"Study of Flora, Intertidal Macrobenthic Fauna and Fishery of Ulhas River estuary and Thane Creek to assess the pollution status and decide mitigation strategy."



Final Report : November 2003.

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Dr. R.P. Athalye
Chief Investigator

Contents

Sr. No.	Title	Page No.
1.	Acknowledgement	i - ii
2.	Contents	iii.
3.	Chapter I - Introduction	1 - 7
4.	Chapter II - Mangroves	8 - 20
5.	Chapter III - Hydrology - Study of Water Parameters	21 - 52
6.	Chapter IV - Plankton	53 - 92.
7.	Chapter V - Study of Sediment	93 - 107.
8.	Chapter VI - Macrobenthos	108 -157.
9.	Chapter VII - Fishery	158 - 163.
10.	Chapter VIII - Heavy Metals	164 - 171.
11.	Chapter IX - Awareness Lectures	172 - 173.
12.	Chapter X - Conclusion and Remedial Measures	174 - 182.
13.	Chapter XI - Bibliography	183 - 191.
14.	Plates	192 - 211.

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Chapter I

Introduction

Estuaries and creeks are coastal aquatic ecosystems which have connection with the open sea. Due to this reason they are influenced by the oceanic high and low tides. The tidal incursion of marine water produces brackish water conditions due to mixing of fresh and saline waters. This leads to formation of salinity gradient with high salinity on the seaward side and low salinity on the riverine end. Even at a station, the salinity in the creeks and estuaries vary with the tides, which is infact the unique feature of these ecosystems. Many organisms who have physiological ability to tolerate the varying salinities take shelter in different zones and establish themselves. As there are many salinity zones, there are diverse faunal types in the creeks and estuaries.

In these ecosystems the sea water penetrates deeper and hence the wave force weakens to make the environment calm as compared to the sea. This facilitates settling of silt, clay and nutrient rich humus brought by the rivers leading to formation of mudflats. The soft sediment mudflats favor establishment and growth of specially adapted mangroves. The root system of mangroves enhance the mudflat formation, finally leading to development of dense mangrove vegetation.

Mangrove forests are very vital ecosystems as they provide support to a complex community assemblage, reduce coastal erosion and serve as sinks for macronutrients, micronutrients and heavy metals. The mangrove plants take nutrients from the tidal seawater and river water and in turn provide natural food to mangrove dwelling fauna (Odum *et al.*, 1982). The forest detritus comprising of fallen leaves and branches from the mangroves, provides nutrients to the marine environment and supports immense variety of sea life in intricate food webs associated directly through detritus and indirectly through planktonic and epiphytic algal food chain (Martinez *et al.*, 1982). As the creeks, estuaries and mangroves along their banks are nutrient rich ecosystems, many marine and freshwater fish visit them for laying their eggs. The young ones grow in these sheltered breeding grounds and then migrate to the sea. There are others which venture into these ecosystems with high tide to exploit them as feeding grounds. Thus, estuaries creeks and mangroves being the feeding and breeding grounds of many marine organisms play an important role in supporting the fishery.

The creeks and estuaries infact have a good flushing ability because of diurnal tidal cycles. The sewage and effluents released in them get flushed with the tide to the ocean and are diluted. This quality has made the two ecosystems suffer. We are over exploiting them by allowing excessive industralization and Urbanization in their vicinity. This has tremendously increased the sewage and effluent load beyond their assimilation capacity, leading to their pollution. Not only effluents are being released in them but their banks are being used as dumping grounds for the solid wastes. Such activities cause hindrance in tidal flushing, leading to accumulation of pollutants, sewage sludge and silt. Thane creek and Ulhas river estuary, the ecosystems encircling Thane Mumbai Complex, are suffering all these stressful conditions described above.

Environmental setting of the study area.

Ulhas river estuary. Ulhas river starts from north of Bor ghat in Sindhudurg district (Long. E 73° 20' and Lat. N 18° 45') nearly 400 m. above the mean sea level. After a North-West course of about 150 Kms, it meets the Arabian sea at Vasai (Long 72° 45' E and Lat. 19° 16' N) together with its main tributaries Kalu and Bhatsai rivers. Highly urbanised and industrialised Ulhasnagar, Kalyan, Thane and Bassein (Vasai) are located on the banks of the downstream 54 km stretch of this river known as Ulhas river estuary. The stretch commences just below the NRC Weir at Wadawali and ends at Bassein ~~(Plate 1)~~

The Ulhas river is mainly monsoon fed river in which the fresh water flow dwindles down during non monsoon season. Near Balkumb, it has a minor connection with Thane creek. The river is situated amidst balastic rocks and receives lot of lithogenic metal load from their chemical weathering. Apart from this, large amount of industrial effluents are released into the river from the industries like chloro-alkail, rayon, pigments, thermal power plants, oil refineries, electroplating, steel, etc. (Mahajan *et al.*, 1987). Sahu and Mukherjee (1985) investigated the effluents discharged from only 18 of the 48 major industries in the vicinity of Ulhas river estuary and inferred heavy pollution. Zingade and Desai (1981), Patel & Patel (1982) have corroborated this conclusion. Thus the estuary is under the influence of industrial wastes. Recently increased urbanization, especially on the south bank, has increased the domestic sewage load into the estuary

through out its stretch. Intensive monitoring under the dept. of Ocean development (DOD) has identified Bombay harbour and Ulhas river estuary as hot spots of pollution.

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 minor connection with 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 cretaceous period (Blasco, 1975; Tandale, 1993). The creek is narrow and shallow at the riverine end due the presence of geomorphic head near Thane city and is broader and deeper towards the sea. It is tidally influenced with dominance of neretic waters and negligible fresh water flow except during monsoon. The substratum of the creek is made up of consolidated and unconsolidated boulders intermingled with the loose rocks and rarely with sand and gravel. Extensive mudflats are formed along the banks of the creek which are characterised by growth of mangroves.

A few decades back heavy industrialization and consequently urbanization have occurred along both the banks of the creek. On the east bank exists Asia's largest industralized zone namely Thane Belapur industralized area along with the Navi Mumbai Urban area. The west bank has highly urbanised Mumbai and Thane region 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 % are engineering 4 % are textile & pharmaceutical and other 23 %. Moreover the human population in Thane city alone has doubled in past 10 years. Such an extensive industralization and urbanization has adversely affected the creek. Gajhbhiye *et al.*, (1981) reported Thane creek to receive 27 mld. of industrial waste water and 6 mld sewage, which increased to 180 mld. and 350 mld. respectively (Mathew 1989). The TMC-ES report (2000) quotes 294 mld. and 145 to 260 mld. industrial waste and domestic sewage waste respectively, released in the creek within the Thane city limits. To this more is added from the Urban areas of Mulund, Bhandup, Kanjurmarg, Deonar, Vikhroli, New Mumbai, Vashi etc. Not only the industrial effluents and domestic wastes 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.

The urbanization and industralization around Ulhas river estuary and Thane creek and the load of the effluents indicate detrimental state of these ecosystems. For such ecosystems under the stress of anthropogenic activities, careful and continuous monitoring of different ecological aspects is necessary so as to access the status and impact of pollution. Such studies will help in deciding the preventive and remedial measures. They can also help in assessing effectiveness of implemented remedial measures. Unfortunately, such monitoring is not seriously practiced in our country, as a result many coastal ecosystems are subjected to uncontrolled pollution affecting their productivity.

A few decades ago the Thane creek and Ulhas river estuary had luxuriant growth of mangroves, other vegetation and a variety of seafood wealth. Different types of prawns, crabs, shells and fishes flourished even in the inner upstream stretches of both the ecosystems. However, in the past 20 years the status of these rich environments has deteriorated. It is very essential to study different parameters of the ecosystems to assess their present status.

Literature survey

Various agencies like BARC, NIO, IIT, NEERI, CPHERI have investigated ecological parameters of Thane creek in past few decades. Metcalf and Eddy (1979) investigated physicochemical parameters of Thane creek while studying the coastal pollution off Bombay. These studies did not include the study of flora and fauna of the entire stretch of the creek. The faunal studies in the shallow upstream region of the creek have been conducted in Thane creek since 1981.Tandel (1984), Pejaver (1984) studied the fish and crustacean fishery during the year 1981-82. Borgaonkar (1988) studied biology of crab *Illyoplax gangetica* from the mangrove mudflats of Thane creek. Athalye (1988) and Mukherjee (1993) analysed macrobenthic fauna of Thane creek. Gokhale *et al.* (1995) studied plankton, benthos and fisheries of Thane creek during period 1991 - 1993. All these faunal studies were confined to 5 km upstream stretch of Thane creek.

Studies on Ulhas river estuary also are intermittently done and the entire stretch has not been assessed systematically. Scientist from NIO have investigated distribution of phytoplankton (Lodh, 1990) and subtidal benthos (Mathew, 1989) up to Bassein creek region of Ulhas river estuary. While studying coastal region of Bombay harbor bay, NEERI and IIT have investigated physico-chemical parameters of the estuary. Qamrul

Hassan (1984) studied the fish *Mystus gulio* to assess the effect of pollution due to effluent near Kalyan-Bhivandi MIDC area. Tandel (1984) and Pejaver (1984) studied fish and prawn fishery only at 1 station on Ulhas river estuary. Mukherjee (1993) compared macrobenthos of a station (Diva) of Ulhas river estuary and a station (Vitawa)on Thane creek. Floral aspects, especially mangrove distribution, was studied by Navalkar, (1947), Pradhan (1951), Chaphekar (1959) and Ashwini Kumar (1983).

Aim of the study.

It became evident from the above literature survey that there had been very few studies which assessed the entire stretch of the creek and the estuary. Different biotic and abiotic environmental aspects were not examined together at one time and the studies dealt with one or few parameters of the environment. It was also noticed that there was lack of study since 1995 which infact was a big gap. The studies should have been conducted atleast alternate year (once in 2 years). Hence the present project was planned so as to assess water, sediment, mangrove flora, aquatic flora and fauna, sediment flora and fauna (Benthos) and fishery of the entire stretches of Thane creek and Ulhas river estuary. According to Bilyard (1979), the benthic fauna is sedentary and resides in the ecosystem, due to which pollution stresses produce significant and noticeable changes in it. Hence he has suggested that the studies on the benthic fauna should be often conducted to assess pollution. Following objectives (aims) were decided while proposing the project

1. The primary aim was to assess the recent status of pollution in Thane creek and Ulhas river estuary by studying hydrological and sedimentological parameters, plankton, mangroves, macrobenthic fauna of intertidal mudflats and fishery.
2. To initiate the base line study so as to find plants or animals which have ability to permanently remove toxic metals from the environment. To find such useful organisms is a slow process and it is not expected to get favourable results immediately.
3. To educate students, NGOs and common people regarding importance of the ecosystems and to have views of different scientist regarding pollution of creeks and estuaries.

Significance of the study

It is expected that

1. The study will provide knowledge about the present ecological conditions of the entire stretch of Thane creek and Ulhas river estuary.
2. The study will reveal the type of organisms which reside in the ecosystems and their condition with respect to pollution.
3. The data will be useful in estimating fishery potential of the two ecosystems.
4. Metal estimation in the tissues of important fishes will show weather they are safe for consumption.
5. The data will be useful to the Government bodies and TMC in planning mitigation strategies to improve the environmental status of the ecosystem.
6. In future, the data will be useful in judging improvement (if any) in the creek / estuary after employing the remedial measures.
7. The importance of creeks, estuaries, mangroves will be conveyed to the people.

The broad plan of the project include

a) Hydrological study - Monthly

b) Sedimentological study -Monthly

c) Study of intertidal benthic macrofauna - Monthly

d) Study of plankton (Phytoplankton and Zooplankton) - Monthly

e) Fishery studies - General survey.

f) Study of Mangroves

g) Study of Heavy metals in different component of the environment.

h) Awareness drive.

It was decided to conduct the study at total 20 stations, 10 from Ulhas river estuary and 10 from Thane creek. However 12 stations from each ecosystem (total 24 stations) were selected.

Description of the study locations.

While selecting the sampling stations following criteria were applied.

1) Care was taken that maximum stretch of the creek and estuary gets represented. In case of Ulhas river estuary the estuarine conditions prevailed from the mouth near Bhayander to Thakurli near Kalyan, hence that much stretch of 40 km was studied by selecting stations along it. In case of Thane creek the total stretch was 25 kms from

Balkum, near the confluence of Thane creek and Ulhas river estuary to Trombay, near the open sea.

2) Stations were uniformly distributed along both the banks so that the environmental status of both the banks will become known.

3) Location with known polluting sources and known human interference get represented.

Following table shows the names of station, bank and presence of any near by polluting source etc. The stations are shown on map of the two ecosystems on Plate 1.

Zone	Stn. No.	Near by location	Bank	Remark	Stn. No.	Near by location	Bank	Remark
	1	Thakurli	S	NPSNB	13	Balkum	W	MEFDA & SWD
	2.	Surya village	N	NPSNB	14	Vitawa	E	Effluents from Vitawa
	3.	Dombivili	S	Near effluent nala	15	Saltpans	W	Major effluents from TMC
	4	Alimghar	N	On island NPSNB	16	Airoli Bridge	E	Residential & Industrial effluents
	5	Mumbra	S	Near the confluence with Thane creek. SWD	17	Mulund / Bhandup	W	Effluent from nearby suburbs
	6	Kasheli	N	MEFDA & industrial effluents	18	Rabale	E	NOCIL, Digha, etc. effluents
	7	Wagbil	S	MEFDA	19	Talawali	E	Local & industrial wastes
	8	Keoni Diva	N	MEFDA	20	Vikhroli	W	Effluents from Godrej area
	9	Nagla Gaon	N	MEFDA	21	Koparkhairnae	E	Efluents from Belapur area
	10	Versova Bridge	S	MEFDA	22	Deonar	W	Near Deonar effluents
	11.	Naigaon	N	MEFDA	23	Vashi	E	Effluents from Vashi region
	12	Bhayander	S	MEFDA	24	Trombay	W	High activity of fishing boats

NPSNB - No Polluting Source Near By; MEFDA - Minor Effluents From Domestic Areas;
SWD - Solid Waste Dumping; TMC - Thane Municipal Corporation.
N - North; S - South; E - East; W - West.

Visits to the study stations.

The study stations were visited by hiring a mechanised boat (for faster travel in mid stream) and a canoe (for reaching the mudflats and mangroves for collection). The visits were done during neap tide period of the month from September 2001 to November 2002.

Chapter II

Mangroves

Introduction.

Mangroves are defined as characteristic littoral plant formations of tropical and subtropical protected coastlines extended over 15.5 million hectares worldwide. Mangroves are found extensively in the estuarine regions where mudflats are wide and gently sloping. Besides estuaries they also inhabit the intertidal regions of the shallow bays and creeks where the environment is conducive for their growth. When a few mangrove trees establish and grow on a mudflat, their root network enhances mud settling process which makes the mudflats extensive. On these sheltered mudflats the mangroves flourish to form a mangrove forest.

The most extensive and luxurious mangroves extend across the Indo-Pacific regions where they are best developed in the delta system of major rivers. These plant communities are well adapted to colonise in saline environments where other species are unable to grow. To survive in the extreme climate the mangroves have special adaptations which are described below.

Adaptations which the mangroves have for living in saline environments

1. Pneumatophores (breathing roots) to survive in the water logged soil
2. Columnar roots to support the inclined stem.
3. Cable roots that form a network in the soil to help the plant remain erect in the soft, sinking mud.
4. Leaves have special salt glands which either store the excess salt or expel it.
5. Viviparous germination so that seeds germinate on the mother plant and the propagules get a chance to germinate in the soft mudflat and are not washed away by the tidal water. (Plate- 6)

Importance of Mangroves

The mangrove forests serve as breeding ground and act as nursery for fish, number of crustaceans, prawns, crabs etc. They also shelter and support growth of molluscs like bivalves and gastropods, that have a number of species ranging in size from a few mm. to about 5 to 8 cms. The mangrove mudflats harbour benthic organisms like the polychaetes, oligochaetes, nematodes, platyhelminthes and a number of bacteria that help

in the decomposition of the mangrove litter. The mangrove litter makes the mudflats so rich in organic matter that they export the nutrients to the aquatic system around (i.e. creeks and estuaries) as well as to the sea and support their authotrophic food chain and the fishery. Thus mangroves create a highly productive environment around them and also make the adjacent water bodies productive.

Other uses of Mangroves:

The earliest reference to the use of mangroves dates back to the year 1280. Following are some of the many uses of mangroves.

Mangroves are used by the coastal villagers for fuel wood and fodder for domestic animals. *Avecinnia* propagules are used as food and a source of proteins and vitamins.

The wood timber does not get warped in water and is termite resistant hence is used for housing, boat building, fencing, poles etc.. It is also a rich source of tannin and a number of chemicals of medical and pharmaceutical importance. Wine extracted from *Avicennia* has aphrodisiac effects. The potential role of mangrove ecosystems is also that it acts as a sink for anthropogenic contaminants in tropical and subtropical areas. Mangrove forests protect the shoreline from erosion. Recently this was observed in Orissa where the damage by cyclone was of lesser extent in the regions where mangroves prevailed. The mangroves in fact can be compared to our lungs. The dense foliage helps in reducing CO_2 sequestration and provide oxygen.

From the above discussion it becomes evident as to why mangroves should be studied and conserved. Studies on the mangroves of Mumbai have been reported by Blatter (1905), Navalkar (1951), Blasco (1975), Untawale (1980), Deshmukh (1990), Gokhale and Athalye (1995). They have warned about the destruction of mangroves.

Inspite of this, the mangroves of Ulhas River Estuary and Thane Creek are declining, due to over exploitation and pollution. In the present project therefore the status of mangroves along the banks of these two ecosystems is assessed.

Materials and Methods :

For the present survey of mangroves of Thane creek and Ulhas River Estuary during the period Sept. 2001 to Nov. 2002, two methods were used.

1) Quadrant Method :

This was employed at every study station (1 to 12 in Ulhas River Estuary and 13 to 24 in Thane creek.) A 10m x 10m quadrant was drawn and the proportion of the plants in the quadrant was decided. Such 5 quadrants were studied to calculate average proportion.

2) Visual estimation :

This was done from the boat while going from one station to another. The mangroves were observed through binoculars to get a rough estimate of the width of the mangrove belt, types of mangroves, damaging factors etc.

While presenting the data was consolidated zone wise as Zone 1 - riverine end, Zone 2 - middle zone and Zone 3 - Seaward; each zone consisting of four study stations.

Results & Discussion:

In all 13 species of mangroves, 13 species of associated plants and 8 species of nonmangrove halophytes were recorded along Thane creek and Ulhas River Estuary (Tables 1 to 3). The dominant species are described below.

Description of some of the dominant mangroves and the mangrove associates that occur along the Ulhas River Estuary and Thane Creek.

A) **Mangroves** (Plate-7)

Avicennia marina var.marina Family: Verbenaceae /Avicenniaceae.

It is one of the front mangroves. It requires continuous inundation by tidal waters.

The pneumatophores are narrow and pointed.

The stem is stout, inclined and is supported by columnar roots. The branches are well spread out with dense foliage.

The leaves are sessile, ovate, with an acute apex. They are thick, with water storage tissue; upper surface is shiny and lower surface is white due to salt accumulated which is extruded from the salt glands.

The flowers are fragrant, yellow

Flowering - April to June.

Uses

1) Wood used as fuel, fencing and poles, Leaves used as fodder, Used for pilings.

2) Aromatic, bitter juice used as abortifacient,

3) Bark used for tanning.

Table 1. List of True Mangroves and their zone wise occurrence.

Genera	Family	Ulhas			Thane		
		zone1	zone2	zone3	zone1	zone2	zone3
1) *Avicennia marina* var. *marina* (Forsk) Vierh	Avicenniaceae	--	+	+++	+++	+++	+++
2) *Avicennia marina* (Forsk.) Vierh. Var. *acutissima* Stapf &Mold		--	--	+++	+++	+++	+++
3) *Avicennia officinallis* (L).		--	+++	++	++	++	++
4) *Aegiceras corniculatum* (L) Blanco (semi mangrove)	Myrsinaceae	--	++	++	++	++	++
5) *Bruguiera Gymnorrhiza* (L) Lamk.	Rhizophoraceae	--	+	+	--	+	--
6) *Bruguiera caryophylloides* (BL)		--	--	+	--	--	--
7) *Ceriops decandra*		--	--	++	--	--	--
8) *Ceriops tagal* (Perr.) Robin		--	--	--	--	+	--
9) *Rhizophora apiculata* (BL).		--	++	--	--	+	--
10) *Rhizophora mucronota* Lamk		--	++	--	--	+	--
11) *Sonneratia apetala* Buch. Ham	Sonneratiaceae	++	+++	+++	+++	+++	+++
12) *Sonneratia griffithi.*		+	++	--	++	++	--
13) *Excoecaria agallocha* (L).	Euphorbiaceae	--	--	++	++	++	++
Total number of species		3	8	8	7	11	6

Table 2 : List of mangrove associates and their zone wise occurrence.

