l	100%	± 1 point
Dissolved oxygen	2.5 mg/l	10 %	± 1 point
PO4-P	0.09 mg/l	25 %	± 1 point
NO3-N	1.26 mg/l	25 %	± 1 point
Soil redox potential	200 mV	25 %	± 1 point
Soil Organic carbon	1.22%	25 %	± 1 point

* - Grading for pH should be reconsidered if pH increases beyond 9.5 as it would not be healthy condition and should be given negative marks.

@ - The standard value for the suspended solids of estuarine waters is not available. Hence the suspended solids average 1.703 mg/l of 1981-82 data (Tandel, 1984 and Pejaver, 1984) is considered as the limit of pollution as the dissolved oxygen was never below the hypoxic limit of 2.5 mg/l at that time.

φ One can change / modify the limits / scheme for freshwater lentic and lotic systems.

By using the above methodology the Pollution Evaluator Index (PEI) was calculated for Thane creek confirming the ecosystem to be much polluted as the PEI for the total average values was –37 (Table Pe-3). The index helps in emphatically stating that the creek is highly polluted in the shallow and narrow region of Thane creek near Thane city, i.e. towards the riverine end stations of 2 to 6. This statement can be further supported by the visual observations that the shallow region faces maximum anthropogenic pressure by way of solid waste disposal, construction & reclamation activities and effluent & sewage release. The station 1 is comparatively less polluted as it is at the junction of Ulhas river where the pollutants are diluted to some extent. Station 12 i.e. the seaward end station seems to be the least polluted of all the sampling stations of the study area. This can be attributed to the large volume of seawater at this station negating the influence of human activities in the region. Both these stations have given low PEI.

Thus the above index can be conveniently used as a tool in estimating the level of pollution in a given time frame. The PEI can be employed in various other ecosystems by considering the tolerance limits for the ecosystem and meticulous planning. With minimum mathematical knowledge, PEI can be correctly and effectively used by a biologist and even by a non-biologist.

Table Pe-3.:Stationwise averages of various parameters and the corresponding calculation of the Pollution Evaluator Index (PEI).

Station wise average values of different parameters used to calculate the Pollution Evaluator Index (PEI).													
Parameters ↓	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12	Average
pH HT	7.37	7.41	7.62	7.73	7.74	7.84	7.74	7.77	7.81	7.75	7.75	7.7	7.69
pH LT	7.6	7.53	7.64	7.9	7.71	7.88	7.88	7.71	7.81	7.77	7.71	7.7	7.74
SS HT	3.08	4.05	6.7	6.43	10.13	4.35	3.88	3.9	6.23	4.43	5.5	5.17	5.32
SS LT	7.47	5.75	1.9	6.88	10.17	8.17	4.28	9.52	9.88	6.75	5.35	6.98	6.93
DO HT	2.73	1.13	1.47	2	2.16	2.98	2.52	2.21	2.9	2.29	2.75	3.11	2.35
DO LT	4.02	2.04	1.88	2.05	1.36	2.09	2.09	3.62	2.1	2.94	2.01	3.12	2.44
PO4-P HT	0.18	0.45	0.354	0.4	0.398	0.34	0.255	0.213	0.204	0.172	0.21	0.1	0.273
PO4-P LT	0.179	0.314	0.337	0.288	0.323	0.294	0.308	0.238	0.245	0.206	0.21	0.107	0.254
NO3-N HT	0.987	0.893	0.945	0.97	0.976	1.073	1.029	0.863	0.939	1.022	1.108	0.836	0.97
NO3-N LT	0.865	0.905	0.922	1.184	0.784	0.995	0.863	1.046	0.914	0.878	0.918	1.102	0.948
Soil Eh	-30.15	-23.58	-30.49	-29.56	-27.75	-28.87	-23.33	-26.57	-22.35	-27.4	-23.68	-24.07	-26.48
Soil OC	2.61	3.9	2.76	2.63	3.46	2.38	2.73	2.1	2.41	2	2.23	2.14	2.63
Points allotted after calculating the % difference from the Pollution limit.													
pH HT	-8	-7	-5	-3	-3	-2	-3	-3	-2	-3	-3	-4	-4
pH LT	-5	-6	-5	-1	-4	-2	-2	-4	-2	-3	-4	-4	-3
SS HT	-1	-1	-3	-3	-5	-2	-1	-1	-3	-3	-2	-2	-2
SS LT	-3	-2	-1	-3	-5	-4	-2	-5	-5	-3	-2	-3	-3
DO HT	1	-5	-4	-2	-1	2	1	-1	2	-1	1	2	-1
DO LT	6	-2	-2	-2	-5	-2	-2	4	-2	2	-2	2	-1
PO4-P HT	-4	-16	-12	-14	-14	-11	-7	-5	-5	-4	-5	-1	-8
PO4-P LT	-4	-10	-11	-9	-10	-9	-10	-7	-7	-5	-5	-1	-7
NO3-N HT	1	1	1	1	1	1	1	1	1	1	1	1	1
NO3-N LT	1	1	1	1	2	1	1	1	1	1	1	1	1
Soil Eh	-5	-4	-5	-5	-5	-5	-4	-5	-4	-5	-4	-4	-5
Soil OC	-5	-9	-5	-5	-7	-4	-5	-3	-4	-3	-3	-3	-5
Total (PEI)	**-26**	**-60**	**-51**	**-45**	**-56**	**-37**	**-33**	**-28**	**-30**	**-26**	**-27**	**-16**	**-37**