Genera	Family	Ulhas			Thane		
		zone1	zone2	zone3	zone1	zone2	zone3
1) *Acanthus ilcifolius* (L).	Acanthaceae	+++	+++	+++	+++	+++	+++
2) *Calatropis gigantea*	Asclepiadaceae	++	++	++	++	++	++
3) *Clerodendrum inerme* Gaer.	Verbenaceae	++	++	++	++	++	++
4) *Cressa critica*	Scrophulariaceae	--	--	++	++	--	--
5) *Derris trifoliata* Lour.	Fabaceae	+++	+++	+++	+++	+++	+++
6) *Derris spp*		+++	+++	+++	+++	+++	+++
7) *Fimbristylis ferruginea* (L) Vahl.	Cyperaceae	+++	+++	++	+++	+++	++
8) *Ipomoea spp*	Convolvulaceae	++	++	++	++	++	++
9) *Pandanus odoratissimus* (L.F).	Pandanaceae	++	--	++	--	++	++
10) *Porteresia coarctata* (Roxh). Tatcoca	Poaceae	++	++	++	++	++	++
11) *Salvadora persica* (L).	Salvadoraceae	+++	+++	+++	+++	+++	+++
12) *Thespesia populnea*	Malvaceae	++	++	++	++	++	++
13) *Urochondra setulosa* (Trim) Hubb.	Poaceae	++	++	++	++	++	++
Total		12	11	13	12	12	12

Table 3 :List of nonmangrove halophytes and their zone wise occurrence.

Genera	Family	Ulhas			Thane		
		zone1	zone2	zone3	zone1	zone2	zone3
1) *Aeluropus lagopoides* (L.) Trim	Poaceae	--	+++	+++	+++	+++	+++
2) *Sesuvium portulacastrum* L.	Aizoaceae	--	++	++	++	++	++
3) *Suaeda maritime* (L.) Dumort	Chenopodeaeceae	--	--	++	--	++	--
4) *Scirpus littoralis* Schrad.	Chenopodeaeceae	++	++	++	++	++	++
5) *Tarmarix troupii*	Tamaricaceae	--	+	--	+	+	--
6) *Hibiscus spp.*	Malvaceae	+	+	+	+	--	--
7) *Cyperus spp.*	Cyperaceae	++	++	++	+	--	--
8) *Hygrophila spinosa*	Acanthaceae	+	+	+	+	+	--
Total		1	4	4	4	5	3

-- Absent ; + Few; ++ Moderate ; +++ Abundant

Avicennia mararina var acutissima. Family :Verbenaceae/ Avicenniaceae.

It is a variety of *A.marina* the leaves are acuminate and longer than *A. marina marina.* The twigs are much branched . It is also one of the dominant mangroves along Thane Creek and Ulhas River Estuary.

Avicennia officinalis . Family :Verbenaceae/ Avicenniaceae.

A small tree with smooth pale bark.

Leaves: have elliptic, oblong or obovate, lamina, apex obtuse, surface glabrous, smooth and shining above, pale below with hard thin tomentum, base acute ,main veins 4-6 pairs with reticulate venation.

Flowers dingy yellow, sessile in small heads on rigid angular peduncles, which are often two together in upper axils.

Calyx 5 partite, almost at the base, sepals broadly ovate, concave ciliate.

Corolla - lobes 4, ovate, acute subequal. Stamens exerted, Ovary and style villous, stigma shortly bifid.

Capsule ovoid, compressed, beaked, green, wrinkled especially at the base.

Seed completely filling the fruit often germinating on the tree.

Flowering April to June.

Uses :

1) Wood used for small cabinet work, creosoted paving blocks.
2) Bark used for tanning.
3) Ashes mixed with paint, to make them adhere more firmly.
4) Green fruits made into poultice for boils.
5) Leaves used as a fodder, propagules though bitter are also used as fodder.

Sonneratia apetala Fam Lythraceae / Sonneretiaceae

It is also one of the front mangroves .The important characters include.

Leaves opposite, fleshy, subsessile, elliptic, oblong, abovate .

Flowers large, terminal, solitary, axillary or 3 together. Calyx cup shaped, lobes 4,

Stamens many, free, anthers versatile, reniform,

Gynoecium with umbrella shaped stigma. Fruit a capsule, depressed, globose.

Flowering February to July.

Uses

1) Wood used for packing cases, especially useful for opium chests.

for MMR-Environment Improvement Society

2) Timber used in house construction, planks, door boards, rough furniture, boat building, making textile mill bobbins & jute mill rollers.

3) Fruits eaten in curries

4) Bark and fruits used for tanning.

Rhizophora mucronata Fam. Rhizophoraceae

A small shrub.

Leaves opposite, elliptic, acute, mucronate, black dotted below.

Flowers sweet smelling, in axillary, few flowered cyme.

Calyx 4 lobed, yellow, petals 4 ,white, fleshy, on a disc, margin hairy, stamens 8 .

Fruit ovoid, conical ,with persistant, reflexed calyx lobes at its base .

There is vivipary.

Pneumatophores very large, and conical; columnar roots well developed.

Flowering August – December.

Uses

1) Wood used for heavy construction, logs used as poles for temporary bridges, buffers, mine and pit props, brake blocks, stakes for fish traps, tool handles, mallet heads and to make dug out boats.

2) Bark richest source of condensed type of tannin, which is used in leather industry. Spent bark exploited as a source of furfural.

3) Bark astringent used in haemorrhages, haematuria and angina.

4) Fruits eaten, juice made into a wine, young shoots cooked and eaten.

5) Baskets for sifting grains are made from split stems.

6) Yields good quality charcoal.

Rhizophora apiculata Fam. Rhizophoraceae

Description much similar to *R. mucronata* only the leaves have acute apex.

Uses

1) Yields pulp for blotting and corrugating papers.

B) Mangrove Associate (Plate 8)

Salvadora persica Fam. Salvadoracae

Shrubs or trees.

A large and much branched evergreen shrub or small tree with soft, whitish yellow wood.

Leaves some what fleshy , often mucronate at the apex or obtuse.

Flowers greenish yellow in axillary and terminal compound lax panicles, corolla very thin.

Stamens shorter than the corolla but much exerted owing to the corolla lobes being reflexed.

Fruit globose, smooth, red when ripe.

Flowering : November to February

Uses

1) Used in the preparation of toothpaste Meswak

2) Leaves eaten as vegetable and used in sauces, Tender shoots and leaves eaten in salads.

3) Leaves used as camel fodder.

4) Fruits edible, sweet used in the preparation of fermenting drink.

5) Fresh root bark used as a vesicant and used as an ingredient of snuff.

6) Decoction used as a tonic and emmenagogue.

7) Stem bark used for gastric trouble and as a ascarifuge.

8) Decoction of leaves used in Asthma and cough their poultice used for piles & tumors.

9) Fruits deobstruent, carminative, lithnotriptic, diuretic used in biliousnes and rheumatism.

10) Seeds purgative and tonic and yield a fatty oil used on rheumatic swellings.

Excoecaria agallocha Fam. Euphorbiaceae

A small, poisonous, evergreen tree with highly acrid juice.

Leaves alternate, thickly coriaceous, elliptic, acuminate ,entire or serrate.

fragrant, minute, yellowish green.

Male flowers in spikes, sepals 3 and stamens 3

Ovary 3 celled, style free. Capsule 3 lobed.

Flowering : July - August.

It is a mangrove associate.

Uses

1) Wood used for toys, legs of bed stead, floats for fishing nets, packing cases and general carpentary work, can be used for power alcohol manufacture.

2) Bark contains tannin, is emitic.

3) Latex applied to obstinate ulcers also used in preprations for rheumatism, leprosy and paralysis. It is a drastic purgative and abortifacient. Used as a fish poison.

4) Decoction of leaves is given in epilepsy.

5) Roots enter into embrocations for swellings.

Acanthus ilicifolius (Sea Holly). Fam. Acanthaceae.

A small erect shrub, growing in tidal swamps.

Leaves opposite, oblong, or elliptic pinnatifid or toothed, stiff acute or truncate margins with sharp spinous teeth on the ends of lateral veins.

Flowers sessile on opposite pairs forming terminal crowded spikes, calyx deeply divided, lobes 4 in 2 opposite parts.

Corolla blue, bilabiate

Stamens 4, didynamous, thick, anthers 1- celled, densely hairy.

Ovary 2 celled, ovules 4, style slender, stigma bilipped.

Fruit a capsule, oblong.

It is a mangrove associate.

Flowering April-May

Uses

1) Leaves employed for fomentation in neuralgia and rheumatism, also used as a expectorant, powdered leaves used as food for fishes and prawns.

2) Roots used in Asthma, paralysis, Leucorrhea and debility.

Zonewise observations along Ulhas river estuary and Thane creek.

Ulhas river estuary : Total stretch studied was approximately 40 kms from Dombivili to Bhayander. The present mangrove cover along Ulhas river estuary is 1.55 km sq. Overall 40 % of Mangrove cover is lost in past decade mainly due to cutting for fuel, sand landing (Reti bunder) activity, clearing for agricultural land and solid waste dumping etc.

Zone 1 : Stations 1-4 (Kalyan to Alimgarh)

Zonal stretch Approximately 15 kms.

This zone from Kalyan to Mumbra is of 15 km stretch and included stations 1 to 4. The salinity ranged between 0.25 to 27.68 ppt. (avg. 8.68 ppt.) showing higher

influence of freshwater. Mangrove belt in this zone had average width 20 m. including both banks ; thus the total area is estimated to be approximately 0.3 sq.km (15 x 0.02)

At the extreme riverine end, where freshwater was dominant and salinity was low the mangrove species were absent. On the banks there were terrestrial trees like *Pongamia pinnata, Tamarindus indicus ,Ficus religiosa* etc. Down stream, from station two onwards the mangroves species were seen which included *Avicennia officinalis* (ht 30 feet.) and *Sonneretia apetala* (ht 30 feet) in 1:1 proportion . *Avicennia marina* was absent. On the north bank of this zone, there were continuous stands of a type of grass namely *Cyperus spp.* (ht.2-3 ft), which is used by fishermen to capture mudskippers on the mud flat (Plate 14).

The main factors causing the damage to the mangroves were cutting for road construction, paddy fields or fuel and solid waste dumping. Along the south bank there were patches of extensive destruction and wherever there was extensive cutting the mangrove associate *Acanthus ilicifolius* had got established . It is a prickly,gregariously growing ,herbaceous shrub that does not allow the germination of mangrove saplings as it grows densely on the mudflats. Though a mangrove associate, it also has the adaptation for saline conditions, having salt glands in the leaves that accumulate the excess salt.

In zone 1 though the overall mangrove cover was less. At Alimghar near station 4 there was luxuriant growth of *Sonneratia* (reaching 25 feet height) on an island near north bank. The overall proportion of *A. officinalis* : *Sonneretia apetala* : *Acanthus ilicifolius*: Others was 35 : 35 : 20 : 10.

Damage causing factors :

Cutting for paddy fields, road construction, and at some places solid waste dumping or Reti bunder (sand landing).

Zone 2 : Stations 5 -8 (Mumbra to Keonidiva)

Zonal stretch 10 kms approximately.

This zone extended 10 Kms from Mumbra to Keonidiva and included stations 5 to 8. The salinity in this zone was higher than zone 1 and ranged from 0.64 to 33.04 ppt. (Av. 14.34 ppt.). In this zone there is confluence of Thane creek and Ulhas river estuary near station 5. The south bank of this zone is used for unloading the dredged sand which has caused extensive destruction of mangroves; the north bank being relatively undisturbed has luxuriant growth of mangroves. Average width of mangrove belt

including both the banks was approximately 50 m. Hence the total mangrove cover could be 0.5 sq.km. (10 x 0.05 km).

This zone had dominance of *Avieninia officinalis* (height 30 feet, diameter 1.5 feet). The front mangroves *Bruguiera gymnorhiza* (height 5 feet) with knee roots occurred occasionally. The proportion of *Avicennia: Sonneratia :* Others was 50: 25: 25. The mangrove associates of this zone included *Excoecaria agallocha* and *Salvadora persica.* The overall proportion of *A. officinalis* : *Sonneretia apetala* : *Excoecaria agallocha : Salvadora persica : Acanthus ilicifolius* was 50 : 25 : 5 : 8: 12.

Damaging Factors:

In this zone there was extensive reclamation of land for paddy fields, in addition to cutting for paddy fields, road construction, and at some places solid waste dumping or Reti bunder (sand landing).

Zone 3: Stations 9-12 (Keonidiva - Bhayander)

Zonal stretch 15 kms.

Being at the seaward end it experienced higher salinity 0.93 to 36.00ppt. (avg. 22.80 ppt.) In this zone average width of mangrove belt, including both banks was 50 m. thus a total cover approximately 0.75 sq.km. (0.05 km x 15 km). However, at some places there was observed extensive growth of mangroves, for example near Versova bridge there was a 0.2 km. x 1.5 km = 0.3 sq.km. patch of mangroves with the representation of all the types of mangroves of this region. In addition a new species *Bruguiera caryophylloides /cylindrica* were also recorded growing up to 3 feet in height. Around stations 9 and 10 of this zone, trees of *Rhizophora apiculata and Rhizophora mucronata* of height 15 to 20 feet with well developed propagules and columnar roots were spotted for the first time. In general, the dominant mangrove type was *Avicennia marina*. However at some places proportion of *A.marina* : *Sonneratia apetala* was 50 : 50. The mangrove associates in this region included *Clerodendron inermae, Ipomoea spp., Excoecaria agallocha, Thespesia populnea and Salvadora persica*

Damage Causing Factors :

The major damage causing factors in this zone include anthropogenic activity, sand landing at Reti bunder, cutting for fuel, roads and construction of houses. The damage was more extensive on the south bank.

Thane creek

The zonewise distribution of mangroves along 26 km. stretch of Thane creek from Balkum to Trombay has been described below. Total existing mangrove cover along the banks of the creek is approximately 2.2 sq km. In general, 40 % mangrove area has been lost in past decade due to solid waste dumping, reclamation, cutting for aquaculture ponds, etc.

Zone 1 Stations 13- 16 (Balkum - Airoli)

Total stretch 6kms.

Being on the Riverine side the average salinity was less (19.30 ppt.) and ranged from 0.46 to 34.80 ppt. The mangrove zone was approximately 50 m wide (including both banks) thus making a total cover of 0.3 sq.km. (0.05 km x 6 km). However near stations 14 & 15 there was an isolated island with an area 0.25 sq.km. having tall mangroves (upto 16 feet). In general, there was dominance of *A.marina* var *acutissima* with average height 18 to 20 feet. The mudflats in this zone were extensive unlike Ulhas river estuary. By end of monsoon they were dotted by the saplings of *A.marina* and *S.apetala* growing to a height of around 1 –2 feet. The saplings however could not establish and disappeared by summer. There were 12 spp. of associate mangroves and 4 spp. of non mangrove halophytes in this region.

Damage Causing Factors: The main mangrove damaging factors in this zone were cutting for fuel & fish aquaculture ponds and dumping of solid wastes. Hence, extensive growth of *Acanthus ilicifolius* was observed. Proportion of *Avicennia marina : Sonneretia apetala : others* was 40: 40: 20.

Zone 2: Stations 17- 20 (Airoli - Ghansoli)

Total stretch 10 kms.

In this zone the salinity was slightly higher (1.90 to 38.00 ppt. Avg. 23.51 ppt.), the average width of the mangrove belt was 100 m. hence the total cover 1 sq.km. (0.1 km. x 10 km.). The dominant mangrove type was *A.marina* reaching a height of 3 m. Due to mangrove plantation done near Vikhroli by Godrej, the species diversity in this region was more. Species like *Bruguiera cylindrica, Ceriops tagal, Rhizophora mucronata , Aegiceras corniculatum,* were recorded in this region. Most of the associate species were also recorded in this zone along with the mangrove associate *Excoecaria agallocha.*

Damage Causing Factors: The mangroves suffered damage due to reclamation for saltpans, fish aquaculture ponds and cutting for fuel. A layer of oil & grease was seen on the mangroves probably due to industrial pollutants released in this region.

Zone 3 : Stations 21- 24 (Ghansoli - Trombay)

Total stretch 10 to 12 kms.

This zone being at the seaward end experienced higher average salinity (5.20 to 38.00 ppt. Avg. 27.42 ppt.). The distribution of mangroves was uneven in this zone. The average width of the mangrove belt was 75 m hence total mangrove cover was 0.9 sq.km.. The dominant mangrove type was *A.marina* along with patches of *S.apetala*, whereas the dominant associate plant type was *Acanthus ilicifolius.* The other associates also occurred significantly in this region. The proportion of *A.marina* : *S.apetala:* others was 60: 25 :15.

Damage Causing Factors : Cutting for fuel, and aquaculture ponds was the main factors damaging the mangroves. In certain regions solid waste dumping also damaged the mangroves.

Seasonal variations

Monsoon

- ✓ **Early monsoon** - flowering of ***Avicennia spp.***
- ✓ Fruiting of ***Avicennia spp***. which continues up to October
- ✓ Flowering and fruiting of ***Sonneratia spp.***
- ✓ **Late monsoon** - flowering of ***Rhizophora spp.***, fruiting continues upto the next year into premonsoon.
- ✓ Flowering and Fruiting of ***Salvadora spp.***
- ✓ Flowering of ***Excoecaria spp.***
- ✓ Infestation of ***Hablea purea*** moth to ***Avicennia spp.***
- ✓ Occurrence of **Tassar silk moth**.
- ✓ Occurrence of **Praying mantis, leaf curl insects**
- ✓ Germinating propagules of mangroves on the mudflats.
- ✓ Secondary growth of the mangroves starts with onset of monsoon resulting in much branching.

Post monsoon

- ✓ *Rhizophora spp.* flowering
- ✓ Death of germinated propagules.

Premonsoon

- ✓ Flowering of *Acanthus ilicifolius*

Conclusions.

In general, the Ulhas river estuary, showed low mangrove diversity on the Riverine end and more diversity in zones 2 & 3. Thane creek had more diversity in the middle zone due to plantation efforts by Godrej. Cutting for fuel, solid waste dumping, reclamation for road or construction were the damaging factors common to both Thane creek and Ulhas river estuary. However, reclamation for agriculture and sand landing centers, cutting for fuel were predominant along Ulhas river estuary, while reclamation for fish aquaculture, solid waste dumping were the significant factors for Thane creek. In spite of favourable water conditions for mangrove growth in Ulhas river estuary, it had comparatively less mangrove cover along its banks (1.5 sq. km.) than Thane creek (2.3 sq.km.) It was observed that the mangrove cover in both the ecosystems was rapidly declining. In past one decade extensive cover is lost due to various anthropogenic activities. Conservation of mangroves needs to be done on top priority basis.

Recommendations.

Mangrove trees are very important for protecting the shoreline. They also provide food to the aquatic fauna. Their destruction by cutting for fuel and reclamation for various purposes should be stopped. If at all they are cut and utilized for the benefit of local people, then their plantation should also be done and taken care of by the people who have reaped the benefits of these plants. People should not wait for some expert, outside agency or government agency to take a project to do the plantation, they should do it themselves.

If the mudflats are cleared for aquaculture ponds, only the required piece of land should be cleared, and the banks of these ponds should be specially planted by mangrove trees which will also be a source of nutrients to the growing shrimps and fishes in the aquaculture ponds.

If proper plantation is not done and the mudflats are left exposed, the prickly *Acanthus* will occupy that place. As it is very difficult to destroy *Acanthus illicifolius,* the mangrove cover will be lost.

To achieve conservation, local people need to be educated and motivated.

Chapter III

Hydrology – Study of Water Parameters

Introduction

Hydrological studies have their own significance in assessment of aquatic ecosystems. They can illustrate the metabolic processes taking place in water and also indicate pollution status of the ecosystem. The only draw back of these studies is, they can indicate about the happenings at the time of collection and not the past ones. However, when water parameters are studied from time to time and compared, can indicate the changes (such as deterioration etc.) in the ecosystem. The hydrological studies include the studies of physical and chemical parameters of water.

Materials and Methods

The surface water samples were collected monthly from the 12 stations each in both the ecosystems, during spring high tide and spring low tide, using clean PVC containers. The following parameters were analysed using Standard Methods (APHA, AWWA, WPCF, 1971).

Parameter	Method
Water temperature (°C)	Alcohol thermometer (0 - 110 °C).
Light penetration (cms)	Secchi disc of diameter 20 cm
Suspended solids (gm/l)	Evaporation of filtered and unflitered samples at 70 °C
pH	Systronics pH meter.
Dissolved Oxygen (mg/l)	Wrinklers' Method.
Biochemical Oxygen Demand (mg/l)	5 day BOD at 20 °C using Wrinklers' method.
Phosphate Phosphorus (mg/l)	Ammonium molybdate method.
Nitrate Nitrogen (mg/l)	Phenol disulphonic acid method.
Silicate Silicon (mg/l)	Molybdo silicic acid method.

The water temperature, light penetration and dissolved oxygen were studied on the field, while Suspended solids, pH, BOD and nutrients were analysed in the laboratory.

Physical parameters.

Water temperature (°C)

Water temperature is very important parameter. It has direct impact on the physiology, growth and reproduction of aquatic organisms, both plants and animals.

In Ulhas river estuary the water temperature ranged from 20 to 35 °C. The minimum was observed in winter and the maximum in summer season (Table Temp. 1 & 2). In general high tide showed warmer temperature than the low tide (Fig. Temp. 1). stationwise average temperatures showed gradual increasing trend from station 1 on riverine end to station 6 near confluence with Thane creek followed by drop in temperature by approximately 2°C at station 7 and then again gradual increase up to station 12. The variations in general were not statistically significant. The monthwise trend (Fig. Temp. 2 and 3) indicates influence of seasonal variations on the water temperature.

In Thane creek the temperature varied in a wider range from 21°C (in winter) to 35 °C (in summer). If annual averages are compared (Figs Temp 4 & 5), Thane creek showed warmer waters. This could be due to more shallow nature of Thane creek and less water mass than the Ulhas river estuary. Warmer high tide temperatures (Fig Temp. 1) suggest warmer seawater. Stationwise trend (Fig. Temp. 1) showed lower temperature on the riverine side (Station 13) which gradually increased seawards, whereas monthwise trend (Fig. Temp. 2 and 3) indicated low temperatures in winter, warm in summer and again drop in temperature during rainy season.

Table Temp-1: Monthly and stationwise variations in water temperature (°C) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	30.5	31.5	31	32	32	29.5	30	30	29.5	29.5	29.5	29.5	30.38	29	28	28	29	29.5	29.5	29	30.5	30	30	30	30.5	29.42	29.92
Oct	30	30.5	31	31.5	32	32	31	31	30	30	30	30	30.75	31	30	30	29.5	30	30	31	31.5	31	32	31	31.5	30.71	30.73
Nov	27.5	27.5	28	28	28	28.5	28.5	27.5	27	27	27	27	27.63	27.5	27.5	28	28	27.5	28.5	28.5	28	28.5	27.5	28.5	28	28.00	27.81
Dec	27.5	27	27.5	27.5	27	27	27	28	28	29	29	29	27.79	28	27.5	28	28	28.5	28.5	27.5	29	27	27.5	27	29	27.96	27.87
Jan	27.5	27.5	27.5	26.5	26.5	25	25	26	26.5	26.5	27	27	26.54	25	25	25	25	26	26	27	27	27	27	27.5	27.5	26.25	26.40
Feb	25	25	25.5	25.5	26	26	25.5	26	26.5	26.5	27	27	25.96	24	24	24.5	24	24.5	24.5	24.5	25	30	29.5	29.5	29.5	26.13	26.04
Mar	28	28	28	28.5	28.5	28.5	27.5	27.5	27.5	28	29	29	28.17	28	29	29	29	29.5	29.5	30	30	30	30	31	31	29.67	28.89
Apr	32	32	32.5	32.5	32.5	32.75	30	30	30.5	30.5	30.5	31	31.40	31	31.5	31.5	32	32.5	32.5	33	33.5	33.5	33.5	33.5	34	32.67	32.01
May	30.5	30.5	31	31	31.5	31.5	30.5	30.5	31	31	32	32	31.08	31	31.5	31.5	31.5	32	32	32.5	32.5	32.5	32.5	32.5	32.5	32.04	31.54
Jun	29	29	29	29.5	29.5	30	27	28	29	29	29.5	29.5	29.00	34	34	33.5	33.5	33.5	34	34	35	35	35	34.5	35	34.25	31.52
Jul	28	28	28.5	28.5	28.5	29	28.5	29	29	29	29.5	30	28.79	30	30	30	30	30	31	31	31	31	31	31	31	30.58	29.65
Aug	28	28	28	29	29	29.5	27	27.5	27	28	28.5	29	28.21	31	31	31.5	31.5	31.5	31.5	32	32	32	32.5	32.5	32.5	31.79	29.93
Sept	31	31	31.5	31.5	32.5	32.5	29	29	29.5	30	30	30	30.63	28.5	27.5	28	27.5	28	28.5	29	29	29.5	29.5	29.5	30	28.71	29.71
Oct	31	31	31.5	31	31	30.5	31	32	30	31	31	30.5	30.96	30	30	31	30	30	30.5	30.5	31	31	31	31	32	30.67	30.82
Nov	26	26	26	26.5	27	27	26	26	27	27	27	27	26.54	27	27.5	28	27.5	27.5	28	28.5	28.5	28.5	29	29	29	28.17	27.32
Avg	28.77	28.83	29.10	29.27	29.43	29.28	28.23	28.53	28.53	28.80	29.10	29.17	28.92	29.00	28.93	29.17	29.07	29.37	29.63	29.87	30.23	30.43	30.50	30.53	30.87	29.80	29.34

Table Temp-2: Monthly and stationwise variations in water temperature (°C) during Low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	29.5	30	30	30	30	29	29	29	29	28.5	28.5	28.5	29.25	28	27.5	27.5	28	28	28	28.5	29	28.5	29	28.5	29	28.29	28.79
Oct	27	28	28.5	28.5	28.5	30	30	30	29.5	29.5	29	29	28.96	29	28.5	29	29	29	29	28.5	29.5	28.5	29.5	29	29.5	29.00	28.98
Nov	26	26.5	26.5	27	27	27	27	27	26.5	27	27.5	27.5	26.88	28	28	26.5	26.5	26.5	26.5	27	27	27	27	27	27	27.00	26.94
Dec	27	27	27	27.5	27.5	27.5	27	27.5	27	27	27	27	27.17	26	27	27	27.5	27	26	26.5	27	26.5	28.5	26.5	27	26.88	27.03
Jan	22	22.5	22.5	23	23	23.5	20	22	24	25.5	24	23	22.92	24	24.5	24.5	24.5	25	25	26	26	26.5	26	26.5	26.5	25.42	24.12
Feb	21	21	21.5	21.5	22	22	22	21.5	22	22	24	23	21.96	22	21.5	21.5	21	22	22	23	23	29	29	29	29	24.33	23.10
Mar	21	21	21	21.5	21.5	22	20	20.5	20.5	21	21	21	21.00	28	28.5	28.5	28.5	29	29	29	29	29.5	29.5	30	30	29.04	24.86
Apr	28	31	31	31.5	31.5	31.5	31	31	31	31.5	31	32	31.00	31	31	31	31	32	32	33	33	33	33	33	33	32.17	31.56
May	29	29	29.5	29.5	30	30	30	31	31	31.5	31.5	31.5	30.29	30	31	31	31	31.5	31.5	32	32	31.5	32	31.5	32	31.42	30.83
Jun	33	33	33	33.5	34	35	33	33	33	32.5	33.5	34	33.38	33	33	33	33	33	33.2	33.6	34	34	34	34	34	33.48	33.43
Jul	27	27	27.5	27.5	28	29	29	29	28.5	29	29.5	29.5	28.38	29	29	29.5	29.5	29.5	30	30	30	30	30	30.5	30.5	29.79	29.06
Aug	27	31	31	31	30.5	30.5	28	29	29	29	30	30	29.67	31	31	31	31	30	30	30	30.5	30	32	32	32	30.88	30.25
Sept	29	29	30	30	30	31	28	28	29	29	29	29.5	29.29	28	27	27	27	27.5	27.5	28	28	28.5	29	29	30	28.04	28.69
Oct	29	29.5	29.5	29.5	30	30	28.5	28.5	29	30	30	30	29.46	29	27.5	27.5	28	28	29	29	29.5	29.5	29.5	30	32	29.04	29.26
Nov	25.5	25.5	25.5	26	26.5	27	25	24.5	26.5	26.5	26.5	27	26.00	27	27	27.5	27	27	27.5	27.5	27.5	28	28	28	28.5	27.54	26.74
Avg	26.73	27.40	27.60	27.83	28.00	28.33	27.17	27.43	27.70	27.97	28.13	28.17	27.71	28.20	28.13	28.13	28.17	28.33	28.41	28.77	29.00	29.33	29.73	29.63	30.00	28.82	28.24
Ht+Lt Avg	27.75	28.12	28.35	28.55	28.72	28.81	27.70	27.98	28.12	28.38	28.62	28.67	28.31	28.60	28.53	28.65	28.62	28.85	29.02	29.32	29.62	29.88	30.12	30.08	30.43	29.31	28.79

Fig. Temp-1: Comparison of the average high tide and low tide variations in water temperature.

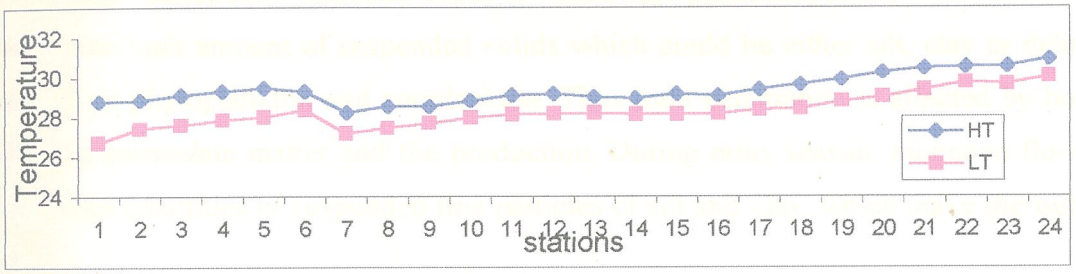


Fig. Temp-2: Comparison of monthly average water temperature during high tide in Ulhas river estuary and Thane creek.

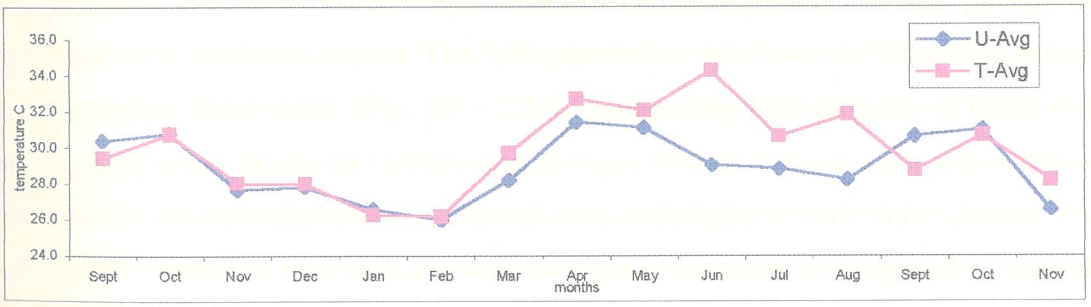


Fig. Temp-3: Comparison of monthly average water temperature during low tide in Ulhas river estuary and Thane creek.

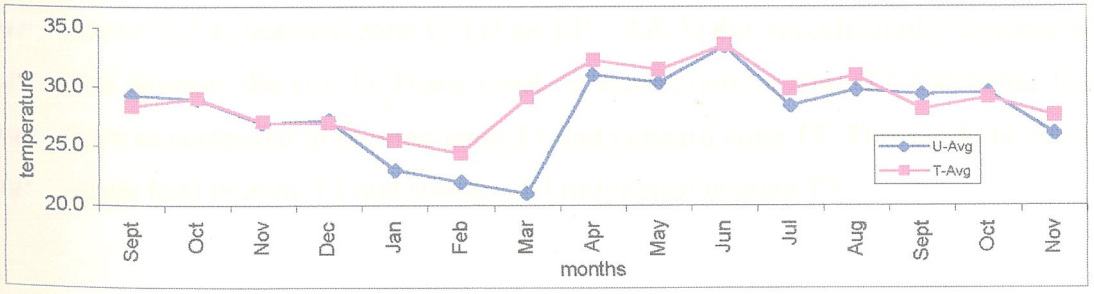


Fig. Temp-4: Zonewise comparison of annual average water temperature during high tide in Ulhas river estuary and Thane creek.

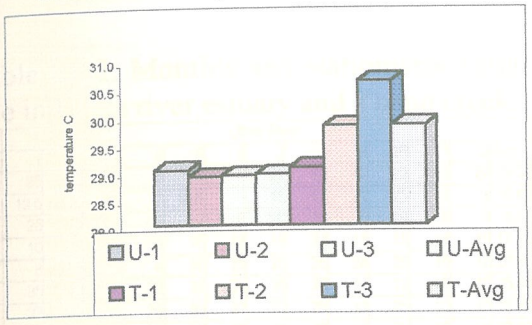
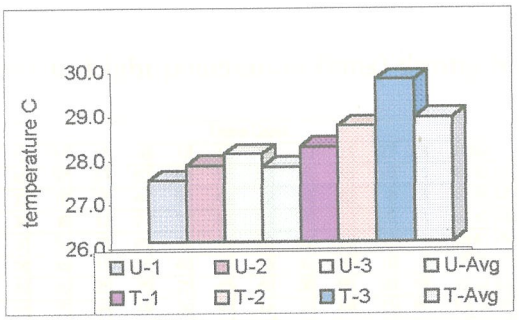


Fig. Temp-5: Zonewise comparison of annual average water temperature during low tide in Ulhas river estuary and Thane creek.



Light penetration (cms)

Light penetration indicates depth to which light penetrates in the water. It can be low due to high amount of suspended solids which could be either silt, clay or debris particles or phytoplankton and zooplankton. Thus light penetration is affected by both polluting particulate matter and the production. During rainy season, monsoon floods bring large quantities of suspended fine particles of silt and clay, which make the water turbid.

The light penetration in Thane creek and Ulhas river estuary ranged from 1 cm to 122 cms and 1 to 85 cms. respectively (Table LP- 1 & 2). In general low light penetration was observed in monsoon season. The light penetration was lower in Ulhas river estuary as compared to Thane creek (Fig. LP. - 2,3,4,5) suggesting high turbidity in Ulhas river estuary. This could be due to 1) More and stronger flow of riverine water which caused more turbulence with tidal water. 2) Extensive sand dredging activity in the estuary. Due to high turbulence the high tide showed low light penetration as compared to low tide (Fig. LP-1). In Thane creek the comparison between low tide and high tide did not show any definite trend (Fig LP 1). In Ulhas river estuary the light penetration decreased from riverine zone U-1 to seaward zone U-3 (Figs LP. - 4 & 5) this was effect of the increasing turbulence towards the sea. In Thane creek however, middle zone T2 had better light penetration as compared to riverine zone T1 and seaward zone T3. This could be due to high sewage load in zone T1 and strong tidal turbulence in zone T3.

Comparison of the present data with past data from Ulhas river estuary (Mishra, 2002; Fig LP-6) and Thane creek (Quadros 2001; Fig LP-7) showed slightly improved light penetration in Ulhas river estuary and declined average in Thane creek.

Table LP-1: Monthly and stationwise variations in Light penetration (cms) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	85	35	56	5	19	8	22	18	40	22	18	20	29.00	45	57	67	62	68	85	22	20	88	10	1	36	46.75	37.52
Oct	19.5	15	32	7	18.5	3	15	17	31	25	6	8	16.42	32	18	55	44	56	48	42	33	82	8	3	40	38.42	26.98
Nov	26	15	35	10	21	6	20	25	8	19	6	9	16.67	36	36	43	29	29	80	51	35	122	5	1	40	42.25	28.95
Dec	10	20	25	18	15	13	18	33	11	15	14	15	17.25	30	30	45	45	48	68	50	30	114	5	1	35	41.75	29.01
Jan	8	35	5	8	10	25	25	35	38	25	15	15	20.33	38	35	15	35	45	50	55	32	110	10	5	10	36.67	28.17
Feb	35	40	30	32	36	35	25	25	15	12	15	10	25.83	30	30	25	25	25	45	45	36	95	20	15	15	33.83	29.67
Mar	27	29	28	22	30	32	20	25	15	25	12	10	22.92	25	35	35	38	29	40	44	35	88	15	15	10	34.08	28.28
Apr	38	35	25	25	30	25	20	22	18	20	15	8	23.42	30	30	35	35	30	35	40	30	60	10	10	25	30.83	26.98
May	35	32	30	30	25	20	15	20	10	15	17	10	21.58	25	25	15	36	34	36	38	32	48	8	10	15	26.83	24.10
Jun	40	35	30	30	25	20	18	20	15	20	15	15	23.58	15	20	20	35	30	33	35	34	30	15	10	15	24.33	23.94
Jul	15	20	20	15	10	15	20	22	30	22	14	5	17.33	20	20	22	30	32	32	35	30	68	15	8	15	27.25	22.09
Aug	18	18	15	10	10	12	15	18	24	18	16	5	14.92	15	28	20	25	30	46	40	25	50	10	8	10	25.58	20.04
Sept	65	40	45	20	35	10	25	26	35	30	15	25	30.92	30	50	55	58	75	88	30	25	75	15	4	30	44.58	37.48
Oct	35	28	20	18	35	5	30	25	30	25	20	20	24.25	32	35	40	45	50	65	35	30	75	15	9	30	38.42	31.05
Nov	35	20	45	20	25	15	20	22	33	25	15	25	25.00	30	25	40	35	45	45	40	42	75	10	10	25	35.17	29.88
Avg	32.77	27.80	29.40	18.00	22.97	16.27	20.53	23.53	23.53	21.20	14.20	13.33	21.96	28.87	31.60	35.47	38.47	41.73	53.07	40.13	31.27	78.67	11.40	7.33	23.40	35.12	28.28

Table LP-2: Monthly and stationwise variations in Light penetration (cms) during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	40	38	45	58	35	15	33	39	14	18	19	15	30.75	35	20	60	56	43	38	35	20	102	10	1	36	38.00	34.23
Oct	45	29	30	26	35	18	30	20	19	18	15	15	25.00	40	25	50	50	48	47	30	33	75	15	1	40	37.83	31.16
Nov	33.5	35	38	34	30	12	30	22	18	10	7	10	23.29	20	30	55	35	20	65	33	35	98	15	2	40	37.33	30.03
Dec	29	35	33	30	28	8	22	35	12	14	15	12	22.75	25	18	55	35	27	60	39	30	90	10	5	35	35.75	28.99
Jan	15	50	10	10	20	26	43	38	48	33	10	18	26.75	40	35	20	40	57	60	60	40	95	15	20	35	43.08	34.59
Feb	55	50	40	44	50	45	30	35	20	17	9	8	33.58	35	40	35	45	57	55	65	60	60	33	25	40	45.83	39.46
Mar	76	32	45	50	55	55	65	45	25	20	15	10	41.08	38	35	30	40	45	45	58	58	55	55	20	40	43.25	42.12
Apr	45	52	10	35	65	28	75	50	25	35	20	20	38.33	22	30	30	48	35	32	5	7	10	10	10	22	21.75	30.37
May	68	32	5	29	60	35	77	58	35	30	2	5	36.33	25	35	35	30	30	25	25	30	15	15	15	25	25.42	31.09
Jun	60	45	20	34	60	10	19	30	15	25	3	1	26.83	33	43	35	20	33	33	65	65	18	15	15	10	32.08	29.35
Jul	25	27	8	20	25	28	15	15	10	15	3	3	16.17	20	30	32	35	19	20	25	25	35	35	20	25	26.75	21.25
Aug	57	25	20	27	33	28	13	15	15	25	2	8	22.33	27	47	35	22	60	58	20	24	35	35	32	30	35.42	28.61
Sept	70	35	20	35	40	6	30	30	40	30	25	20	31.75	45	30	35	40	62	70	45	35	70	20	8	20	40.00	35.71
Oct	50	35	10	30	30	3	35	33	45	20	25	25	28.42	40	40	25	25	35	40	33	28	96	18	15	25	35.00	31.58
Nov	30	35	25	10	20	10	25	30	35	20	15	15	22.50	25	20	25	40	50	40	45	50	80	15	15	30	36.25	29.10
Avg	46.57	37.00	23.93	31.47	39.07	21.80	36.13	33.00	25.07	22.00	12.33	12.33	28.39	31.33	31.87	37.13	37.40	41.40	45.87	38.87	36.00	62.27	21.07	13.60	30.20	35.58	31.84
Ht+Lt Avg	39.67	32.40	26.67	24.73	31.02	19.03	28.33	28.27	24.30	21.60	13.27	12.83	25.18	30.10	31.73	36.30	37.93	41.57	49.47	39.50	33.63	70.47	16.23	10.47	26.80	35.35	30.06

Fig. LP-1: Comparison of stationwise average high tide and low tide variations in light penetrations (cms)

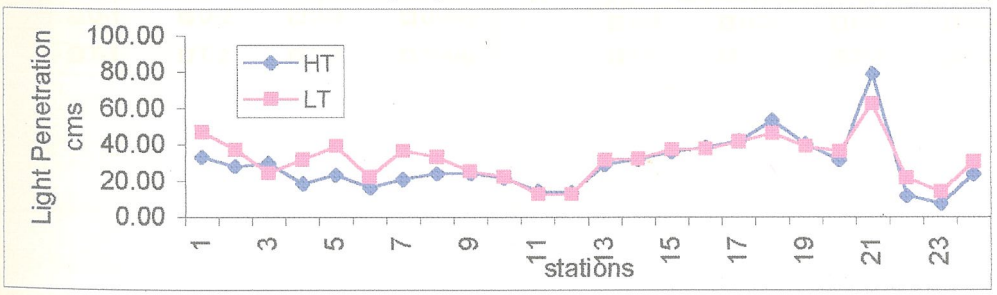


Fig. LP-2: Monthwise variations in light penetration (cms) during high tide in Ulhas river estuary and Thane creek.

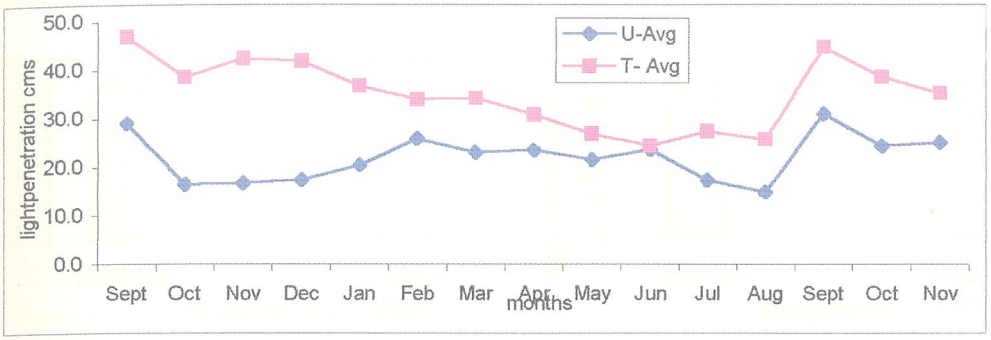


Fig. LP-3: Monthwise variations in light penetration (cms) during low tide in Ulhas river estuary and Thane creek.