In order to authenticate the index it was calculated for the average values of the past **available** data of Thane creek & compared with the present (Table Pe-4). It is clear from the data that the creek was healthy enough during the years 1979-80 (PEI = +12), when Varshney (1982) had raised concern over the deteriorating conditions of the creek. His fear was later confirmed by Athalye (1988) when he suspected stressed environmental conditions in the creek (PEI = -11). However from the present study detrimental condition of the creek is evident. It should be noted here that the PEI for comparison are calculated using averages of the data on few (5) available parameters. Inspite of this, the index has indicated the deteriorating state of the creek. By calculation of the Pollution Evaluator Index one can emphatically point out the changing patterns in an ecosystem and determine the various levels of deterioration by simple mathematical calculation. However it must be noted that atleast 5 environmental parameters should be considered for PEI calculation. When more number of parameters are included in the calculation, the result would be of help in arriving at a correct and unbiased conclusion.

Table Pe-4: Comparison of the past data of Thane creek using the pollution evaluator index

Study period	1979-80		1984-85		Present study.	
Parameters	Average Data	Calculated values	Average Data	Calculated values	Average Data	Calculated values
pH	7.85	- 2	7.45	- 7	7.72	- 3
DO	5.67	+ 12	4.09	+ 6	2.40	- 1
PO4-P	0.174	- 4	0.163	- 3	0.264	- 8
NO3-N	0.185	+ 4	2.047	- 2	0.959	+ 1
OC	1.81	- 2	2.85	- 5	2.63	- 5
Total	--	+ 12	--	- 11	--	- 16

Evaluation of other indices using PEI.

This index is further used to assess the biological and statistical indices, so as to determine the index that gives the correct picture about the status of an ecosystem. This was done by calculating the simple correlation coefficients between the stationwise values of the pollution evaluator index and the statistical indices calculated for macrofauna and meio fauna, presented in Table Pe-5.

The pollution evaluator index is based on the simple principle that the values would fluctuate between positive to negative depending on the status of the ecosystem. The index is **inversely** related to the degree of pollution. i.e. for highly polluted environment the index will give low (more negative) value and for a healthier environment a high value (i.e. positive) will be obtained. Hence when correlation of PEI with the other indices is calculated, it is expected that the indices which have **inverse** relation with the pollution status will give **positive** correlation with PEI, whereas those which have a **direct** relation with pollution status will give **negative** correlation with PEI.

Table Pe-5: Simple correlations of the pollution evaluator index with the statistical indices calculated for benthos.

	N 1	N 2	R 1	R 2	H’	λ	E 5
Total Macrobenthos	0.3461	0.3076	0.4905	0.1201	-0.0286	0.2487	-0.1769
Polychaetes	-0.2160	-0.1813	0.3149	0.1481	-0.2260	0.2198	-0.1672
Seaanemones	0.4532	0.4613	0.4557	0.5426	0.3889	0.1312	0.3664
Gastropods	0.0835	0.2060	-0.1422	-0.5311	0.1519	-0.3490	0.4126
Bivalves	0.3324	0.2270	0.4405	-0.1689	0.4392	-0.4317	-0.1311
Total Meiobenthos	0.5943	0.6033	0.0458	-0.0447	0.6389	-0.6719	0.7195

Values above ± 0.5673 are significant at 5% level of confidence.

From the Table Pe-5 it is evident that only the indices calculated for meiobenthos have given significant & logical (expected) correlations with PEI. The indices N 1, N 2, H’ & E 5 have inverse relation with pollution, hence they have given significant positive correlation with PEI and λ has direct relation with pollution hence has given significant negative correlation. However R 1 & R 2 have given insignificant correlation suggesting that they can be less depended upon for pollution evaluation. As against this different indices calculated for macrobenthos have failed to give significant & logical correlations with PEI. In present case the macrobenthos include different components as polychaetes sea anemones, gastropods, bivalves etc., of which the polychaetes are favoured by pollution, hence have **direct** relation with pollution. Due to this reason the indices for polychaetes have correlations with PEI opposite than expected (negative for N 1, N 2, H’ & E 5 and positive for λ) though they are insignificant. The gastropods, bivalves & sea anemones are adversely affected by pollution, so have **inverse** relation with the degree of pollution. Hence they showed, though insignificant, positive correlation for N 1, N 2, H’ & E 5 and negative for λ (exceptions - sea anemones showing insignificant positive relation for λ and bivalve insignificant negative for E 5). Thus it can be said that, because macrobenthos includes groups that behave differently in a polluted environment, the indices calculated for macrobenthos fail to indicate the status of pollution correctly (corroborating with the discussion in chapter V on macrobenthos). R 1 & R 2 of macrobenthos also gave insignificant and varied correlation coefficients with PEI.

In conclusion following inferences can be drawn

1) In the present study, meiobenthic data & the indices calculated for it could indicate the pollution status of the creek better than the macrobenthos.