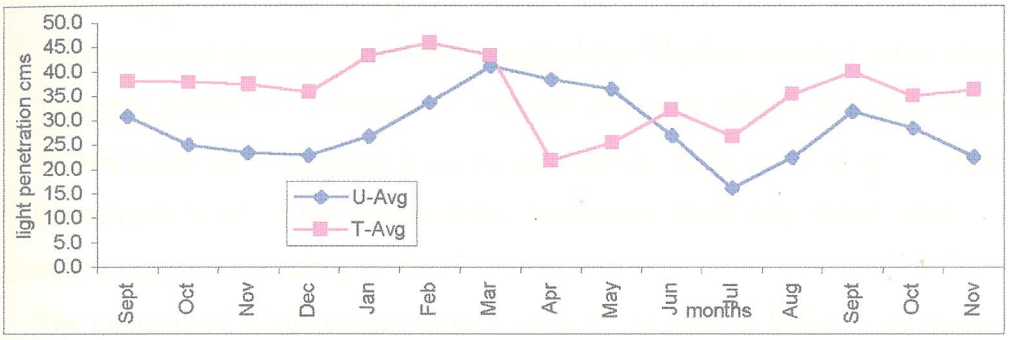


Fig LP-4: Zonewise annual average Light penetration during high tide in Ulhas river estuary and Thane creek.

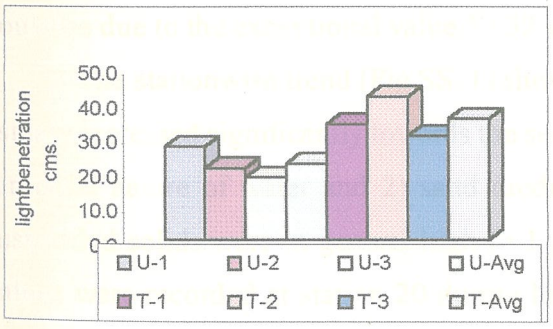


Fig LP-5: Zonewise annual average Light penetration during low tide in Ulhas river estuary and Thane creek.

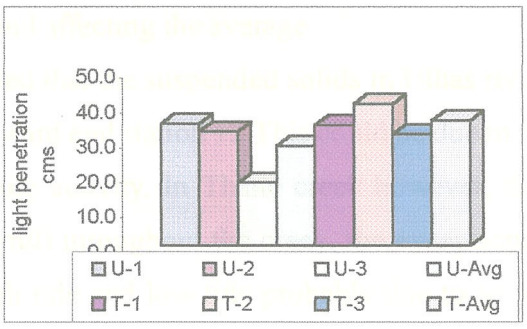


Fig LP-5: Comparison of light penetration in Ulhas river estuary with past data.

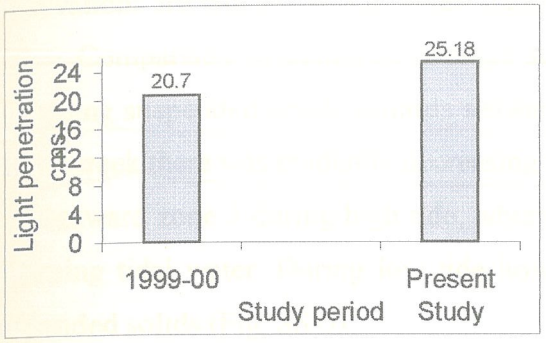
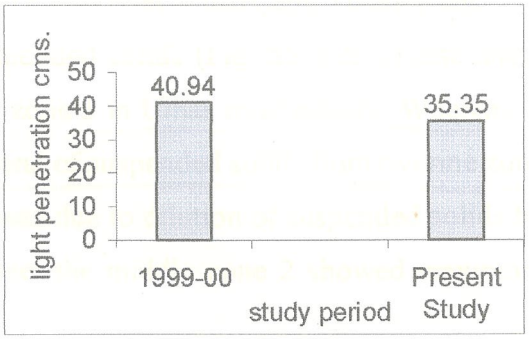


Fig LP-6: Comparison of light penetration in Thane creek with past data.



Suspended solids. (gm/l)

The suspended solids in aquatic bodies are in form of silt and clay particles, suspended debris and phytoplankton and zooplankton. High suspended solids thus may be due to highly productive eutrophic conditions or due to other non-living suspended matter. In any case, high suspended solids obstruct the light penetration in water and hence can adversely affect the productivity. In general, high suspended solids can be considered to indicate unhealthy polluted state of waters.

The suspended solids ranges from 0.02 to 17.04 gm/l in Ulhas river estuary and 0.02 to 53.32 gm/l in Thane creek. The maximum value in Thane creek was an exceptional value observed in April 2002. If it is excluded, the maxima was 20.5 gm/l. The overall average suspended solid value was marginally high in Thane creek, which could be due to the exceptional value 53.32 gm/l affecting the average.

The stationwise trend (Fig SS. 1) showed that the suspended solids in Ulhas river estuary increased significantly towards the seaward end station 12.This could be due to 1) turbulent nature of water and 2) sand dredging activity. In Thane creek however, the suspended solids were in general high (> 1 gm/l) throughout the creek, the exceptional values were recorded at station 20 during high tide and low tide probably due to some polluting source near this station. Due to this, the station showed higher average peak as compared to other stations.

Tidewise comparison showed high suspended solids during low tide suggesting that the suspended solids got diluted during high tide or riverine side origin of the suspended solids. The seasonal variations (Figs. SS 2 & 3) showed lowering of

suspended solids during rainy season suggesting flushing of suspended solids. All these observations are indicative of polluted status of Ulhas river estuary and Thane creek.

Comparison of zonewise average suspended solids (Fig. SS-4 & 5) also show increasing suspended solids towards seaward zone 3 in Ulhas river estuary. Whereas in Thane creek there was gradually decreasing trend of suspended solids from riverine zone 1 to seaward zone 3 during high tide, which was due to dilution of suspended solids by incoming tidal water. During low tide however the middle zone 2 showed maximum suspended solids (Fig. SS-5).

In general, most Indian creeks and estuaries have suspended solids less than 1 gm/l. whereas Ulhas river estuary and Thane creek had average suspended solids more than 1.5 gm/l, which clearly indicates polluted state of these ecosystems.

In past 20 years the suspended solids showed increasing trend in Thane creek and Ulhas river estuary. This has been illustrated in Fig. SS- 6 and 7. This shows deteriorating condition of the ecosystems. In both the ecosystems though there is reduction in average suspended solids, the high quantity of suspended solids as compared to other Indian estuaries and creeks indicates their polluted status.

Table SS-1: Monthly and stationwise variations in Suspended solids (g/l) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	0.200	0.200	0.200	0.400	1.400	0.200	1.800	4.760	3.160	3.080	8.000	8.000	2.62	1.400	1.200	1.200	2.000	1.400	2.000	1.800	2.200	1.600	2.600	1.600	1.800	1.73	2.19
Oct	0.100	0.100	0.200	0.300	1.200	0.400	1.400	3.780	3.360	2.900	7.000	7.200	2.33	1.700	1.400	1.400	1.800	1.600	0.600	2.000	2.000	1.400	2.200	1.700	2.000	1.65	2.00
Nov	0.200	0.120	0.200	0.300	1.400	0.200	1.400	4.000	2.700	4.000	8.000	7.000	2.46	1.500	1.000	1.800	1.800	1.800	1.000	2.200	2.000	1.800	2.800	1.800	1.800	1.78	2.13
Dec	0.140	0.100	0.100	0.300	1.000	0.800	1.800	3.900	3.160	2.680	6.600	7.600	2.35	1.400	1.200	1.800	2.200	1.400	2.400	1.400	2.400	1.600	3.200	1.300	1.800	1.84	2.11
Jan	0.800	0.700	1.500	0.840	0.700	0.900	1.540	1.900	3.900	4.500	7.360	6.840	2.62	6.400	1.600	0.500	3.800	1.900	1.600	1.100	1.100	1.200	1.160	0.900	0.500	1.81	2.23
Feb	0.200	2.000	0.300	0.200	0.100	0.020	0.300	1.600	1.980	1.700	1.900	4.700	1.25	4.000	2.000	4.240	3.300	3.500	0.500	0.440	0.700	0.900	0.880	0.200	0.360	1.75	1.49
Mar	0.100	1.100	0.900	0.700	0.200	0.400	0.300	1.900	2.000	3.000	7.000	11.600	2.43	5.000	3.000	3.300	2.200	3.100	2.500	2.300	3.080	2.000	2.500	1.000	1.200	2.60	2.51
Apr	0.400	0.400	0.800	1.600	0.800	0.200	0.160	0.200	0.500	7.300	0.900	0.020	1.11	2.300	1.000	0.200	0.300	0.180	0.160	0.180	20.500	0.160	0.180	0.920	0.880	2.25	1.65
May	0.300	0.300	1.600	0.500	1.560	1.500	0.900	3.000	1.000	2.500	2.400	3.900	1.62	2.400	1.900	2.500	1.700	0.700	1.300	0.500	4.700	1.700	1.780	1.800	1.300	1.86	1.73
Jun	0.200	0.200	0.200	0.160	0.200	0.400	1.900	1.400	0.500	0.440	2.900	4.700	1.10	2.400	0.500	5.300	0.100	0.100	0.400	1.900	1.700	0.300	0.020	2.400	2.700	1.49	1.28
Jul	0.300	0.500	1.700	0.700	0.240	0.200	0.200	0.500	0.600	0.900	0.500	0.800	0.60	1.700	0.180	1.100	0.500	1.480	1.500	0.300	0.200	1.100	0.180	0.860	0.960	0.84	0.71
Aug	0.700	0.500	1.100	0.800	0.700	0.040	0.100	0.400	0.400	0.100	0.300	0.020	0.43	1.300	0.500	0.900	0.500	0.360	0.900	0.700	0.500	0.500	0.900	0.900	0.800	0.73	0.57
Sept	0.200	0.160	0.300	0.360	1.000	0.600	1.200	3.000	1.500	3.100	4.000	7.700	1.93	2.500	1.000	1.600	1.900	0.800	1.800	2.200	1.900	1.500	2.200	1.100	1.300	1.65	1.79
Oct	0.140	0.140	0.700	0.340	1.100	0.600	1.000	2.000	2.000	3.000	3.600	7.240	1.82	4.500	1.500	2.500	2.200	1.800	1.600	1.400	1.900	1.800	2.200	1.800	1.200	2.03	1.92
Nov	0.220	0.100	1.200	0.400	1.100	0.200	1.300	2.000	2.400	4.700	4.300	8.300	2.19	4.000	2.360	3.300	2.920	3.000	2.000	2.200	3.520	1.900	2.500	2.000	2.000	2.64	2.40
Avg	0.280	0.441	0.733	0.527	0.847	0.444	1.020	2.289	1.944	2.927	4.317	5.708	1.79	2.833	1.356	2.109	1.815	1.541	1.351	1.375	3.227	1.297	1.687	1.352	1.373	1.78	1.78

Table SS-2: Monthly and stationwise variations in Suspended solids (g/l) during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	0.400	0.200	0.200	0.300	1.000	2.000	1.000	3.500	3.560	2.700	7.000	6.000	2.32	2.000	1.800	2.000	2.400	2.400	1.800	2.400	2.400	2.200	2.800	2.000	2.000	2.18	2.26
Oct	0.200	0.200	0.180	0.400	1.600	0.800	1.000	3.360	3.320	3.360	8.000	7.000	2.45	2.100	1.800	1.800	1.800	1.800	1.800	1.800	3.000	1.800	2.400	1.800	2.400	2.03	2.25
Nov	0.200	0.400	0.160	0.400	1.800	1.000	1.200	3.900	3.300	3.500	6.400	7.000	2.44	2.200	2.000	2.200	2.000	1.600	1.400	1.600	2.600	2.200	2.800	1.900	2.000	2.04	2.25
Dec	0.600	0.400	0.200	0.400	1.800	1.800	1.400	4.500	3.380	3.100	7.600	7.400	2.72	2.000	1.000	2.400	2.400	2.200	2.000	2.200	3.600	1.400	3.600	1.600	2.600	2.25	2.49
Jan	0.700	0.420	1.100	0.780	0.880	1.100	1.580	1.800	4.320	5.500	7.400	7.000	2.72	6.400	1.700	0.300	2.800	2.220	1.560	1.340	1.880	1.300	1.500	1.500	0.700	1.93	2.34
Feb	0.020	1.900	0.160	0.020	0.100	0.100	3.000	2.600	1.760	3.700	3.740	13.900	2.58	4.300	1.540	3.780	3.100	4.300	0.760	0.840	1.140	1.180	0.920	0.280	0.400	1.88	2.24
Mar	0.160	1.500	1.000	0.700	0.740	0.300	0.240	3.900	1.900	3.500	8.200	11.000	2.76	5.500	2.400	2.500	3.100	3.300	2.200	2.500	2.900	2.100	2.700	1.800	2.200	2.77	2.76
Apr	0.600	0.500	1.200	1.200	1.240	0.500	0.040	0.100	1.080	17.040	0.220	0.220	2.00	2.500	1.600	0.100	0.200	0.200	0.280	0.200	53.320	0.200	0.300	1.120	0.900	5.08	3.47
May	0.400	0.240	1.500	0.900	1.300	1.700	1.800	4.000	1.800	6.500	7.000	5.100	2.69	2.700	2.200	1.380	1.100	0.300	1.700	1.080	15.760	1.920	2.000	2.400	2.400	2.91	2.79
Jun	0.220	0.240	0.400	0.100	0.100	0.600	3.360	1.000	0.640	0.660	0.080	0.960	0.70	2.220	0.220	2.500	0.020	0.300	0.500	2.140	2.000	0.700	0.060	5.160	6.760	1.88	1.27
Jul	0.400	0.640	1.800	0.800	0.400	0.200	0.400	0.700	0.700	0.800	0.300	0.700	0.65	1.960	0.300	0.900	1.100	1.380	1.780	0.240	0.300	1.360	0.300	1.160	1.900	1.06	0.85
Aug	0.940	0.640	0.880	0.900	0.180	0.020	0.020	0.380	0.460	0.160	0.500	0.020	0.43	0.500	0.380	0.420	0.420	0.420	1.040	0.440	0.500	0.520	1.080	1.180	1.240	0.68	0.55
Sept	0.300	0.200	0.600	0.300	1.560	1.120	1.400	2.700	1.600	3.500	4.200	7.000	2.04	1.900	1.500	2.000	2.000	1.600	1.900	2.000	2.200	1.800	2.300	1.400	1.500	1.84	1.94
Oct	0.200	0.200	1.500	0.500	1.300	0.800	1.500	2.500	3.100	3.360	4.200	7.500	2.22	4.560	1.800	2.760	2.700	2.500	1.900	1.560	2.500	2.000	2.400	2.200	1.900	2.40	2.31
Nov	0.260	0.200	1.700	0.700	1.200	0.760	1.800	3.560	3.500	6.200	6.500	8.500	2.91	4.300	2.900	3.100	3.560	3.700	2.500	2.480	3.300	2.000	2.400	2.200	2.700	2.93	2.92
Avg	0.373	0.525	0.839	0.560	1.013	0.853	1.316	2.567	2.295	4.239	4.756	5.953	2.11	3.009	1.543	1.876	1.913	1.881	1.541	1.521	6.493	1.512	1.837	1.847	2.107	2.26	2.18
Ht+Lt Avg	0.327	0.483	0.786	0.543	0.930	0.649	1.168	2.428	2.119	3.583	4.537	5.831	1.949	2.921	1.449	1.993	1.864	1.711	1.446	1.448	4.860	1.405	1.762	1.599	1.740	2.017	1.981

Fig. SS-1: Stationwise comparison of average suspended solids(gm/l) during High tide and low tide

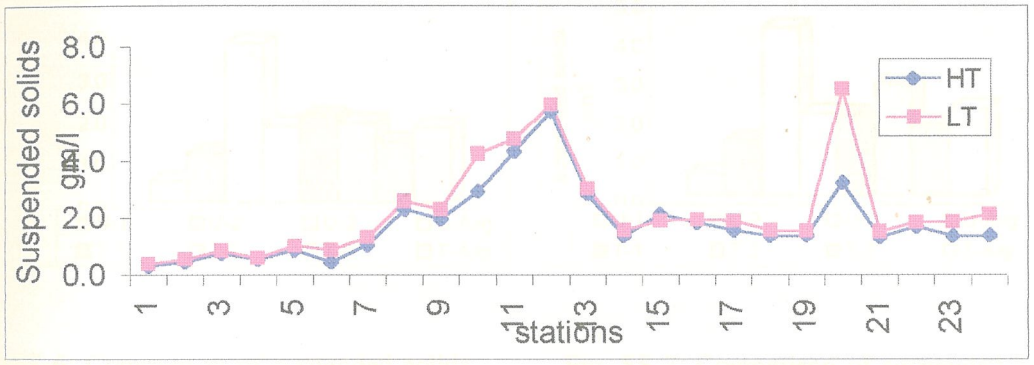


Fig. SS-2: Monthly variations in average suspended solids (gm/l) during high tide in Ulhas river estuary and Thane creek.

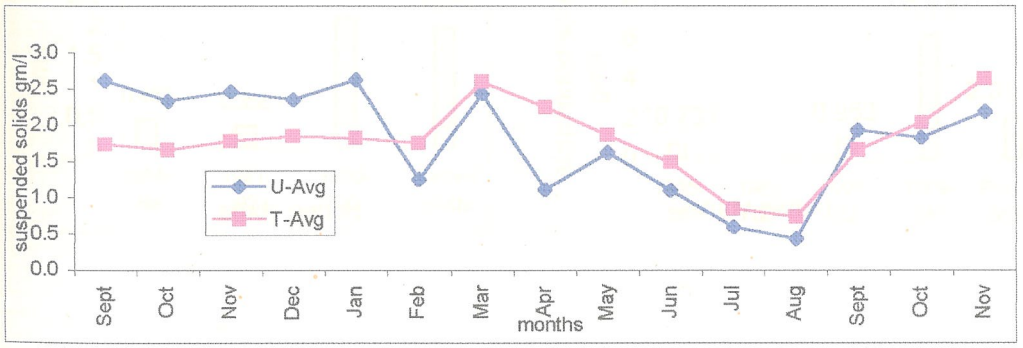


Fig. SS-3: Monthly variations in average suspended solids (gm/l) during low tide in Ulhas river estuary and Thane creek.

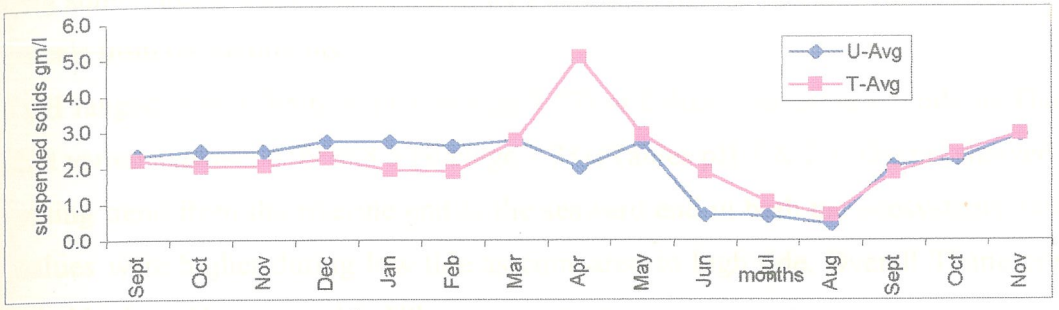


Fig. SS-4: Zonewise annual average suspended solids (gm/l) in Ulhas river estuary and Thane creek during high tide

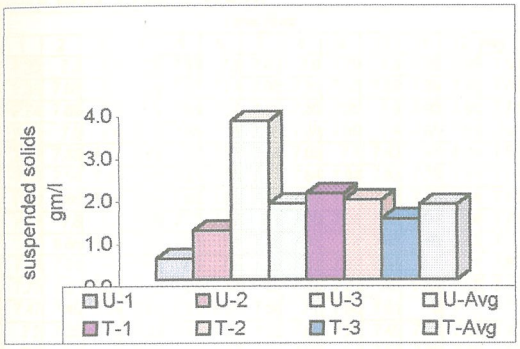


Fig. SS-5: Zonewise annual average of suspended solids in Ulhas river estuary and Thane creek during Low tide.

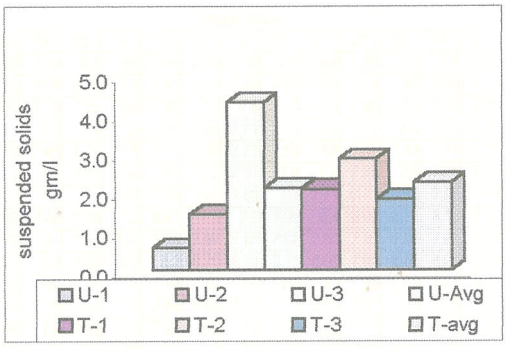


Fig. SS-6: Comparison of suspended solids (gm/l) in Ulhas river estuary with past data.