2) Of the indices used Hills' numbers (N 1 & N 2), Shannon Weaver index (H'), Simpsons' index (λ) and Evenness index (E 5) were found more reliable to indicate pollution as compared to R 1 & R 2.(Margalef's index (1958) and Menhinick's index (1964))

Giere (1993) has suggested the usefulness of meiobenthic studies as compared to macrobenthos in analysis of pollution. In fact the results of the present dissertation suggest that when meiobenthos and macrobenthos are considered together, the presence of meiobenthos in large numbers with low density and diversity of macrobenthos (along with polychaete dominance) indicate polluted environment. Whereas dominance of macrobenthos (especially mollusca) over meiobenthos indicates healthy conditions. If only meiobenthos is studied, its lower diversity, evenness, low number of dominant groups / species (Hills' numbers) can indicate extent of pollution in a better manner.

From the above discussion it becomes clear that various biological indices N 1, N 2, H', λ, E 5, R 1 R 2 etc., are sometimes reliable to indicate pollution status, whereas sometimes they fail. The main reason for this seems to be the differential response of animals to the pollution stress. However, as PEI is based on water and sediment parameters, it gives more reliable indication about pollution status. It should not be however forgotten that PEI also has some limitations. It may fail to evaluate pollution (or mislead) if the results of single sample study are considered for its calculation, whereas if it is based on average values obtained by studying many samples, it will prove more accurate than the biological indices. This automatically highlights significance of biological studies & indices, which can depict the pollution status, even if single or a few samples are studied to analyse organism types present in the ecosystem. In short, choice of suitable pollution evaluating index should be made thoughtfully.

Conclusion

On the basis of the present study on Thane creek and the comparison of the present data with the comparable past available data, the following, important inferences are drawn.

Hydrology :- The temperature fluctuations in the creek were wide mainly due to the shallowness of the creek. Over the years, the suspended solids have considerably increased affecting the light penetration in the creek. Average salinity of the creek has also reduced due to increasing effluent load and obstructions in tidal flow which indirectly suggests poor flushing of the pollutants. Due to this, dissolved oxygen concentration has got significantly lowered and mostly hypoxic conditions prevail in the creek. The nutrients like phosphates, nitrates and silicates have gradually built up in the creek waters. The hydrological parameters indicate overall detrimental state of the creek.

Sediment :- The study has shown increased siltation due to excess of human aggression in form of solid waste dumping, construction & reclamation activities, etc. Due to siltation the sediment composition has changed in past 15 years from high percentage of clay (silty-clay) to high percentage of silt (Clayey-silt). Moreover the sediments are acting as a sink for nutrients like organic carbon, phosphorus and nitrogen. High organic carbon values suggest high pollution in the creek.

The hydrological and sedimentological studies revealed that the deterioration is maximum on the riverine end and gradually reduces towards the sea.

Plankton :-

a) **Phytoplankton –** The phytoplankton analysis indicates growing eutrophication in Thane creek, with increased phytoplankton density over the past 15 years. Total 45 phytoplankton genera were observed in the creek of which 19 were pollution tolerant genera described by Palmer (1969), and the Palmers' algal genus index totaled a score of 25 indicating high organic pollution.

b) **Zooplankton –** The zooplankton studies also revealed increased density in Thane creek with dominance of opportunistic species like polychaete larvae, certain copepods, hydromedusae, etc. The study also highlights the dissapearance of chaetognaths, fish larvae, ctenophora indicating the dire state of the creek.

c) **Microphytobenthos -** The study of microphytobenthos forms a baseline data for Thane creek. The microphytobenthos comprised mostly of diatoms of epipelic (on mud) and endopelic (in sediment) type; dominated by *Navicula spp., Nitzschia spp., Coscinodiscus spp.* & *Oscillatoria spp.* The benthic algae were patchy in distribution and were governed in a complex manner by the environmental parameters. Further the Palmers' algal genus index for microphytobenthos totaled a score of 15 indicating organic pollution in the creek and corroborating the observations made for the phytoplankton.

Benthos:-

1) **Meiobenthos -** Meiobenthos showed dominance of Nematode group among the 13 organism groups recorded. Meiobenthos dominated the fauna at the stressed stations. Different biological indices calculated for meiobenthos could indicate the levels of pollution at different stations. Thus as mentioned by Giere (1993), meiobenthos data can prove useful in assessment of pollution.
2) **Macrobenthos –** The macrobenthos of Thane creek was dominated by polychaetes, followed by bivalves, gastropods, insect larvae and sea anemone. The faunal density, biomass and diversity varied according to the status of pollution. The upstream stations of the creek were more polluted and had dominance of polychaetes, while the downstream stations had a dominance of molluscs as they were less polluted due to dilution of pollutants by the tidal neritic water. Further it was noticed that various diversity indices calculated for the macrobenthos data did not correctly depict the extent of pollution.

Miscellaneous notes :- Quantitative and qualitative analysis of various aspects related to the intertidal fauna was done. It was observed that the fishery of the creek ecosystem had dwindled considerably and only 5 fishery species occurred dominantly; however, the avian fauna of the creek was rich. Further, the gut content analysis of the various organisms revealed phytoplankton to be the most common diet of all consumers except sea anemones and crustaceans. The productivity aspects showed a mixed picture of the creek with dominance of macrofauna at less polluted stations of the creek, while meiofauna was predominant at the polluted stations. Based on the productivity aspects, the fishery potential of the benthos of the creek was calculated which was observed to be high. However it was noticed that the fishery was not attracted into the creek for feeding and breeding, probably due to the polluted state of the creek, indicating unutilization of the benthic fishery potential.

Based on the findings of the present studies on water and sediment a new Pollution Evaluation Index (PEI) was formulated. The index helped in pointing out the impact and the extent of pollution. The index confirmed that the upstream stretch of the creek was more polluted than the downstream stretches. Moreover a comparison with the past data also indicated a gradual accumulation of pollutants and deterioration.

Further the PEI was correlated with the diversity indices; the results of which emphasized that meiofaunal analysis was a more reliable tool to assess pollution.

Reasons for deterioration

- Heavy industrialization and urbanization in the region, which have increased the effluent load, much higher than the assimilation capacity of the ecosystem.
- Improper management of solid waste disposal, reclamation and construction activities, violation of Coastal Regulatory Zone (CRZ) laws etc. have modified the creek ecosystem. These have resulted in obstruction of the tidal flow, hampered the flushing ability and increased siltation in the creek.
- The industries might be releasing effluents according to the pollution control board norms, but their high number around an ecosystem accentuates the pollution effect.
- The most important reason is lack of political will and public pressure to check the pollution.

Mitigation Strategies

Based on the present study of Thane creek the following mitigation strategies are strongly recommended .

1. Domestic sewage should be minimized, It should be released only after proper treatment to reduce BOD and other toxic substances. In highly urbanized areas and municipal corporation limits it can be made compulsory to the residential complexes and housing societies to treat sewage and effluents and use the nutrient rich water for gardening or other suitable purpose.
2. Industrial effluents should also be properly treated before release. Infact, pollution control board should revise the norms of effluent quality, especially when there is a congregation of industries around one particular ecosystem.

3. Compulsion should be made to follow the coastal regulatory zone (CRZ) laws and violators should be strictly punished. Construction and reclamation activities as far as possible should be avoided, if absolutely necessary, should be meticulously planned so as to avoid obstruction in tidal flow.
4. Banks of the creeks should not be used for solid waste dumping. To achieve this, maximum efforts should be made to minimize the solid wastes. For this purpose bio-composting of decomposable solid wastes should be encouraged within the residential complexes and dry, non decomposable solid wastes should be recycled by developing suitable industries.
5. The common man should be educated about the ecological importance and the need for conservation of resources. This can be achieved by conducting educational trails within and around the creek, as the creek is also rich in avian fauna.
6. Plastics is a menace of the 21^{st} century, to tackle this problem the government needs to completely ban the use of plastics (at least the carry bags) and enforce the use of alternate materials instead.
7. Thane creek is fringed by mangroves and industries along both the banks and both are equally important. The government should strategically plan and compel the industries to protect the mangroves and even take up replantation drive.
8. Most important, the government should try and make the villages self sufficient as a strategy to reduce migration to cities and minimize the associated problems.

Summary

Degradation of natural resources is a major environmental issue the world is currently facing (Twilley *et al.,* 1998). Estuaries and creeks are such fertile, tidally influenced ecosystems that face the onslaught of human activities, leading to pollution. To monitor and detect pollution, various environmental aspects are studied, of which the sedentary, residential benthic fauna from the intertidal mudflats has a lot of significance in the assessment of the ecosystem (Pearson and Rosenberg, 1978). According to Varshney (1982), study of benthos is important as these organisms are more or less sessile and reflect not only the conditions at the time of sampling but also the conditions that prevailed earlier.

Thane creek (Long. 72°.55' to 73°.02' E & Lat. 19°.00' to 19°.15' N) is a mangrove fringed tropical coastal ecosystem which is surrounded by heavily industrialized and urbanized region. The creek is 26 km long which extends northwards from the Bombay harbour bay and joins the Ulhas river by a minor connection near Thane city. The literature surveyed revealed that the creek has been extensively studied by various organizations such as BARC, CPHERI, NEERI, NIO, etc., The aspects that were frequently analysed included hydrology, phytoplankton, zooplankton, fishery, subtidal benthos; while mangroves and the associated saltpans have also been occasionally investigated. However the study on the intertidal mudflats of the entire 26 km stretch was totally lacking, hence the present study was conducted to assess the intertidal fauna and its related aspects. The study was done from May 1999 to April 2000 from 12 stations along the 26 km stretch of the creek. Stations were selected along both the banks (east and west) to represent the entire creek. The observations and findings of the study are summarized below.

Hydrology

Water is the all accommodating solvent and in any ecological study, water analysis forms the base. The hydrological parameters were studied monthly from 12 stations during the neap high tide and neap low tide.using 'Standard Methods'.

Temperature – ranged from 20.5 to 35.5°C (Av. 27.56°C). It was influenced by atmospheric temperature. The relatively wide range was attributed to shallow nature of Thane creek.

Light penetration – varied between 1 to175 cms. (av. 40.94 cms). It was mainly governed by the suspended particulate material in the water column.

Suspended solids – in Thane creek were abnormally high and ranged from 0.2 to 59.2 gm/l (av. 6.12 gm/l). The high suspended solids in the creek were due to the large amount of sewage and effluents released into the creek as well as poor flushing due to hinderance in the tidal flow caused by solid waste dumping and unplanned construction activities. Many fold increase in suspended solids has taken place in past few years, which is alarming.

pH - ranged from 6.36 to 9.45 (av. 7.71), and was also governed by the pollutant load. Lowering of average pH was observed when compared to past available data.