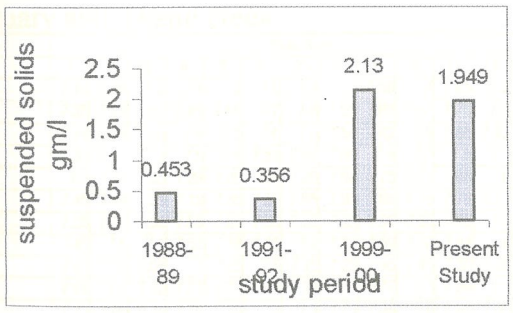
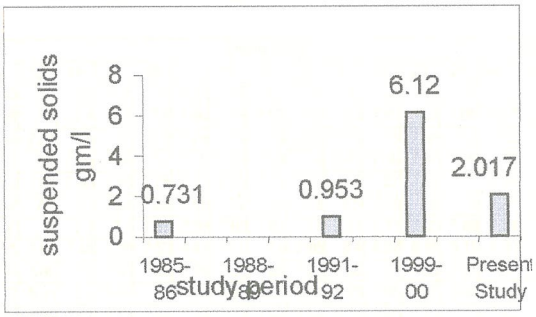


Fig. SS-7: Comparison of suspended solids (gm/l) in Thane creek with past data.



pH

In aquatic ecosystems the pH is the function of dissolved carbondioxide content (Odum, 1971) and gives the idea weather the pH is acidic or alkaline. The estimation of pH can 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.

The pH ranged from 6.85 to 8.11 (average 7.57) in Ulhas river estuary while in Thane creek it varied between 6.99 to 8.5 (average 7.73) (Tables pH-1 & 2.). The pH showed an increasing trend from the riverine end to the seaward end in both the ecosystems, while the values were higher during low tide as compared to high tide. Overall Thane creek recorded higher pH compared to Ulhas river estuary.

Table pH-1: Monthly and stationwise variations in pH during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	7.25	7.3	7.6	7.27	7.35	7.3	7.45	7.6	7.79	7.9	7.95	7.95	7.56	7.65	7.76	8.1	7.95	7.95	7.45	7.55	7.6	7.62	7.65	7.75	7.6	7.72	7.64
Oct	7.34	7.85	7.5	7.39	7.67	7.71	7.98	7.55	7.35	7.85	7.98	7.98	7.68	7.68	7.78	8.25	7.8	7.85	7.5	7.62	7.58	7.55	7.74	7.85	7.65	7.74	7.71
Nov	7.74	7.85	7.5	7.6	7.58	7.57	7.85	7.58	7.95	7.9	7.95	7.85	7.74	7.77	7.75	7.05	7.99	7.65	7.5	7.6	7.77	7.74	7.85	7.55	7.74	7.66	7.70
Dec	7.29	7.5	7.4	7.13	7.65	7.15	7.35	7.88	7.89	7.9	7.85	7.85	7.57	7.7	7.5	7.9	7.12	7.09	7.05	7.71	7.75	7.71	7.71	7.6	7.71	7.55	7.56
Jan	7.33	7.43	7.11	7.49	7.5	7.51	7.44	7.68	7.7	7.82	7.97	8.08	7.59	7.63	7.45	7.75	7.75	7.71	7.09	7.71	7.53	7.57	7.57	7.43	7.71	7.58	7.58
Feb	7.55	7.54	7.35	7.49	7.51	7.55	7.77	7.84	7.84	7.83	7.76	7.91	7.66	7.7	7.7	7.61	7.69	7.65	7.7	7.77	7.8	7.9	7.75	7.8	7.9	7.75	7.70
Mar	7.63	7.66	7.65	7.59	7.66	7.65	7.52	7.71	7.71	7.71	7.77	7.84	7.68	6.99	7.1	7.1	7.57	7.59	7.63	7.63	7.7	7.71	7.71	7.85	7.88	7.54	7.61
Apr	7.73	7.8	7.3	7.78	7.77	7.57	7.1	7.59	7.94	8.03	7.94	8.04	7.72	7.67	7.48	7.76	7.53	8.41	8.5	7.9	7.95	8.4	8.07	8.15	8.15	8.00	7.85
May	6.85	6.88	6.92	7.1	7.08	7.1	7.35	7.35	7.4	7.45	7.45	7.48	7.20	7.69	7.87	7.65	7.69	7.99	7.89	7.85	7.65	7.85	7.99	7.95	7.95	7.84	7.51
Jun	7.88	7.83	7.44	7.92	7.8	7.7	7.76	7.81	7.89	8.04	8.1	8.11	7.86	8.01	8.1	8.08	8.2	8.2	8.25	8.01	8.15	8.06	7.95	8.05	8.05	8.09	7.97
Jul	7.73	7.81	7.59	7.78	7.08	7.57	7.56	7.71	7.71	7.9	7.95	7.95	7.70	7.65	7.65	7.76	7.95	7.45	7.52	7.66	7.62	7.52	7.65	7.71	7.71	7.65	7.68
Aug	7.47	7.49	7.69	7.84	7.91	8.06	7.56	7.7	7.66	7.61	8	7.72	7.73	7.45	7.45	7.31	7.52	7.59	7.62	7.61	7.7	7.75	7.51	7.6	7.75	7.57	7.65
Sept	7.2	7.25	7.2	7.35	7.45	7.55	7.32	7.65	7.75	7.45	7.85	7.85	7.49	7.95	7.6	7.58	7.75	7.85	7.9	7.8	7.8	7.65	7.7	7.7	7.75	7.75	7.62
Oct	7.3	7.3	7.25	7.35	7.65	7.45	7.38	7.68	7.7	7.65	7.85	7.68	7.52	7.98	7.8	7.7	7.88	7.65	7.9	7.85	7.8	7.8	7.85	7.65	7.9	7.81	7.66
Nov	7.25	7.35	7.25	7.55	7.68	7.77	7.62	7.75	7.85	7.95	7.98	7.95	7.66	8	7.5	7.7	7.5	7.55	7.9	8.05	7.95	7.95	7.95	7.9	7.95	7.83	7.74
Avg	7.44	7.52	7.38	7.51	7.56	7.55	7.53	7.67	7.74	7.80	7.89	7.88	7.62	7.70	7.63	7.69	7.73	7.75	7.69	7.75	7.76	7.79	7.78	7.77	7.83	7.74	7.68

Table pH-2: Monthly and stationwise variations in pH during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	7.16	7.26	7.2	7.4	7.5	7.6	7.4	7.53	7.59	7.7	7.81	7.8	7.50	7.8	7.58	7.68	7.71	7.61	7.77	7.7	7.65	7.51	7.66	7.58	7.6		7.57
Oct	7.36	7.22	7.33	7.45	7.65	7.7	7.8	7.55	7.65	7.67	7.75	7.8	7.58	7.8	7.4	7.6	7.8	7.66	7.8	7.65	7.6	7.55	7.88	7.6	7.65	7.67	7.62
Nov	7.44	7.15	7.25	7.4	7.5	7.6	7.5	7.58	7.62	7.8	7.85	7.82	7.54	7.85	7.5	7.8	7.8	7.75	7.9	7.9	7.65	7.75	7.5	7.55	7.7	7.72	7.63
Dec	7.33	7.36	7.3	7.5	7.5	7.55	7.55	7.65	7.6	7.7	7.5	7.7	7.52	7.7	7.75	7.85	7.7	7.75	7.8	7.8	7.6	7.85	7.59	7.57	7.65	7.72	7.61
Jan	7.3	7.34	7.05	7.29	7.35	7.66	7.25	7.58	7.75	7.77	7.88	8	7.52	7.63	7.45	7.75	7.75	7.71	7.09	7.71	7.53	7.57	7.57	7.43	7.71	7.58	7.55
Feb	7.45	7.44	7.25	7.19	7.35	7.59	7.65	7.99	7.65	7.78	7.76	7.71	7.57	7.7	7.7	7.61	7.69	7.65	7.7	7.77	7.8	7.9	7.75	7.8	7.9	7.75	7.65
Mar	7.35	7.35	7.55	7.55	7.56	7.35	7.35	7.35	7.66	7.65	7.55	7.7	7.50	6.99	7.1	7.1	7.57	7.59	7.63	7.63	7.7	7.71	7.71	7.85	7.88	7.54	7.52
Apr	7.45	7.6	7.1	7.58	7.78	7.25	7.2	7.66	7.39	7.78	7.84	8	7.55	7.67	7.48	7.76	7.53	8.41	8.5	7.9	7.95	8.4	8.07	8.15	8.15	8.00	7.77
May	7.01	6.95	7.03	7	7.25	7.5	7.25	7.25	7.45	7.45	7.35	7.35	7.24	7.69	7.87	7.65	7.69	7.99	7.89	7.85	7.65	7.85	7.99	7.95	7.95	7.84	7.52
Jun	7.68	7.7	7.22	7.71	7.71	7.71	7.26	7.71	7.77	8.1	7.99	8.1	7.72	8.01	8.1	8.08	8.2	8.2	8.25	8.01	8.15	8.06	7.95	8.05	8.05	8.09	7.90
Jul	7.71	7.68	7.35	7.71	7.25	7.3	7.1	7.71	7.58	7.8	7.95	7.65	7.57	7.65	7.65	7.76	7.95	7.45	7.52	7.66	7.62	7.52	7.65	7.71	7.71	7.65	7.61
Aug	7.5	7.71	7.55	7.54	7.55	7.9	7.36	7.7	7.56	7.55	7.96	7.7	7.63	7.45	7.45	7.31	7.52	7.59	7.62	7.61	7.7	7.75	7.51	7.6	7.75	7.57	7.60
Sept	7.1	7.2	7.15	7.2	7.5	7.5	7.3	7.55	7.5	7.6	7.75	7.5	7.40	7.8	7.6	7.6	7.7	7.6	7.7	7.6	7.6	7.55	7.7	7.6	7.65	7.64	7.52
Oct	7.25	7.25	7.3	7.3	7.6	7.4	7.35	7.58	7.6	7.7	7.8	7.7	7.49	7.9	7.5	7.65	7.75	7.65	7.85	7.9	7.65	7.75	7.9	7.65	7.75	7.74	7.61
Nov	7.28	7.2	7.35	7.35	7.65	7.7	7.55	7.65	7.58	7.7	7.8	7.8	7.55	7.95	7.4	7.65	7.65	7.65	7.85	7.95	7.65	7.75	7.9	7.85	8	7.77	7.66
Avg	7.36	7.36	7.27	7.41	7.51	7.55	7.39	7.60	7.60	7.72	7.77	7.76	7.52	7.71	7.57	7.66	7.73	7.75	7.79	7.78	7.70	7.76	7.76	7.73	7.81	7.73	7.62
Ht+Lt Avg	7.40	7.44	7.32	7.46	7.53	7.55	7.46	7.64	7.67	7.76	7.83	7.82	7.57	7.70	7.60	7.67	7.73	7.75	7.74	7.77	7.73	7.78	7.77	7.75	7.82	7.73	7.65

Fig. pH-1: Comparison of stationwise average pH during high tide and low tide in Ulhas river estuary and Thane creek.

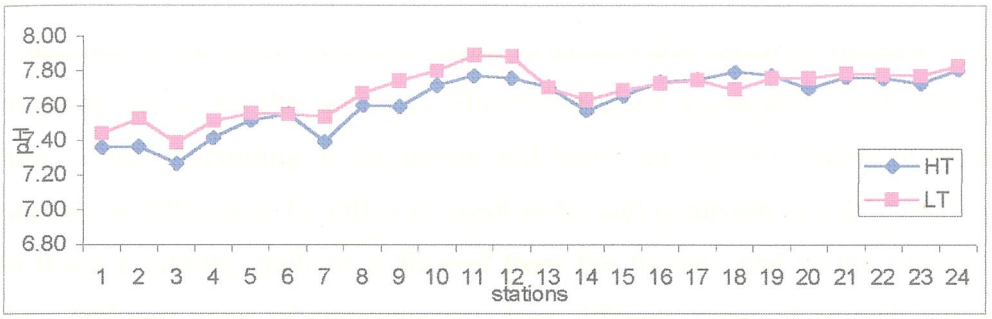


Fig. pH-2: Monthly variations in average pH during high tide in Ulhas river estuary and Thane creek.

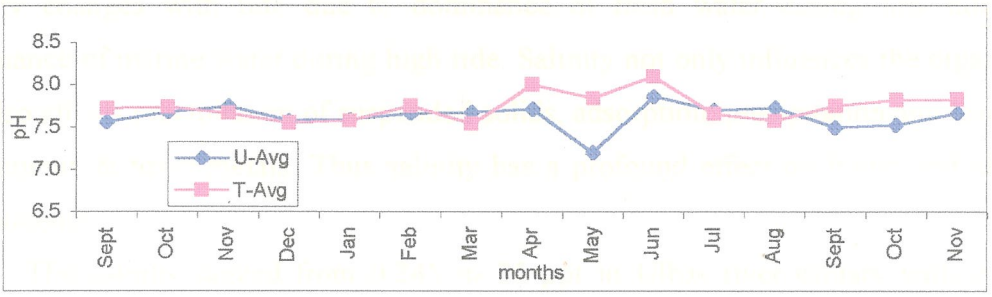


Fig. pH-3: Monthly variations in average pH during Low tide in Ulhas river estuary and Thane creek

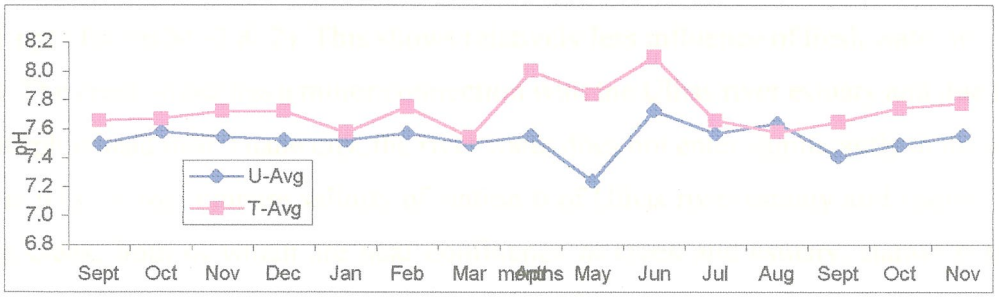


Fig. PH-4: Zonewise variation in the annual average pH during high tide in Ulhas river estuary and Thane creek

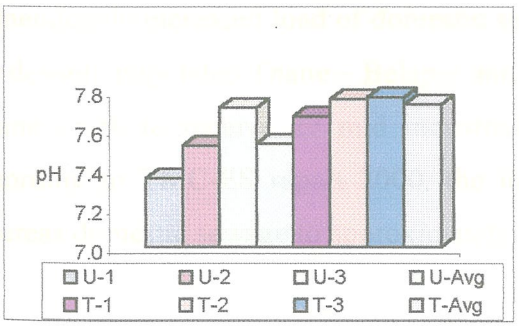
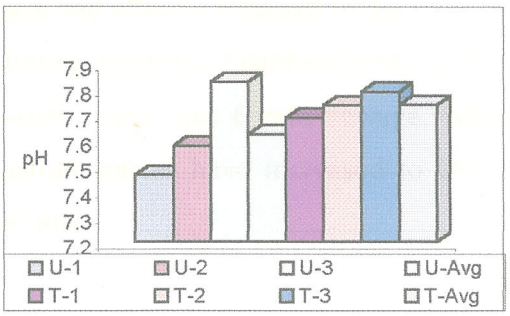


Fig. PH-5: Zonewise variation in the annual average pH during low tide inUlhas river estuary and Thane creek



Salinity (ppt.)

Salinity is the most important factor in creeks and estuaries because it causes physiological stress to the animals influencing their occurrence and distribution (Levinton, 1982). According to Anirudhan and Nambisan (1990), salinity in the creeks and estuaries is influenced by influx of fresh water and incursion of tidal marine water. Due to these a salinity gradient is formed from the riverine end to the seaward end, providing different types of environment where different types of animals can reside depending upon their ability to manage the salinity stress. At a particular location also the salinity changes with tide due to dominance of fresh water during low tide and dominance of marine water during high tide. Salinity not only influences the organisms but also affects precipitation of suspended solids, adsorption; precipitation and leaching of nutrients & toxic metals. Thus salinity has a profound effect on biotic and abiotic components.

The salinity ranged from 0.245 to 36 ppt in Ulhas river estuary with overall average 15.46 ppt. This indicated almost 50 : 50 dilution of marine water by the riverine fresh water. The Thane creek had salinity range 0.46 to 38 ppt. with overall average 23.41 ppt (Tables SL-1 & 2). This shows relatively less influence of fresh water in Thane creek. The creek infact has a minor connection with the Ulhas river estuary and due to the geomorphic head near Thane city, the river water does not enter significantly in the creek. That is why, if we compare salinity of station 6 of Ulhas river estuary and station 13 of Thane creek, both of which are near confluence of creek and estuary, station 6 shows lower average salinity around 14 ppt. and station 13 has higher average salinity around 18 ppt. In Thane creek, in spite of low fresh water flow from river, the overall average salinity was around 24 ppt. Indicating 2:3 dilution of sea water. This could be due to the tremendously increased load of domestic sewage and effluent released in the creek from the densely populated Thane – Belapur and Mumbai complex. Gajbhiye (1981) reported Thane creek to receive 27 mld industrial waste water and 6 mld sewage, whereas according to TMC-ES report 2000. the industrial wastes have increased to 294 mld whereas domestic sewage to approximately 260 mld.

The station wise comparison (Fig. Sl-1) showed gradually increasing salinity from the riverine end to the sea ward end both in Thane creek and Ulhas river estuary. It also showed marginally higher salinity during high tide than the low tide. The month wise variations (Figs. Sl –2 & 3) showed significant drop in salinity during monsoon and gradual recovery in Ulhas river estuary. As compared to this the postmonsoon salinity rise in Thane creek was fast due to less influence of fresh water.

Zonewise comparison of average salinity (Figs. Sl – 4 & 5) showed salinity around 10 ppt. in riverine zone of Ulhas river estuary, in spite of being almost 40 km. away from the sea. This shows significant incursion of sea water, suggesting relatively weak fresh water flow. In Thane creek the riverine zone had higher salinity around 20 ppt. The zone wise variation in salinity was relatively more in Ulhas river estuary as compared to Thane creek.

In Fig SL-6, the present average salinity of Ulhas river estuary is compared with the data of 1999-2000 (Mishra, 2002) which shows insignificant increase in salinity from 15.25 ppt to 15.45 ppt. In Thane creek however as compared to average salinity of 1975 (NIO, 1975) and 1985 (Tandel 1986) the salinities in 1999 (Quadros, 2001) and the present one are significantly lower. This indicates 1) growing freshwater load which is mainly due to rise in domestic sewage quantity and 2) reduction in tidal sea water incursion, which is probably caused by obstruction due to solid waste dumping reclamation, construction of bridges, etc.