Salinity - varied between 0.1 to 44.5 ppt. (av. 19.23 ppt.). Salinity in general indicated dominance of marine tidal water as compared to freshwater. Low salinities were recorded only during monsoon. However, comparison with past data, revealed lowering of average salinity of the creek due to (1) influence of large quantity domestic and industrial effluent & (2) reduced tidal flow due to obstruction and growing shallowness of the creek.

Dissolved oxygen – in the creek was mostly hypoxic, and fluctuated between 0 to 7 mg/l (av.2.4 mg/l). comparison of the dissolved oxygen levels with the past data on the creek revealed significant deterioration due to pollution. Hypoxia has become characteristic feature of the creek.

The nutrients in general showed higher quantities than most other comparable ecosystems. PO_4-P ranged 0.003 to 0.745 mg/L (av. 0.26 mg/l); NO_3-N ranged 0.126 to 2.84 mg/l (av. 0.96 mg/l) and SiO_3-Si ranged 1.65 to 66.7 mg/l (av. 15.3 mg/l). Build up of silicates in past 10 years was discernible which could be due to dredging & construction activities and geochemical properties of this region.

In general, hydrological parameters indicated higher pollution in the upstream part of the creek compared to the downstream stations.

Sedimentology

The sediment is known to act as the reservoir of nutrients in water. It replenishes these nutrients in times of need and also remove them from water which helps the biological cycle of the system. The sediments of the intertidal mudflats were studied.

Moisture content – varied from 53.94 % to 80.12 % (av. 61.69 %). The moisture content was mainly governed by the sediment texture.

Sediment texture – was predominantly clayey-silt as the silt content averaged 65 %, clay 29 % and negligible sand component. As compared to sediments of 1984-85 studies, which had high clay than silt, the present composition indicated growing siltation in the creek.

Soil pH and Redox potential – varied between 6.83 to 8.24 (av. 7.45), and 10 mV to –72.94 mV (av. –26.48 mV) respectively. The later indicated reduced conditions in the creek.

Chlorides – ranged between 0.099 to 5.616 % (av. 2.04 %) and significantly affected the distribution of biota.

Organic carbon fluctuated between 1.21 to 4.43 % (av. 2.63%), and indicated organic pollution in the creek.

The other nutrients i.e.**Total Phosphorus** (range 0.009 to 1.448 %, av. 0.68%), Available Phosphorus (range 0.005 to 0.026 %, av. 0.017 %) and **Total Nitrogen** (range 0.063 to 0.378 %, av.0.186 %) were also high in the creek showing that the sediments acted as sinks for the nutrients.

The sedimentological parameters suggested pollution status of the creek similar to that suggested by the hydrological parameters.

Plankton

The plankton form a major link in the energy transfer and play a significant role in the production potential of the aquatic environment. The diversity and production estimates of plankton are used to evaluate the biological sensitivity of the area.

Phytoplankton :- are the primary producers occupying the first position in the food chain. In the present investigation the phytoplankton density varied in a wide range between 1200 to 543000 x 10^3 cells /l (av. 52106.88 x 10^3 cells /l), with the riverine stations reporting higher density than the seaward stations.. Total 44 genera and 7 unidentified forms were recorded, of which 43 were observed during low tide. In general 7 genera of phytoplankton were most dominant during high tide and 8 during the low tide.(Viz. *Coscinodiscus spp., Leptocylindrus spp., Skeletonema spp., Thalassiosira spp., Navicula spp., Nitzschia spp., Euglena spp.* and *Chaetoceros spp.*). from the 44 genera 25 represented diatoms, 11 genera consisted of green algae and 7 others. The density of phytoplankton was higher during low tide compared to the high tide. A comparison with the past available data indicated eutrophic conditions of the creek. Moreover from the phytoplankton observed during the study 19 were pollution tolerant and Palmer's index score of 25 indicated high organic pollution in the creek.

Zooplankton – forms the vital link in the pelagic food chain. The abundance of zooplankton practically acts as an index to assess the fertility of water masses. The zooplankton were not studied from every station but were assessed from 5 representative zones in the creek. High zooplankton density was recorded during the present study varying between 902.31 to 492100 no/m^3 (av. 27918 no/m^3) while the biomass ranged from 0.442 to 6.192 ml/m^3 (av. 2.984 ml/m^3). 34 types of zooplankton were observed and categorized into 4 groups. Namely (1) **Zooplankton occurring throughout the creek** included cyclopoid and calanoid copepods, nematodes, nauplii of balanus, zoea of crab, insect larvae, larval stages of gastropods & bivalves and fish eggs. (2) **Zooplankton occurring almost through out the entire creek** consisted of polychaete larvae, ostracod, megalopa of crab and water mites. (3) **Zooplankton influenced by salinity** comprised of the rotifera, penilia and oligochaetes occurring at riverine end, while foraminifera, tintinnida, coelentrates, mysis & shrimps were recorded at the seaward end. (4) **Sporadically occurring zooplankton** included the appendicularia, cirripedia larvae, gammarus spp., prawn and salpa.