Table Sl-1: Monthly and stationwise variations in Salinity (ppt.) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River												Thane Creek												Tota
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	0.245	0.299	0.245	0.568	0.927	2.183	3.618	4.695	6.130	15.101	20.125	20.842	6.25	12.589	9.001	9.719	13.307	10.077	17.972	18.689	20.842	16.536	29.813	25.866	21.919	17.19	11.5
Oct	1.824	2.183	3.260	3.260	6.489	7.207	9.001	9.719	12.589	20.842	23.354	24.072	10.32	11.872	19.048	13.666	14.742	13.307	19.766	20.484	22.995	20.842	28.019	26.943	23.713	19.62	14.7
Nov	1.107	2.901	5.413	5.771	7.924	9.719	10.436	11.872	16.178	21.560	24.431	23.354	11.72	19.766	21.201	16.178	22.637	24.072	21.201	19.766	24.790	20.842	30.531	26.943	25.148	22.76	17.0
Dec	3.977	4.336	7.207	8.283	10.436	11.154	12.589	14.025	17.254	23.713	24.790	25.148	13.58	20.484	14.383	21.560	24.790	25.148	24.072	23.354	26.943	23.354	29.813	28.378	27.660	24.16	18.6
Jan	10.800	10.800	9.720	15.720	11.150	12.590	22.640	32.200	30.400	34.800	35.910	35.910	21.89	20.480	21.560	23.710	25.400	28.550	28.550	29.200	30.400	30.400	32.800	32.520	33.780	28.11	24.8
Feb	16.900	16.900	13.310	25.870	27.660	29.100	29.100	29.100	30.480	34.800	34.680	36.000	26.99	30.400	34.680	28.540	33.780	32.520	32.020	37.750	38.000	37.930	34.320	35.000	35.000	34.16	30.4
Mar	16.200	16.200	9.000	25.870	25.870	29.100	33.100	33.040	33.040	33.040	35.910	35.000	27.11	32.200	32.200	32.600	25.400	31.560	31.800	33.400	34.000	35.300	32.600	33.400	35.000	32.46	29.6
Apr	15.100	16.180	11.870	27.660	25.870	25.870	27.690	29.100	29.100	32.200	33.040	34.680	25.70	22.640	24.200	34.320	27.250	28.550	29.200	32.520	33.000	33.600	33.250	33.500	34.000	30.50	28.0
May	16.900	16.900	13.640	26.590	27.660	29.100	28.540	29.100	33.040	34.800	35.910	35.910	27.34	30.400	34.300	34.800	30.400	33.100	32.800	36.600	35.900	38.000	36.000	36.800	37.750	34.74	30.8
Jun	15.720	15.720	13.310	24.200	25.870	25.870	27.690	27.690	29.100	28.690	29.100	29.100	24.34	27.250	26.020	23.850	20.610	31.100	32.500	31.400	33.900	34.000	35.200	35.800	36.800	30.70	27.3
Jul	0.300	0.300	0.300	1.070	2.900	2.900	1.070	1.070	1.070	1.930	1.930	2.180	1.42	0.750	0.460	1.200	0.800	2.600	1.900	2.700	4.200	5.200	5.900	6.200	10.000	3.49	2.4
Aug	0.460	0.460	0.460	0.710	0.820	0.820	0.820	1.070	1.180	1.290	1.390	1.390	0.91	4.200	5.440	5.440	6.160	10.140	10.400	10.860	10.900	14.470	14.500	14.800	26.940	11.19	5.8
Sept	1.110	2.180	5.410	5.770	7.210	6.490	7.210	7.920	7.920	9.720	19.700	20.120	8.40	13.640	15.100	15.720	16.180	16.180	17.970	18.690	19.700	19.770	23.000	24.790	26.940	18.97	13.4
Oct	9.720	10.800	8.280	10.440	12.590	15.100	11.150	13.640	16.900	19.770	22.640	23.350	14.53	15.720	16.900	19.050	19.050	16.180	19.770	21.200	23.350	26.940	28.020	29.810	33.730	22.48	18.3
Nov	10.800	10.800	9.720	15.720	13.310	16.180	22.640	29.100	30.400	34.800	35.910	35.910	22.11	20.480	21.560	23.710	25.400	28.550	28.550	29.200	30.400	30.400	32.800	32.520	33.780	28.11	24.9
Avg	8.08	8.46	7.41	13.17	13.78	14.89	16.49	18.22	19.65	23.14	25.25	25.53	16.17	18.86	19.74	20.27	20.39	22.11	23.23	24.39	25.95	25.84	28.44	28.22	29.48	23.91	19.8

Table Sl-2: Monthly and stationwise variations in Salinity (ppt) during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	0.245	0.299	0.245	0.461	0.927	2.183	2.901	3.618	5.413	14.025	18.331	19.766	5.70	9.00	6.85	7.92	11.51	7.57	14.74	16.18	16.18	16.18	25.15	24.79	16.54	14.38	9.87
Oct	1.824	2.183	3.260	2.183	6.489	6.489	10.077	9.001	11.154	19.766	22.637	23.354	9.87	11.87	10.44	12.59	12.59	10.80	17.97	18.69	23.00	19.05	26.94	25.87	23.00	17.73	13.64
Nov	1.107	2.901	5.413	5.054	7.924	7.924	9.001	10.436	14.025	21.201	24.431	24.431	11.15	14.02	12.59	16.18	21.56	22.64	19.77	19.77	23.35	19.77	29.45	25.87	23.35	20.69	15.73
Dec	3.977	4.336	7.207	6.848	9.001	9.719	11.154	12.230	15.819	23.713	24.431	24.790	12.77	15.10	13.67	20.48	23.71	23.35	22.64	22.64	25.15	23.00	25.87	26.94	25.15	22.31	17.35
Jan	10.077	10.795	7.566	13.307	9.000	10.080	20.125	29.096	29.096	34.119	35.555	35.913	20.39	20.48	21.56	23.71	25.40	28.55	28.55	29.20	30.40	30.40	32.80	32.52	33.78	28.11	24.10
Feb	15.460	16.895	9.719	20.125	22.637	22.637	25.866	25.866	27.660	29.096	32.684	33.043	23.47	30.40	34.68	28.54	33.78	32.52	32.02	37.75	38.00	37.93	34.32	35.00	35.00	34.16	28.60
Mar	16.180	16.180	9.000	22.640	25.870	27.660	27.000	29.100	29.100	33.040	34.680	35.910	25.53	32.20	32.20	32.60	25.40	31.56	31.80	33.40	34.00	35.30	32.60	33.40	35.00	32.46	28.85
Apr	14.383	15.101	9.719	16.178	19.766	13.666	22.278	21.919	22.995	28.019	28.737	26.584	19.95	22.64	24.20	34.32	27.25	28.55	29.20	32.52	33.00	33.60	33.25	33.50	34.00	30.50	25.01
May	15.640	15.460	11.150	25.870	27.000	27.660	27.660	27.000	27.660	34.680	35.000	35.000	25.82	30.40	34.30	34.80	30.40	33.10	32.80	36.60	35.90	38.00	36.00	36.80	37.75	34.74	30.10
Jun	15.101	15.101	12.230	16.178	20.484	20.484	25.866	26.584	28.737	31.966	33.043	35.913	23.47	27.25	26.02	23.85	20.61	31.10	32.50	31.40	33.90	34.00	35.20	35.80	36.80	30.70	26.94
Jul	0.250	0.300	0.300	0.930	2.180	2.900	0.930	0.750	0.930	1.070	1.070	1.070	1.06	0.75	0.46	1.20	0.80	2.60	1.90	2.70	4.20	5.20	5.90	6.20	10.00	3.49	2.23
Aug	0.389	0.389	0.461	0.461	0.640	0.712	0.748	0.819	1.071	1.178	1.286	1.394	0.80	4.20	5.44	5.44	6.16	10.14	10.40	10.86	10.90	14.47	14.50	14.80	26.94	11.19	5.78
Sept	0.930	1.110	3.260	5.050	5.410	5.410	6.490	7.210	7.210	9.000	19.700	19.700	7.54	11.87	13.64	13.64	15.72	15.10	16.18	17.97	17.97	16.18	19.70	19.70	23.00	16.72	11.95
Oct	7.210	9.720	7.210	9.720	11.150	14.380	10.440	11.150	15.720	18.690	21.560	21.560	13.21	14.46	15.72	16.18	18.69	18.69	18.69	19.05	19.05	19.70	25.15	25.87	29.20	20.04	16.49
Nov	9.720	9.000	9.000	12.230	12.230	15.100	20.480	25.870	28.740	34.680	34.680	35.550	20.61	19.42	20.48	21.56	23.71	25.40	26.02	26.02	28.55	29.20	31.56	31.56	32.50	26.33	23.35
Avg	7.50	7.98	6.38	10.48	12.05	12.47	14.73	16.04	17.69	22.28	24.52	24.93	14.76	17.60	18.15	19.53	19.82	21.44	22.35	23.65	24.90	24.80	27.23	27.24	28.13	22.90	18.67
Ht+Lt Avg	7.79	8.22	6.90	11.82	12.91	13.68	15.61	17.13	18.67	22.71	24.89	25.23	15.46	18.23	18.94	19.90	20.11	21.78	22.79	24.02	25.43	25.32	27.83	27.73	28.81	23.41	19.28

Fig. Sl-1: Stationwise variations in the average salinity (ppt) during High tide and Low tide in Ulhas river estuary and Thane creek

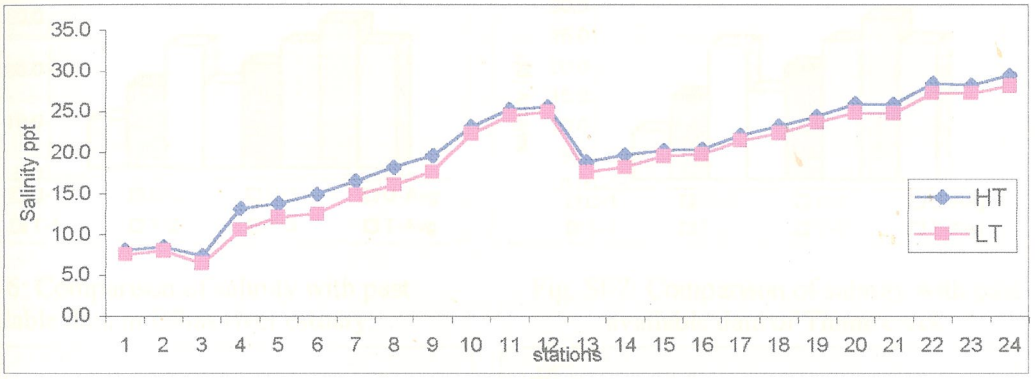


Fig. Sl-2: Monthly variations in average salinity (ppt) during high tide in Ulhas river estuary and Thane creek.

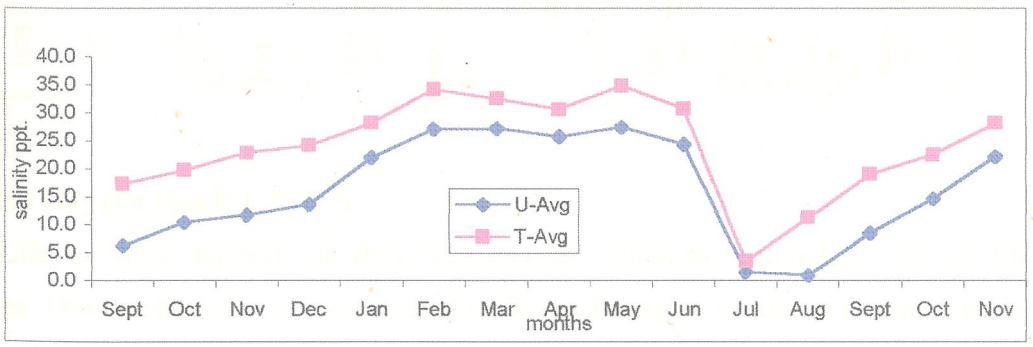


Fig. Sl-3: Monthly variations in the average salinity during low tide in Ulhas river estuary and Thane creek

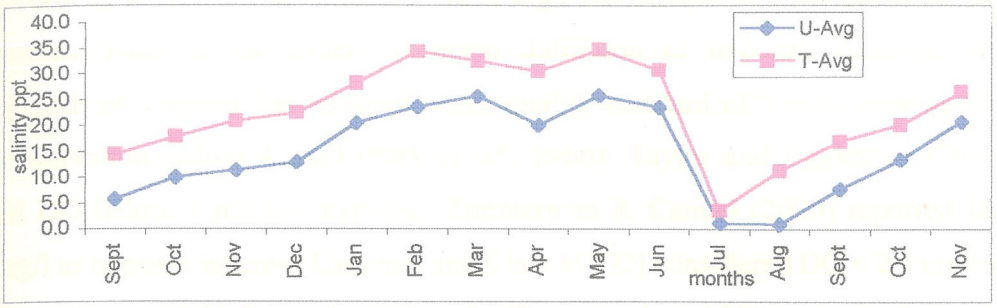


Fig. Sl-4: Zonewise variations in the average salinity (ppt) during high tide in Ulhas river estuary and Thane Creek

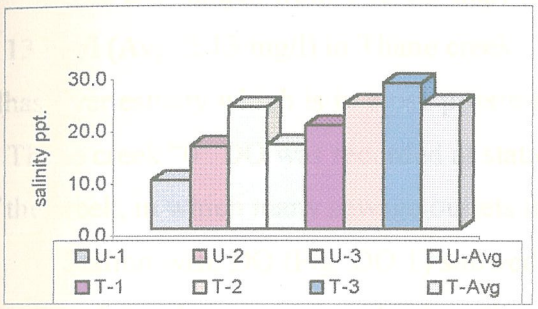


Fig. Sl-5: Zonewise variations in average salinity (ppt) during low tide in Ulhas river estuary and Thane creek

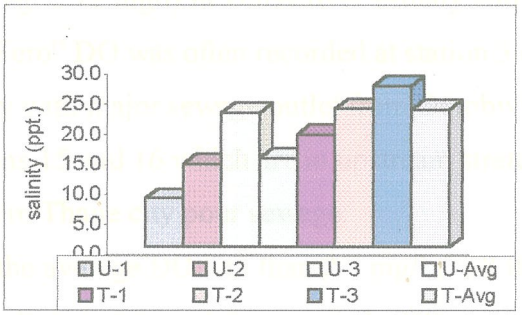


Fig. Sl-6: Comparison of salinity with past available data in Ulhas river estuary.

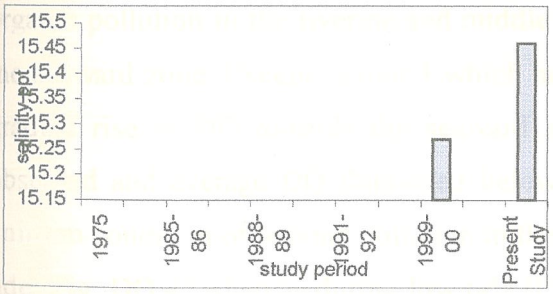
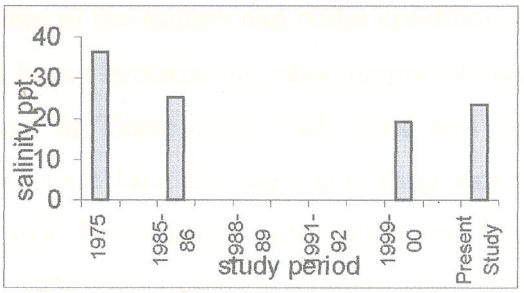


Fig. Sl-7: Comparison of salinity with past available data of Thane creek



Dissolved Oxygen (mg/l) (DO)

Life in water depends on dissolved oxygen which is required for the all life processes. Oxygen from the air dissolves directly in the water, so also it is produced by the process of photosynthesis. On the other hand respiration of plants and animals and decomposition of organic material consume the dissolved oxygen from the water. All these processes can significantly alter the DO. Especially the bacterial decomposition can

rapidly remove the DO to produce hypoxic condition in aquatic ecosystems (Adeney, 1908). According to Metcalf & Eddy (1979), 4 mg/l DO is optimum for estuarine and coastal waters. There is no widely accepted definition of hypoxia, however, the Commonwealth of Virginia has adopted water quality standard of 5 mg/l average DO with no observation below 4 mg/l (Park *et al.*, 1966). Taylor and Eggleston (2000) considered DO below 3 mg/l as hypoxic; Zimmerman & Canuel (2000) reported DO below 2 mg/l as hypoxic whereas Laponite and Clark (1992) considered DO < 2.5 mg/l as hypoxic in nutrient enriched aquatic system. In Thane creek and Ulhas river estuary the nutrient levels are quite high due to heavy sewage load, hence DO below 2.5mg/l can be considered as hypoxic.

The DO ranged from 0 to 6.9 mg/l (Avg. 2.72 mg/l) in Ulhas river estuary and 0 to 13 mg/l (Avg. 2.13 mg/l) in Thane creek. "Zero" DO was often recorded at station 3 of Ulhas river estuary which is in close proximity with major sewage outlet from Dombivli. In Thane creek "0" DO was recorded at stations 15 and 16 which are in upstream stretch of the creek, in which many sewage outlets from Thane city pour sewage.

Station wise DO (Fig. DO 1) showed the average DO less than 2.5 mg/l at all the stations of the Thane creek indicating the polluted status of the creek. In Ulhas river estuary stations 9,10,11 and 12 had average DO higher than 2.5 mg/l. this suggest high organic pollution in the riverine and middle zone of the estuary and better condition in the seaward zone. Except station 3 which had heavy hypoxia, the other station showed gradual rise in DO towards the seaward zone. In Thane creek such trend was not observed and average DO fluctuated below hypoxic limit 2.5 mg/l indicating almost uniform condition of organic pollution in the creek. This was true especially during high tide (Fig. DO 4) whereas during low tide (Fig. DO-5) the upstream riverine zone 1 had the lower average DO due to heavy pollutant load and less water mass.

Monthwise comparison (Figs. DO 2 &3) showed low DO during winter months Nov-Dec and better DO in summer and monsoon. This could be due to increased primary productivity and dilution of pollutants by monsoon floods respectively. In general, DO conditions were better during high tide as compared to the low tide.

Comparison of the overall average dissolved oxygen in Ulhas river estuary (Fig. DO-6) with the past available data of 1988-89 (Mukherjee, 1993), 1999-2000 (Mishra,

2002) shows significant reduction in the dissolved oxygen indicating growing pollution in Ulhas river estuary especially in past 3-4 years. In Thane creek the average dissolved oxygen level was excellent in 1975 (NIO, 1975) optimal in 1985 (Tandel, 1986) whereas by 1999-2000 it got significantly lowered due to growing pollution. The present DO level indicates further deterioration in Thane creek.

Table DO-1: Monthly and stationwise variations in Dissolved oxygen (mg/l) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	1.7	1	1.8	1.7	3.4	1.6	1.6	2.6	3.5	4.4	4.5	5	2.73	3.2	3.5	3.6	1.4	3.6	3.6	3.4	2.1	1.5	2	3.4	2.5	2.82	2.77
Oct	1.5	0.8	0.5	1.9	3.5	2	1.7	2.7	3.2	4	4.5	4.8	2.59	2.4	2.3	2.7	1.2	2	2.8	3	2	1.5	2.1	3	2.4	2.28	2.44
Nov	1.8	0.9	0	1.6	0.2	2	1.8	2.6	3.3	3.9	4.1	4.9	2.26	2	2.3	0.3	0.8	0.7	1.2	1.5	0.7	1.1	1.5	1.5	0.6	1.18	1.74
Dec	1.2	0.5	0.1	1.3	0.5	1.3	1.4	2.5	2.7	2.9	3.5	3.6	1.79	0.4	0.5	0.1	0.5	0.5	1.1	0.8	0.5	0.9	1.3	1.2	0.7	0.71	1.27
Jan	1.5	1.8	0.5	1.6	1.6	2.5	2.4	2.4	2.6	3.2	3.7	3.6	2.28	1.5	2.5	2.7	0.8	1	1.5	1.8	1.9	1.5	1.9	3.2	2.5	1.90	2.10
Feb	3	2.8	0.8	2.6	2.6	2.5	2.6	2.9	2.9	3	2.8	2.9	2.62	1.8	2.5	2.4	1.8	1.7	1.9	2	2	2	2.2	2.25	2.2	2.06	2.35
Mar	3.8	4	2.1	2.6	2	2.4	2.6	3.6	6.9	4.1	4.1	4.1	3.53	2.1	1.7	2	1.5	2	1.8	1.7	1.7	2	2.1	2	2	1.88	2.74
Apr	3.3	2.7	1	3	3.5	2.8	2.5	3	3.9	3.8	3	2.9	2.95	2.5	1.6	1.95	2	1.8	1.95	1.9	1.9	1.4	1.6	2.4	2.5	1.96	2.47
May	3.8	3	1.5	3	2.9	3.1	2.8	2.9	3.5	3.2	3.1	2.7	2.96	2.4	1.4	1.7	1.9	1.8	1.65	1.9	1.7	1.8	1.8	2	2.4	1.87	2.44
Jun	4.3	4.1	2.5	2.9	3.1	3	3	2.9	3.2	3	3.1	3	3.18	3.2	1.7	1.5	1.65	1.9	1.9	2.1	2.1	2.3	2.4	2.3	2.4	2.12	2.67
Jul	4.9	4.6	2.6	3.2	3.2	3.5	2.9	2.7	4.5	4	3.8	3.2	3.59	3.1	2.8	2.7	2.9	2.8	2.7	2.6	2.5	2.8	2.7	2.6	3	2.77	3.20
Aug	4	4.1	2.5	3.7	3.5	3.1	3	3.8	3.5	3.1	3.3	3.4	3.42	2.9	2.9	2.6	2.8	2.9	2.9	3.1	3.3	3	2.9	3.1	2.9	2.94	3.19
Sept	4.2	3.5	3.5	3	3.1	2.7	3.6	3.5	3.8	3.9	4.2	4.3	3.61	2.7	2.5	3.2	2.9	2.7	3	3	3	2.7	2.4	2.5	2.8	2.78	3.21
Oct	2	2.4	2.2	1.9	2.3	2.1	3.2	3	2.9	3.5	3.8	3.8	2.76	2.1	2.3	2.7	2.7	3.1	2.9	2.8	2.7	2.4	2.1	2.6	2.7	2.59	2.68
Nov	1.8	1.9	1.8	1.9	2	2	1.9	2.3	2.5	3.1	3.2	3.1	2.29	2.3	2.3	2	2.4	2.9	2.7	2.5	2	1.7	2	2.1	2.5	2.28	2.29
Avg	2.85	2.54	1.56	2.39	2.49	2.44	2.47	2.89	3.53	3.54	3.65	3.69	2.84	2.31	2.19	2.14	1.82	2.09	2.24	2.27	2.01	1.91	2.07	2.41	2.27	2.14	2.50

Table DO-2: Monthly and stationwise variations in Dissolved oxygen (mg/l) during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	1.9	1.1	1.9	1.7	3.5	1.9	1.9	2.6	3.7	4.4	4.5	5	2.84	3	3	3.1	1.5	3	3.7	3.2	2.1	1.4	2	2.9	2.4	2.61	2.73
Oct	1.6	0.9	0.6	1.7	3.3	1.8	1.8	2.7	3.5	3.9	4.5	4.8	2.59	2.1	2.5	2.5	1.5	2.5	2.4	2.7	1.8	1.2	1.8	2.7	2.4	2.18	2.39
Nov	1.7	0.9	0.1	1.5	0.5	1.8	1.8	2.5	2.5	3.7	4.1	4.8	2.16	1.8	2.1	0.2	0.9	0.9	1.1	1.7	0.6	0.9	1.5	1.5	0.6	1.15	1.67
Dec	0.9	0.7	0.3	1.1	0.6	1.4	1.5	2.4	2.8	3	3.7	3.8	1.85	0.2	0.7	0	0.8	0.5	1	0.9	0.4	0.8	1.1	1.1	0.7	0.68	1.29
Jan	0.8	2.4	0	1.3	1.5	2.2	2.8	2.3	3.9	3.4	5	4.5	2.51	1.8	0.8	1.5	0.8	0.7	0.6	2.6	2.5	2.8	2	2.2	2.1	1.70	2.12
Feb	1.2	3.5	3.3	3.9	2.1	2.1	0.94	2.1	1.15	1.57	2.9	2.31	2.26	1.25	0.4	0.55	0.5	0.1	0.1	3.1	3.1	7.4	1.3	1.3	2.5	1.80	2.04
Mar	3.5	3	0.9	2.6	2.4	2.5	2.3	2.8	2.5	2.6	2.7	2.75	2.55	1.8	0.8	0.85	1	1.2	1.5	1.8	1.7	1.9	3.2	2.6	2.7	1.75	2.17
Apr	2.8	4	0	4.8	2.7	2.7	3.3	3.75	5.4	2.7	3.5	3.4	3.25	2.8	2.9	0.7	4.9	13	13	3.4	3.4	5.5	4	4	2.5	5.01	4.10
May	2.7	3.2	0	1.1	1.6	2.5	1.9	2.6	2.2	2.3	2.3	2.65	2.09	1.65	0.9	1.9	3.5	3.2	3.3	2.9	2.7	3.6	3.7	2.6	0.7	2.55	2.31
Jun	2.4	2.7	1.2	3.2	2.2	2.1	2.8	3	4.8	4.3	4.4	4.3	3.12	1.6	0.7	1.9	0	3.1	3.1	1.6	1.6	2.9	0.4	0.4	2.5	1.65	2.41
Jul	2.5	3	0.9	2.9	2.5	2.5	2.7	1.9	4.1	2.6	4.1	2.95	2.72	1.8	0.95	2	0.25	0.7	0.32	0.84	2.5	3.5	2.6	2.7	2.4	1.71	2.24
Aug	2.7	3.1	0.7	3	3	3	4.1	0.3	4.7	4.3	5.2	4.2	3.19	1.65	0.3	0.2	1	1.5	1.7	2.3	2.6	3.5	2.3	2.5	2.2	1.81	2.53
Sept	3.5	3.1	2.6	2.7	2.7	2	2.9	2.9	2.9	3.5	4	4.3	3.09	2.4	2.2	2.7	2.7	2.9	2.7	3.1	2.7	2.6	2.5	2.3	2.3	2.59	2.85
Oct	1.1	2.2	2	1.8	2.4	1.6	2.7	2.8	2.7	3.5	3.5	3.7	2.50	2.3	1.9	1.7	2.2	2.9	2.7	2.9	2.6	2.6	1.9	2.5	2.5	2.39	2.45
Nov	1.6	2.1	2	1.75	2.1	1.5	2	2.6	2.6	2.9	3.3	3.3	2.31	2.5	1.9	1.9	2.1	2.5	2.5	2.6	1.9	2	1.9	2	2.4	2.18	2.25
Avg	2.06	2.39	1.10	2.34	2.21	2.11	2.36	2.48	3.30	3.24	3.85	3.78	2.60	1.91	1.47	1.45	1.58	2.58	2.65	2.38	2.15	2.84	2.15	2.22	2.06	2.12	2.37
Ht+Lt Avg	2.46	2.47	1.33	2.37	2.35	2.27	2.41	2.69	3.41	3.39	3.75	3.74	2.72	2.11	1.83	1.80	1.70	2.34	2.44	2.32	2.08	2.37	2.11	2.32	2.17	2.13	2.44

Fig. DO 1: Stationwise average dissolved oxygen (mg/l) during high tide and low tide

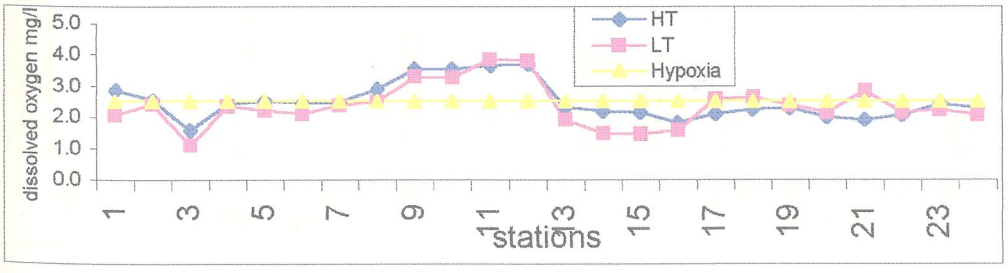


Fig.DO 2: Monthly variations in the average dissolved oxygen (mg/l) during high tide in Ulhas river estuary and Thane creek

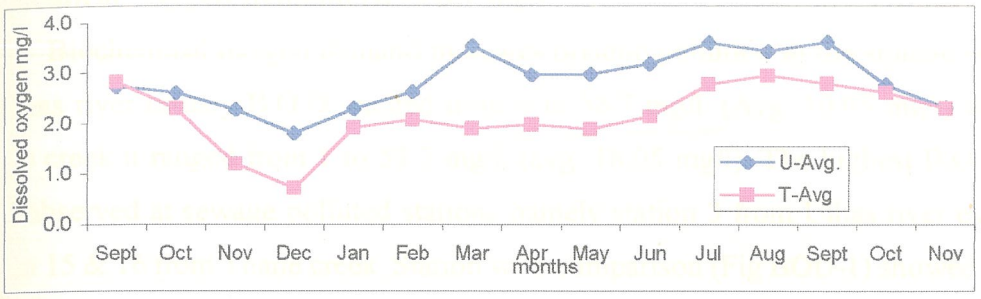


Fig.DO 3: Monthly variations in the average dissolved oxygen (mg/l) during Low tide in Ulhas river estuary and Thane creek.

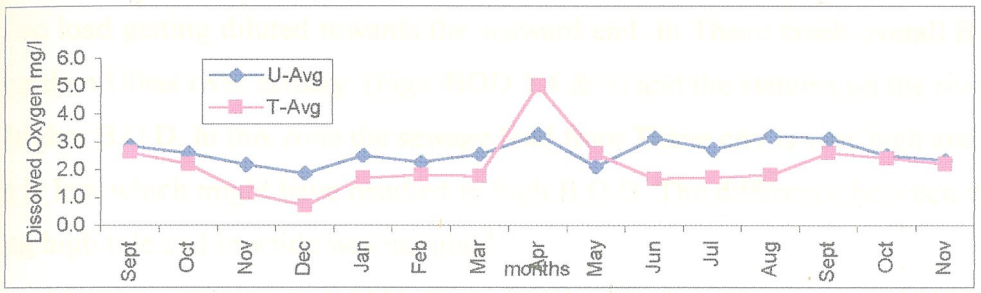


Fig DO 4: Zonewise variations in the average dissolved oxygen (mg/l) in Ulhas river estuary and Thane creek during High tide

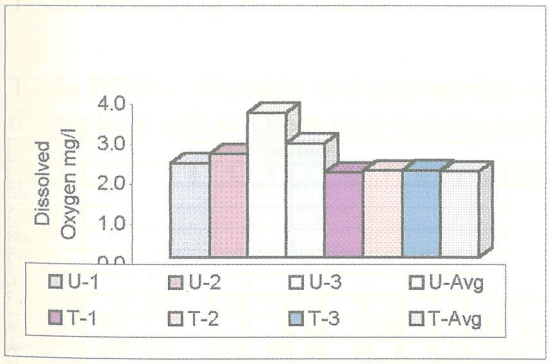


Fig DO 5: Zonewise variations in the average dissolved oxygen (mg/l) in Ulhas river estuary and Thane creek during Low tide

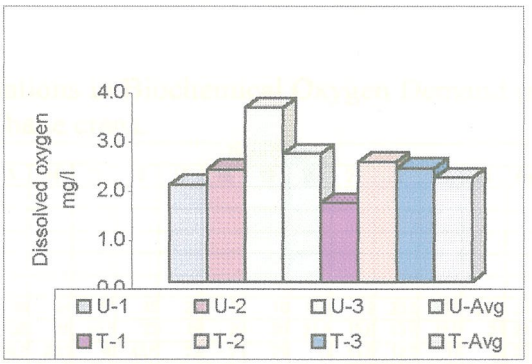


Fig. DO 6: Comparison of Dissolved Oxygen with past available data of Ulhas river estuary

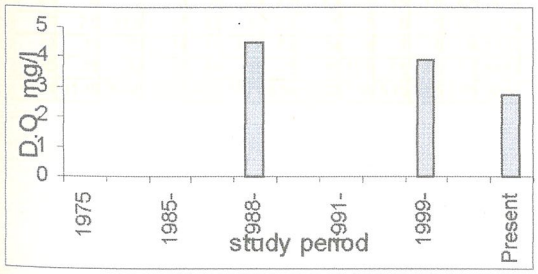
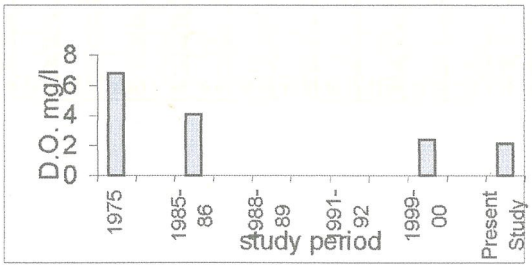


Fig. DO 7: Comparison of Dissolved Oxygen in Thane creek with past available data



Biochemical Oxygen Demand (B.O.D.) mg/l

Biochemical oxygen demand indicates organic pollution in the aquatic ecosystem. In Ulhas river estuary B.O.D. ranged from 0 to 58.7 mg/l. (Avg. 10.05 mg/l) whereas in Thane creek it ranged from 1 to 53.7 mg/l. (avg. 18.05 mg/l). The highest B.O.D. values were observed at sewage polluted stations namely station 3 from Ulhas river estuary and station 15 & 16 from Thane creek. Station wise comparison (Fig BOD-1) showed very high average B.O.D at station 3 of Ulhas river estuary. The other stations had moderate B.O.D. around 10 mg/l which gradually declined towards the seaward end. This could be due to the organic load getting diluted towards the seaward end. In Thane creek overall B.O.D. was higher than Ulhas river estuary (Figs. BOD 1,4 & 5) and the stations on the riverine zone had higher B.O.D. In this zone the sewage load from Thane city is very high and the water mass is low which might have resulted in high B.O.D. The difference between the B.O.D. during high tide and low tide was marginal.

Monthly variation in B.O.D. (Figs. BOD- 2,3) showed lowering of B.O.D. during monsoon (June to August) due to flushing of organic matter by the monsoon floods. Zonewise trend showed lowering of B.O.D. towards seaward zone 3 in both URE and Thane creek (Fig. BOD 4 &5).

Table BOD-1: Monthly and stationwise variations in Biochemical Oxygen Demand (mg/l) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept																											
Oct																											
Nov																											
Dec																											
Jan																											
Feb	12.6	11	28.4	11.5	6.9	17.9	7.3	16	11	7	8.5	7.3	12.12	36	24	47	45	20	15	19	13.3	12	23.5	23.8	20.9	24.96	18.28
Mar	15	17.5	49.2	16	9	18	8.3	15	9.5	7.2	7.2	6.5	14.87	38	19	53.5	32	19	22	20	21.9	15.6	13.8	15.9	21	24.31	19.40
Apr	12	13.2	41.5	15	15.8	15.7	8.4	14	9	6	7.3	7.3	13.77	28.7	20.3	16	43.5	22	21	21	11	11.5	12.2	17	19	20.27	16.89
May	13.3	13	47.8	14	10	15	8	13	8	8	8	8.3	13.87	40.1	35.7	47.7	47.5	28	24	25	19.5	14.3	15.7	17	17.2	27.64	20.48
Jun	5.8	5.7	31.5	7	6.8	6.8	3	5	5.5	4	1.2	1.2	6.96	15	7	9	17	6	5	3.5	3.5	7	7	9	11	8.33	7.62
Jul	5.2	8	25.1	1.2	3.1	3	3	3.1	1.2	1.2	1.3	1.3	4.73	17	9	19	16	8	6	5	3.2	1.7	1.9	1.9	3.3	7.67	6.14
Aug	3.5	8	7	3	5	2.3	7.1	1.2	0.5	3.5	4.5	4.1	4.14	15	3	18.6	12	6.1	6.7	5	3.2	2.1	2.1	3.7	3.7	6.77	5.40
Sept	7	7.5	11.5	15	10	15	7.2	5	8	6	5	5.2	8.53	18	20	18	22	22	20	21	19	13	15	9	11	17.33	12.76
Oct	12	13	23	14	11	16.8	7.5	14	8	7	6	6	11.53	27	25	32	35	23.3	21.8	24	18	13.1	15.4	11	12	21.47	16.30
Nov	15	15	39	17	14	18	8	16	10.9	7.6	7.5	7.3	14.61	37	28	48	39	25.4	23	22.3	20	14	19	19	19.2	26.16	20.15
Avg	10.14	11.19	30.40	11.37	9.16	11.71	6.54	10.23	7.16	5.75	5.65	5.45	10.40	27.18	19.10	30.88	30.90	17.98	16.45	16.58	13.26	10.43	12.56	12.73	13.83	18.49	14.28

Table BOD-2: Monthly and stationwise variations in Biochemical Oxygen Demand (mg/l) during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total avg
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	
Sept																											
Oct																											
Nov																											
Dec																											
Jan																											
Feb	12.3	12.5	32.2	9.2	6.4	21.6	5.66	15.32	10.55	6.6	7.8	7.2	12.28	32.5	27.8	42.2	53.7	24	20	21.7	15	14.3	19	13.2	19.5	25.24	18.50
Mar	13.3	13.9	55.9	11.5	6.4	21.8	6	15.5	8	6	6	5	14.11	27	19	35.5	35	20	20	18	17	11.3	11.5	14.3	17.5	20.51	17.18
Apr	11.3	10.3	58.7	10.3	8.8	21.3	6.4	12.4	7.4	5.4	6.4	6.9	13.80	24.3	15.7	10.7	44.2	20.7	19.5	15.4	13.2	9.2	13.2	15.7	15.4	18.10	15.86
May	13	13.1	50.9	13.5	9.7	14.1	5	12	6.5	6.8	7	7	13.22	35.6	34.5	44.9	43.2	24.8	23.2	19	15	11.3	14.5	18	18.4	25.20	18.97
Jun	5.2	5.2	41.2	5.2	4.2	3.2	1	2.7	2.2	1	1.2	1	6.11	11	5	7.5	15.5	4.5	3.5	2.7	2.3	2	2.5	8	10.5	6.25	6.18
Jul	5	8.3	28.3	0.6	2.9	2	2	2	1	0.3	0.5	0.4	4.44	11	4	16	15	2	2	2.5	2	1	1.8	1.8	3	5.18	4.79
Aug	3.2	9.2	13.9	1	3.2	1.2	6.3	0.3	0	3.3	4.3	3.3	4.10	13	2	11	13	6	6	4.5	3	2	2	4	4.3	5.90	4.96
Sept	5	6	15	10	7	9	4.1	3.2	4.3	4	4.1	5	6.39	15	27	20	29	23.5	25	25.1	19.3	15	15.2	11	11.8	19.74	12.80
Oct	10	12.5	29	9	9	13.7	5.2	9.4	4.9	4.7	4.7	5.8	9.83	22	29	29	41	26.1	23	25.7	19.4	15.3	16.3	12.4	12.7	22.66	15.99
Nov	12	14.2	43	14.2	13	15	4.9	10.5	8.3	5.5	5.5	7	12.76	30	33	37	44.3	26	27	29	21.7	17.9	20.8	20.4	20.5	27.30	19.74
Avg	9.03	10.52	36.81	8.45	7.06	12.29	4.66	8.33	5.32	4.36	4.75	4.86	9.70	22.14	19.70	25.38	33.39	17.76	16.92	16.36	12.79	9.93	11.68	11.88	13.36	17.61	13.50
Ht+Lt Avg	9.59	10.86	33.61	9.91	8.11	12.00	5.60	9.28	6.24	5.06	5.20	5.16	10.05	24.66	19.40	28.13	32.15	17.87	16.69	16.47	13.03	10.18	12.12	12.31	13.60	18.05	13.89

Fig. BOD 1: Stationwise average BOD (mg/l) during low tide and high tide in Ulhas river estuary and Thane creek.

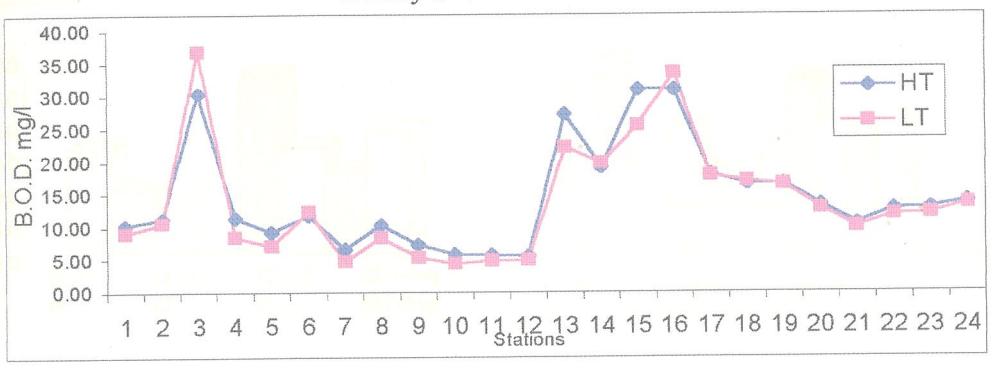


Fig BOD 2: Monthly variations in average B.O.D. mg/l during high tide in Ulhas river estuary and Thane creek

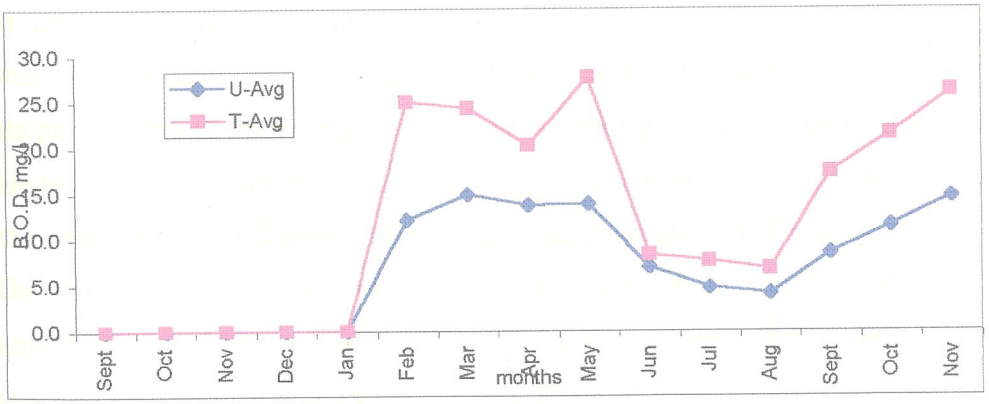


Fig BOD 3: Monthly variations in the average B.O.D. mg/l during low tide in Ulhas river estuary and Thane creek

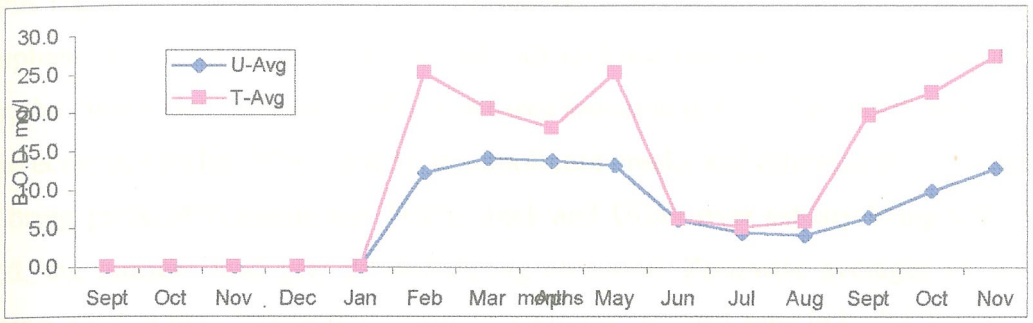


Fig. BOD 4: Zonewise variations in the annual average B.O.D. (mg/l) during high tide in Ulhas river estuary and Thane Creek.

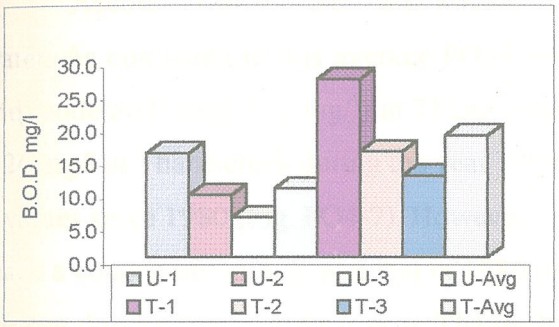
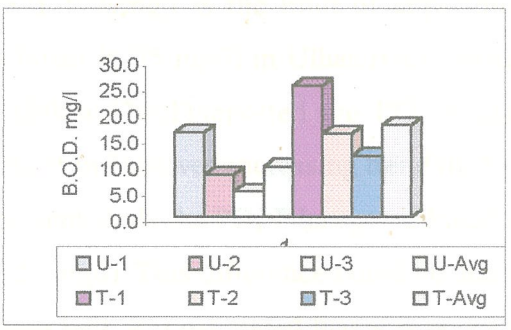


Fig BOD 5: Zonewise variations in annual average B.O.D. (mg/l) during low tide in Ulhas river estuary and Thane creek.



Phosphate – Phosphorus. (PO_4–P) mg/l

In aquatic ecosystems the phosphorus occurs as dissolved inorganic phosphorus, dissolved organic phosphorus and particulate phosphorus. The dissolved inorganic phosphorus is utilized by the primary producers and converted to dissolved and particulate phosphorus (Lemasson and Pages, 1981). Phosphorus is added to the aquatic bodies due to the industrialization, urbanization and use of fertilizers in agricultural fields which get washed with runoff water and get into aquatic ecosystem (Fisher *et al* 1988).