It is important to note that the polychaete larvae were most dominant at the riverine end and overshadowed all the other zooplankton forming almost 60 % of the total zooplankton abundance of the creek. Excluding the polychaetes the other zooplankton showed a increasing trend from the riverine to the seaward end of the creek. Although the density of zooplankton has increased in Thane creek in comparison to the past studies, it highlights the dire state of the creek due to the disappearance of chaetognaths, fish larvae and ctenophora that were once abundant.

Microphytobenthos – are the benthic algae that inhabit the top few cms. of the intertidal sediments in estuarine and coastal waters (Kelly *et al.*, 2001). According to Sundback *et al* (2000), they can function as a filter that controls the flux of dissolved nutrients at the sediment / water interface and also the photosynthetic oxygenation of the sediment surface. The present study forms the base line data for microphytobenthos; the density

varied from 0 to 16300 no/cm^2 (av. 43774 no/cm^2). The microphytobenthos encountered during the study were of epipelic (on mud) and endopelic (in sediment) type. A total of 25 algal genera were observed with the dominance of pennate diatoms (64 %) in the entire creek. They consisted of *Navicula spp., Nitzschia spp., Pleurosigma spp.* & *Gyrosigma spp.* The centric diatoms observed were *Coscinodiscus spp., Rhizosolenia spp., Skeletonema spp., Leptocylindrus spp., Thalassiosira spp., Chaetoceros spp., Biddulphia spp.* & *Triceratium spp.* Other than diatoms the green algae (*Oscillatoria spp.* and *Anabaena spp.)* and blue green algae (*Spirulina spp.*) were also observed.
The microphytobenthos were patchy in its distribution and were governed in a complex manner by the environmental factors. An interesting observation during the study was that both the pelagic and sediment algae belonged to the same genera, but the sediment algae were much larger in size indicating different species (not identified). Moreover the Palmers' algal genus index totaled a score of 15 indicating organic pollution and corroborating with the inference of the phytoplankton.

Benthos

The benthos or the bottom fauna according to Ziegelmeier (1972), is involved in the recycling of materials in the marine ecosystem and plays an important role in detritus food chains, as the plankton do in the pelagic zone. Any alteration in benthic community would affect the productivity and demersal fishery.

Meiobenthos- is an important part of the food web and is considered as the best indicator of water pollution, as they act as an energy sink and are important in the regeneration of nutrients (Kuipers *et al.*, 1981). The meiobenthic abundance and biomass during the present study varied between 18200 to 6208440 no/m^2 (av. 760804 no/m^2) and 0.98 to 166.702 gm/m^2 (av. 34.07 gm/m^2) respectively. The meiobenthos showed an increasing trend from the riverine to the middle region of the creek and thereafter declined towards the seaward end. A total of 13 mostly euryhaline groups were recorded, they occurred in the following decreasing order of abundance. Nematodes (86.4 %) **à** Foraminifera (9.45%) **à** Oligochaeta (1.05 %) **à** Polychaeta (0.919 %) **à** Eggs (0.791 %) **à** Bivalve (0.837 %) **à** Gastropods (0.416 %) **à** Larvae (0.139 %) **à** Copepoda (0.138 %) **à** Sea anemones (0.107 %) **à** Zoea (0.029 %) **à** Crustacean eggs (0.022%) **à** Tube polychaetes (0.018 %).

The meiobenthos showed varied correlations with different environmental parameters and hence it is difficult to specify any one particular parameter governing them. However the distribution of meiobenthos and the various indices like dominance, diversity, richness, evenness, etc., indicated highly polluted state of the creek in the upstream part. Further a 10 % reduction in the meiobenthic density was observed as compared to the data of 1991-93, reflecting on the pollution status of the creek.

Macrobenthos – prey on all lower forms of life and according to Duda *et al.* (1982), help to process organic matter and they act as the principal source of food for most fish, i.e. they play an important role in the food chain. According to Odum (1971), macrofauna make better indicators of pollution than smaller species.

The macrobenthic abundance and biomass in Thane creek varied from 100 to 402580 no/m^2 (av. 29583.5 no/m^2) and 0.1 to 3666 gm/m^2 (av.286.27 gm/m^2) respectively. 75 species representing 12 major groups were recorded. The groups occurred in the following decreasing order of abundance. Polychaetes (50.93 %) **à** Bivalves (23.19 %) **à** Gastropods (22.17 %) **à** Insect larvae (1.66%) **à** Oligochaetes (1.14 %) **à** Crustaceans

(0.49%) à Sea anemones (0.239 %) à Tube polychaetes(0.131%) à Balanus (0.026%) à Planaria (0.009%) à other arthropods (0.006%) à gammarus.(0.0009%).

Dominance of polychaetes in an ecosystem indicates pollution. In Thane creek 10 species of polychaetes were recorded. Total polychaete density ranged 0 to 409700 no/m^2 (av. 15066.7 no/m ^{2}), and biomass varied from 0 to 3501.6 gm/m2 (av. 121.84 gm/m2) but were highly abundant in the upstream region of the creek. The second most dominant group i.e. bivalves were mostly restricted to the lower stretches of the creek. The edible bivalves made for the major bulk of the biomass and were recorded only at the seaward stations. The bivalve abundance and biomass ranged from 0 to 113220 no/m^2 (av. 6862 no/m^2) & 0 to 1025.94 gm/m^2 (av. 90 gm/m^2) respectively. The gastropods reported the maximum number of species i.e. 24 and the density and biomass varied between 0 to 139200 no/m^2 (av. 6558 no/m^2) and 0 to 541.4 gm/m^2 (av. 66 gm/m^2) respectively.The gastropods although distributed throughout the creek were abundant in the downstream stretches of the creek and at times absent in highly polluted locations.

Overall the pollution load in the creek governed the distribution and occurrence of various fauna. For example, oligochaetes were reported from the polluted upstream regions of the creek and sea anemones were restricted to the less polluted downstream regions.

The different faunal groups behaved differently with the environmental parameters. The different biological indices did not clearly depict the status of pollution in the creek. On the contrary the meiofauna seemed to be more accurate in indicating pollution. Hence it can be stated that meiofauna is a better tool to decide pollution status.

Miscellanaeous notes

In addition to the above aspects certain other related aspects were also investigated, which are as follows.

Birds – 61 species of birds were recorded on the mudflats of the creek, the birds were dominant on the west bank compared to the east bank. The Flamingoes were restricted to the downstream stretches of the creek while the black winged stilts occurred only at the polluted upper stations.

Fish – Only 8 species of fish were recorded with dominance of only 5 species. The fishing activity was mostly restricted to the lower stretches of the creek While in the upper stretches of the creek fishing was carried out only during the monsoon months.

Gut Contents – Phytoplankton formed the predominant diet of all the faunal organisms with the exception of sea anemones and crabs.

Productivity - The metabolic indices calculated revealed higher nutritional status in the downstream stretches of the creek compared to the upstream locations. Overall the macrobenthos contributed more than the meiobenthos to the secondary productivity. But in polluted and disturbed locations it was the meiobnenthos that dominated.

Total annual production calculated on the basis of macro and meiobenthos showed higher production in the downstream stretches of the creek compared to the upstream.

The fishery potential calculated on the basis of annual productivity estimates revealed that the benthos can support 21411.433 kg./month fishery . However the benthos mostly remains unconsumed by fishery.

Pollution Evaluator Index (PEI) on the basis of the water and sediment parameters. PEI was formulated. It was found useful in assessing the status of pollution of the entire creek and also could give a better picture of the station wise comparison.

Conclusion

In conclusion it was observed that all the aspects studied, indicated growing pollution in the creek. Upstream stretch of the Thane creek was found more polluted than the downstream stretch.

In the past 15 years gradual deterioration of the creek ecosystem was noticed. Some important aspects highlighting the deterioration include..

1. Hypoxic conditions in the creek.
2. Heavy load of suspended solids
3. High amount of nutrients causing eutrophication
4. Growing siltation and shallowness of the creek
5. High meio and macrobenthos, its non utilization by the fishery organisms and the pelagic phytoplankton forming the main diet of most of the organisms.
6. Declined fishery of the creek.

The deterioration was attributed to

- huge quantity of domestic sewage and industrial effluents released in the creek.
- Solid waste dumping
- Reclamation and construction activities obstructing tidal flow to affect the flushing.

Mitigation

In order to combat the pollution certain mitigation strategies are suggested, important onse are :

- Minimization of sewage and solid wastes at source and treatment of sewage before releasing in the creek.
- Reframing of pollution control norms
- Strict implementation of the CRZ laws.
- Prevent migration by making the villages self sufficient.
- Generate awareness and concern for the natural resources among the people at large.

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* Indicates not referred in original

SYNOPSIS

Name of the candidate	: **Mr. Quadros Goldin Ignatious**
Qualification	**:** M.Sc. Zoology (by Research).
Title of the thesis to be submitted	**:** Study of intertidal fauna of Thane creek.
Degree applied for	**:** Doctor of Philosophy (Ph.D.)
Subject	**:** Zoology
Registration number and Date	**:** 17, 27th July, 1999.
Name of the guiding teacher and Designation	**:** Dr. R.P. Athalye Reader in Zoology.
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SYNOPSIS

Study of intertidal fauna of Thane creek.

Preamble

Estuaries and creeks are tidally influenced ecological systems where rivers meet the sea and freshwater mixes with the salt water. These ecosystems provide nursing and breeding grounds for many organisms including commercially valuable fishes and crustaceans. In tropical and subtropical countries these ecosystems are fringed by mangrove forests.

Mangroves are taxonomically diverse group of mainly arboreal angiosperms that grow in the sheltered shores of the tropics and show special physiological and morphological adaptations to stressful environment (Ellison & Stoddort, 1991). The morphological adaptations like prop and stilt roots, apart from helping the plant to survive, gradually trap the fine suspended particles in water leading to accumulation of sediment and formation of mudflats. The mangrove plants along with the mudflats form the mangrove ecosystem. These ecosystems are regularly inundated by tides and can be divided into three zones, namely the upper intertidal zone where the mangroves grow and are submerged mostly during peak tides, the lower subtidal zone which is always submerged under water and the middle intertidal mudflat zone that gets submerged during high tide. The middle zone is enriched by the nutrients coming from both the mangroves and the tidal waters and hence is known to support rich fauna. The life in this intertidal middle zone includes a variety of organisms. The tidal waters during the high tides bring in phytoplankton, zooplankton, a variety of fishes and crustaceans including prawns, which visit this zone either for feeding or for egg laying (breeding). Apart from these visitors the mudflats have their own resident invertebrate fauna that lives in or on the mudflats and are known as benthos. This includes benthic phytoplankton, zooplankton and different invertebrate organism groups including nematodes, oligochaetes, polychaetes, mollusks and arthropods as the most dominant groups. According to Pearson and Rosenberg (1978), study of this resident intertidal benthic fauna has got a lot of significance in assessment of the ecosystem. This fauna being sedentary or less mobile and cannot migrate to avoid stressful conditions, hence gets maximum affected by the changes that occur in the ecosystem caused due to human activities or any other natural reason. Hence, the study of intertidal benthos is considered to be better than the assessment of water quality which is less reliable due to the frequent and unpredictable changes that occur in it. With these considerations in the present study, more emphasis is given on the intertidal benthic fauna.

Thane creek (Long 72° 55' to 73° 02' E & Lat. 19°.00' to 19°.15'N) is a mangrove fringed tropical coastal ecosystem which is surrounded by heavily industrialized and urbanized region. The creek is 26 km long which extends northwards from the Bombay harbour bay and joins the Ulhas river by a minor connection near Thane city. The literature surveyed revealed that the creek has been extensively studied by various organizations such as NIO, NEERI, BARC etc. The aspects that were frequently analysed include hydrology, phytoplankton, zooplankton, fishery and subtidal benthos, while mangroves and the associated saltpans have also been occasionally investigated.

However, the studies on the intertidal mudflats are meager mainly due to difficult access to the mudflats. Athalye (1988), Mukherji (1993) and Gokhale & Athalye (1995) have reported the intertidal benthos from the 5 km. stretch near Thane city. Govindan *et. al.* (1976) have studied the subtidal benthos of the entire creek in 1975. Thus it was apparent that the full stretch of the creek has not been studied for assessment of the intertidal benthic fauna, which made the present dissertation necessary.

The present study.

The study was conducted for one year, from May 1999 to April 2000, at 12 stations (5 on the east bank and 7 on the west bank) along 26 km. stretch of Thane creek. Though the emphasis was on the intertidal fauna, phytoplankton from water and sediment were also studied. The water and phytoplankton samples were collected during neap high tide and neap low tide. Whereas the sediment and benthos were collected during low tide, from the intertidal mudflats between low level water mark and mid level water mark. According to Bourget & Meissier (1983) this region has rich fauna due to the presence of optimum moisture and represents maximum fauna of the ecosystem. Zooplankton was not collected from every station, instead it was collected from 5 regions during neap high tide. Fishery data was obtained from the local fishermen and the food, feeding of fishes were analysed seasonally. For the study internationally accepted standard methods were used.

Broad outline of the dissertation

Chapter I :- Introduction and Materials & Methods.

The Introduction will deal with the need for the present study along with the national and international literature review and a brief description of Thane creek.

In the materials & methods the sampling sites will be described, the materials and methods used for analysis and statistical & biological indices used for interpretation etc. will be mentioned.

Chapter II :- Hydrology

Water is the all accommodating solvent and its quality has a major influence on the biota of an ecosystem. Monthly and seasonal variations in the hydrological parameters like temperature, light penetration, suspended solids, pH, salinity, DO, PO_4-P, NO_3-N & SiO_3-Si will be discussed in this chapter. The data will be compared with the available data of the earlier studies so as to illustrate the change that has taken place in the ecosystem**.**

Chapter III :- Sedimentology

In this chapter monthly variations in the sediment parameters such as texture, salinity, moisture, total phosphorus, available phosphorus & total nitrogen will be discussed as these factors are responsible for the distribution and abundance of benthic fauna.

Chapter IV :- Plankton

The plankton namely phytoplankton and zooplankton are an important base of any food chain. In this chapter, the pelagic phytoplankton types, distribution and their number during high tide and low tide will be described in the first part. The second part will deal with the types, distribution and number of zooplankton in the creek water during the high tide. The third part will illustrate and discuss with the occurrence and distribution of microphytobenthos (benthic phytoplankton)

Chapter V :- Benthos

This chapter will be divided into 2 parts. The first part will discuss the distribution, density and biomass of meiobenthos of Thane creek. Whereas the second part will comprise of the macrobenthos study wherein the station wise and monthly distribution, density and biomass of different species will be assessed.

Chapter VI :- Miscellaneous notes and productivity aspects of the creek

Part I will include miscellaneous notes regarding the fish, the birds, food & feeding of different organisms. An attempt will be made to establish the trophic links between the different intertidal organisms in the creek.

Part II will discuss the productivity of the creek ecosystem on the basis of phytoplankton, zooplankton, meiobenthos, macrobenthos and available fishery data.

Chapter VII :- Conclusion & Suggestions to mitigate the pollution.

This chapter will be divided into two parts. In the first part the conclusions of the entire study will be drawn based on which in the second part remedial measures to mitigate the pollution will be suggested.

Chapter VIII :-Summary

The important findings of the research, described in chapter I to VII will be briefly summarized.

This dissertation will help to assess the productivity of the creek on the basis of intertidal fauna. It will also be useful in analyzing the impact of human interference and pollution in the creek. Above all it will provide the recent data on the intertidal fauna of the entire stretch of Thane creek, which will be useful in future for comparison and hence assessment of the creek ecosystem.

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