The PO_4–P ranged from 0.003 to 0.248 mg/l (avg. 0.055 mg/l) in Ulhas river estuary and 0.018 to 0.353 mg/l (avg 0.10 mg/l) in Thane creek (Tables PO4 1 & 2). Stationwise comparison of average PO4 – P (Fig PO4-1) showed almost uniform levels of PO_4-P in Ulhas river estuary except significant peak values at station 3 & 6 which could be due to proximity of these stations with major sewage reaches (Dombivili and

Kolshet respectively). As compared to URE Thane creek showed high and fluctuating PO_4 – P. The average phosphate values were significantly high at upstream stations 13 to 16 as this region is narrow and shallow and receives heavy sewage load. The difference in phosphate concentration between the high tide and low tide was not very significant. Further, the monthwise variation in PO_4–P showed lowering of PO_4–P during monsoon in both the ecosystems (Fig PO4 – 2 &3). In unpolluted creeks and estuaries the monsoon floods bring pulse of nutrients but Thane creek and Ulhas river estuary being heavily polluted, the nutrient load gets diluted during monsoon. Zonewise averages showed decreasing trend of PO_4–P from the riverine zone to the seaward zone in both Ulhas river estuary and Thane creek and very high average PO_4–P in riverine zone 1 of Thane creek (Figs. PO4 – 4 & 5).

According to Yentsch and Ryther (1957), 0.09mg/l is the limit of unpolluted water. As compared to this average PO_4-P was lower (0.05 mg/l) in Ulhas river estuary and moderately high (0.1 mg/l) in Thane creek. Goldin (2001) reported avg. PO_4-P value 0.26 mg/l in Thane creek during the year 1999-2000 and showed increasing trend in PO_4-P values since 1980 (Fig. PO4-7). However in present study the PO_4-P has got reduced to reach a concentration less than that in 1980 (0.127 mg/l). This difference could be due to closing down of many industries in Thane-Belapur belt. It is estimated that at least 30 to 40 % industries of this region have been closed down or shifted. A similar decrease in PO4-P has been noticed in Ulhas river estuary. (Fig. PO4-6).

Table PO4-1: Monthly and stationwise variations in Phosphate-phosphorus (mg/l) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	0.022	0.032	0.033	0.042	0.038	0.041	0.041	0.053	0.051	0.039	0.041	0.037	0.04	0.176	0.130	0.177	0.082	0.114	0.077	0.058	0.121	0.065	0.058	0.076	0.108	0.10	0.07
Oct	0.023	0.039	0.142	0.036	0.042	0.045	0.080	0.061	0.053	0.048	0.056	0.061	0.06	0.199	0.160	0.187	0.104	0.124	0.097	0.061	0.123	0.109	0.060	0.080	0.124	0.12	0.09
Nov	0.045	0.033	0.093	0.028	0.053	0.053	0.056	0.066	0.062	0.049	0.052	0.055	0.05	0.183	0.155	0.141	0.077	0.092	0.080	0.049	0.135	0.108	0.063	0.079	0.125	0.11	0.08
Dec	0.052	0.042	0.115	0.030	0.049	0.051	0.070	0.064	0.073	0.058	0.054	0.058	0.06	0.198	0.183	0.180	0.114	0.117	0.111	0.058	0.142	0.114	0.066	0.087	0.139	0.13	0.09
Jan	0.051	0.030	0.100	0.016	0.041	0.047	0.140	0.008	0.037	0.041	0.039	0.030	0.05	0.179	0.114	0.169	0.117	0.105	0.081	0.035	0.087	0.045	0.093	0.093	0.102	0.10	0.07
Feb	0.048	0.051	0.217	0.055	0.055	0.083	0.073	0.062	0.066	0.061	0.047	0.056	0.07	0.148	0.114	0.152	0.114	0.121	0.114	0.051	0.098	0.094	0.067	0.061	0.108	0.10	0.09
Mar	0.023	0.031	0.156	0.151	0.055	0.055	0.051	0.060	0.058	0.061	0.041	0.041	0.07	0.113	0.058	0.117	0.101	0.101	0.110	0.056	0.116	0.090	0.055	0.055	0.022	0.08	0.07
Apr	0.049	0.051	0.113	0.046	0.048	0.248	0.042	0.031	0.036	0.036	0.034	0.035	0.06	0.141	0.110	0.104	0.273	0.089	0.093	0.083	0.092	0.114	0.072	0.092	0.090	0.11	0.09
May	0.203	0.028	0.083	0.048	0.051	0.114	0.031	0.031	0.034	0.031	0.028	0.035	0.06	0.153	0.145	0.136	0.183	0.035	0.048	0.041	0.068	0.110	0.036	0.055	0.050	0.09	0.07
Jun	0.019	0.017	0.110	0.015	0.016	0.031	0.047	0.051	0.053	0.056	0.036	0.036	0.04	0.044	0.035	0.037	0.127	0.031	0.031	0.034	0.034	0.034	0.051	0.030	0.045	0.04	0.04
Jul	0.172	0.010	0.110	0.027	0.017	0.151	0.003	0.003	0.005	0.005	0.052	0.031	0.05	0.157	0.118	0.111	0.124	0.034	0.044	0.040	0.027	0.031	0.049	0.031	0.061	0.07	0.06
Aug	0.034	0.028	0.109	0.034	0.039	0.050	0.041	0.041	0.043	0.043	0.083	0.076	0.05	0.117	0.056	0.108	0.086	0.042	0.042	0.045	0.045	0.028	0.024	0.031	0.036	0.06	0.05
Sept	0.023	0.031	0.093	0.038	0.041	0.049	0.038	0.041	0.037	0.041	0.039	0.030	0.04	0.141	0.110	0.104	0.214	0.105	0.081	0.035	0.087	0.090	0.055	0.076	0.108	0.10	0.07
Oct	0.052	0.042	0.115	0.036	0.042	0.045	0.080	0.064	0.073	0.058	0.054	0.058	0.06	0.148	0.114	0.152	0.114	0.121	0.110	0.056	0.116	0.114	0.066	0.087	0.139	0.11	0.08
Nov	0.048	0.051	0.142	0.048	0.051	0.055	0.083	0.056	0.066	0.061	0.061	0.061	0.07	0.183	0.155	0.141	0.117	0.105	0.111	0.073	0.114	0.117	0.089	0.092	0.114	0.12	0.09
Avg	0.058	0.034	0.115	0.043	0.043	0.074	0.058	0.046	0.050	0.046	0.048	0.047	0.06	0.152	0.117	0.134	0.130	0.089	0.082	0.052	0.094	0.084	0.060	0.068	0.091	0.10	0.07

Table PO4-2: Monthly and stationwise variations in Phosphate phosphorus (mg/l) during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	0.019	0.031	0.031	0.041	0.039	0.042	0.042	0.047	0.052	0.042	0.044	0.041	0.04	0.177	0.133	0.178	0.084	0.116	0.078	0.058	0.115	0.062	0.055	0.078	0.105	0.10	0.07
Oct	0.022	0.032	0.150	0.031	0.040	0.043	0.083	0.063	0.053	0.051	0.057	0.062	0.06	0.200	0.163	0.183	0.103	0.129	0.093	0.062	0.121	0.105	0.061	0.081	0.121	0.12	0.09
Nov	0.041	0.034	0.114	0.023	0.052	0.059	0.055	0.067	0.062	0.052	0.055	0.053	0.06	0.184	0.153	0.145	0.078	0.094	0.083	0.050	0.125	0.108	0.065	0.079	0.124	0.11	0.08
Dec	0.048	0.035	0.131	0.028	0.049	0.053	0.072	0.064	0.073	0.058	0.055	0.061	0.06	0.200	0.179	0.180	0.111	0.118	0.113	0.054	0.139	0.109	0.069	0.088	0.135	0.12	0.09
Jan	0.049	0.027	0.112	0.017	0.046	0.047	0.016	0.009	0.039	0.047	0.040	0.031	0.04	0.177	0.111	0.200	0.118	0.103	0.078	0.030	0.084	0.048	0.108	0.087	0.105	0.10	0.07
Feb	0.046	0.055	0.223	0.052	0.059	0.075	0.071	0.068	0.062	0.058	0.046	0.053	0.07	0.142	0.109	0.149	0.113	0.118	0.111	0.058	0.101	0.095	0.064	0.060	0.106	0.10	0.09
Mar	0.022	0.035	0.150	0.120	0.049	0.052	0.047	0.059	0.055	0.058	0.040	0.040	0.06	0.112	0.054	0.113	0.142	0.113	0.112	0.054	0.113	0.089	0.054	0.054	0.019	0.09	0.07
Apr	0.048	0.046	0.110	0.042	0.044	0.241	0.039	0.025	0.033	0.036	0.032	0.034	0.06	0.138	0.102	0.102	0.353	0.055	0.056	0.042	0.087	0.101	0.038	0.041	0.083	0.10	0.08
May	0.015	0.019	0.113	0.055	0.052	0.112	0.028	0.030	0.054	0.019	0.025	0.042	0.05	0.184	0.134	0.097	0.212	0.030	0.054	0.038	0.068	0.112	0.035	0.058	0.050	0.09	0.07
Jun	0.017	0.009	0.120	0.012	0.012	0.029	0.041	0.053	0.052	0.041	0.035	0.031	0.04	0.042	0.032	0.036	0.127	0.027	0.030	0.032	0.033	0.033	0.048	0.025	0.045	0.04	0.04
Jul	0.019	0.011	0.112	0.030	0.017	0.150	0.034	0.036	0.051	0.051	0.054	0.019	0.05	0.142	0.115	0.112	0.123	0.031	0.042	0.035	0.023	0.030	0.045	0.019	0.054	0.06	0.06
Aug	0.034	0.025	0.115	0.031	0.034	0.050	0.039	0.042	0.043	0.040	0.070	0.058	0.05	0.112	0.054	0.107	0.084	0.040	0.042	0.038	0.040	0.024	0.018	0.030	0.035	0.05	0.05
Sept	0.022	0.028	0.095	0.034	0.045	0.047	0.034	0.044	0.034	0.041	0.041	0.003	0.04	0.146	0.108	0.108	0.180	0.108	0.094	0.031	0.090	0.094	0.061	0.077	0.109	0.10	0.07
Oct	0.045	0.039	0.111	0.031	0.044	0.051	0.070	0.058	0.062	0.055	0.055	0.060	0.06	0.153	0.112	0.154	0.136	0.124	0.117	0.051	0.123	0.120	0.069	0.089	0.140	0.12	0.09
Nov	0.042	0.045	0.144	0.049	0.058	0.059	0.073	0.061	0.064	0.062	0.062	0.062	0.07	0.168	0.151	0.145	0.120	0.108	0.114	0.077	0.120	0.122	0.090	0.093	0.118	0.12	0.09
Avg	0.033	0.031	0.122	0.040	0.043	0.074	0.050	0.048	0.053	0.047	0.047	0.043	0.05	0.152	0.114	0.134	0.139	0.088	0.081	0.047	0.092	0.083	0.059	0.064	0.090	0.095	0.07
HT+LT avg.	0.045	0.033	0.119	0.042	0.043	0.074	0.054	0.047	0.051	0.047	0.048	0.045	0.05	0.152	0.115	0.134	0.134	0.088	0.082	0.049	0.093	0.084	0.059	0.066	0.091	0.10	0.07

Fig. PO4 1: Stationwise average Phosphate Phosphorus (mg/L) variations during High tide and Low tide in Ulhas river estuary and Thane creek.

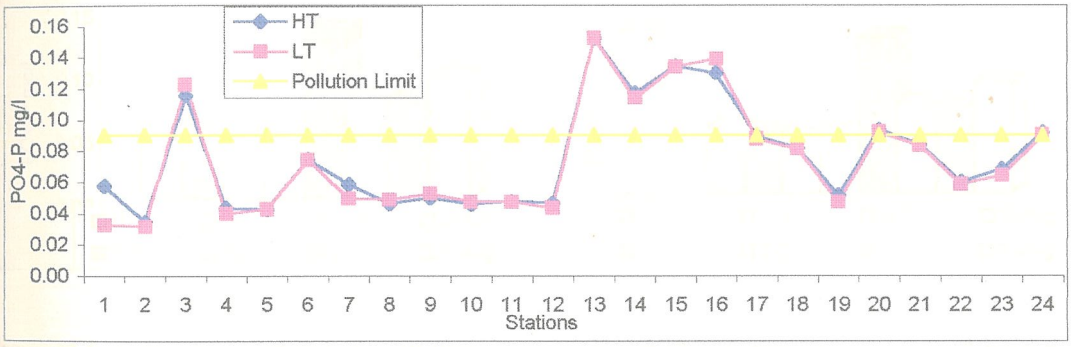


Fig. PO4 2: Monthly variations in PO_4-P (mg/l) during high tide in Ulhas river and Thane creek

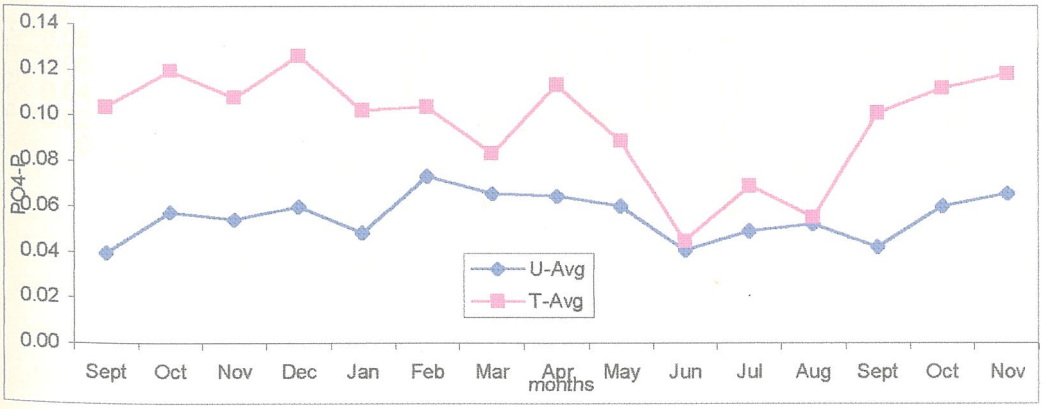


Fig. PO4 3: Monthly variations in PO_4-P (mg/l) during low tide in Ulhas river and Thane creek

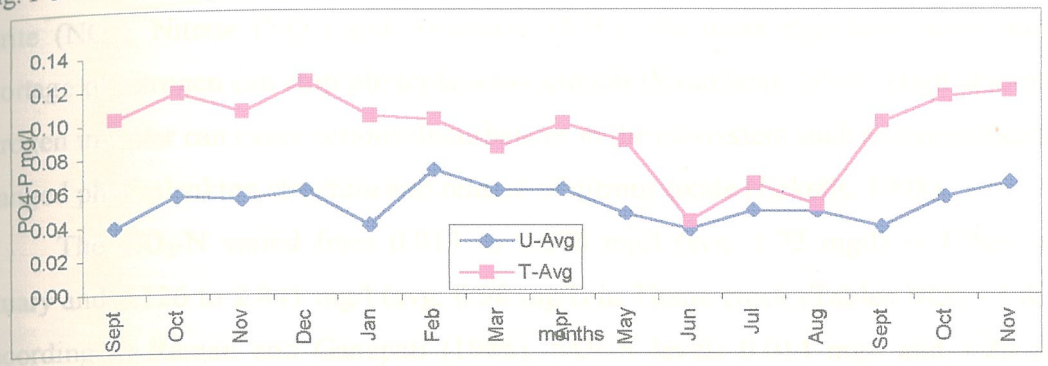


Fig. PO4 4: Zonewise annual average PO_4-P (mg/l) during high tide in Ulhas river estuary and Thane creek.

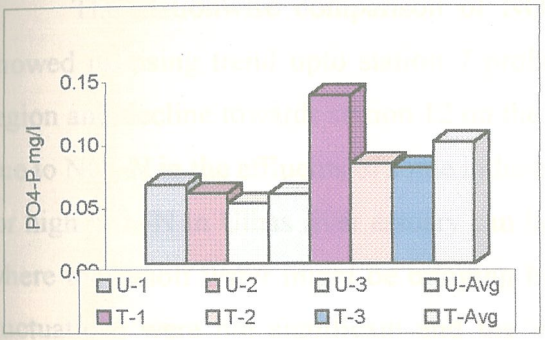


Fig. PO4 5: Zonewise annual average of PO_4-P (mg/l) during low tide in Ulhas river estuary and Thane creek

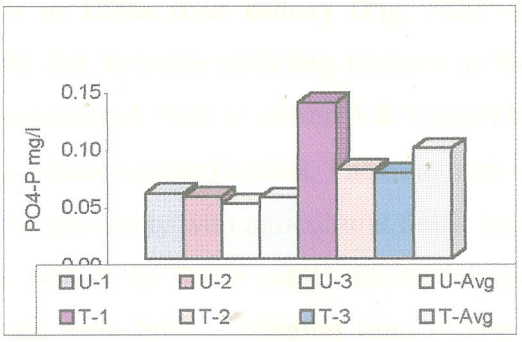


Fig PO4 6: Comparison of PO_4-P with past available data of Ulhas river estuary.

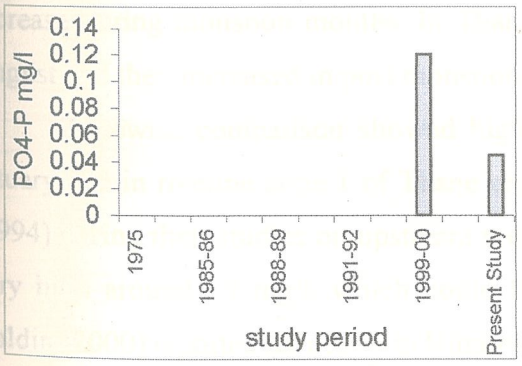
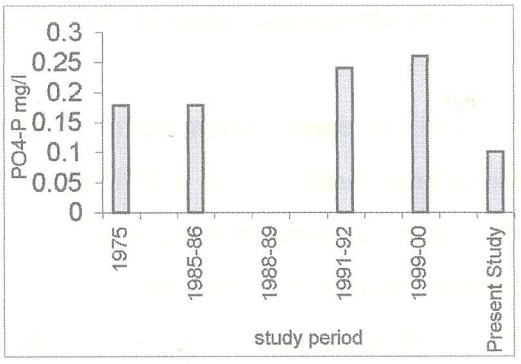


Fig PO4 7: Comparison of PO_4-P with past available data in Thane creek



Nitrate-nitrogen (NO_3-N)

Nitrogen significantly affects phytoplankton growth in natural waters. It occurs as nitrite (NO_2), Nitrate (NO_3) and Ammonia (NH_3), the most abundant being nitrate. Shortage of nitrogen can stop phytoplankton growth (Strickland, 1965). High amount of nitrogen in water can cause serious disturbances in the ecosystem such as eutrophication, changed phytoplankton structure and release of nitrous oxide (Jickells, 1998).

The NO_3-N varied from 0.013 to 9.278 mg/l (avg. 1.72 mg/l) in Ulhas river estuary and 0.126 to 2.841 mg/l (avg. 0.98 mg/l) in Thane creek (Tables NO3 - 1 & 2). According to Raman and Ganapati (1986), NO_3-N levels 0.014 mg/l and 1.26 mg/l indicate unpolluted and semihealthy environments respectively. Accordingly the NO_3-N are quite high in Ulhas river estuary and moderate in Thane creek.

The stationwise comparison of NO_3-N in Ulhas river estuary (Fig. NO3 -1) showed its rising trend upto station 7 probably due to some polluting sources in this region and decline towards station 12 on the seaward end. Peak at station 6 & 7 could be due to NO_3-N in the effluents of some industries releasing near Kolshet. The other reason for high NO_3-N in Ulhas river estuary can be the proximity with agricultural fields from where the runoff water might be bringing high NO_3-N. In Thane creek, the stationwise fluctuations were not significant and the values were below pollution limit of semi-healthy environment (1.26 mg/l). The monthly variations (Fig. NO3- 2 & 3) showed high NO_3-N in Ulhas river estuary during post monsoon October – December and also increase during monsoon months. In Thane creek the nitrates significantly dropped in August and then increased in post monsoon.

Zonewise comparison showed high NO_3-N in the middle zone of Ulhas river estuary and in riverine zone 1 of Thane creek (Figs NO3 4 & 5). Gokhale and Athalye (1994) during their studies on upstream region of Thane creek observed average NO_3-N very high around 17 mg/l, which could be due to some polluting source. However, Goldin (2000) reported reduction in Nitrates in the same region during his studies in 1999 – 2000 indicating non-operation of the polluting source. He observed overall average to be 0.970 mg/l which is comparable with the present average. Thus there is not much change in NO_3-N levels of Thane creek since 1999. The averageNO_3-N levels in the

down stream stretches of Thane creek(0.9 mg/l) is significantly high as compared to the values reported in 1980 (0.3 mg/l; NIO,1980) and 1985 (0.36 mg/l; Athalye,1988) suggesting buildup of NO_3-N in Thane creek. The status of NO_3-N in general leads to two conclusions.

1. The miscellaneous polluting source noticed in 1991 to 1994 is non operative presently.
2. Overall NO3-N in the creek has slightly increased probably due to increased sewage effluent load.

Table NO3-1: Monthly and stationwise variations in Nitrate nitrogen (mg/l) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	0.754	0.075	0.327	0.013	1.936	1.861	2.917	1.157	1.131	0.830	0.880	1.106	1.08	0.754	0.251	0.503	0.377	0.402	0.377	0.503	0.478	0.427	0.629	0.930	0.528	0.51	0.81
Oct	1.282	1.785	1.131	2.011	2.464	2.263	3.394	1.760	2.011	1.131	1.257	1.257	1.81	1.282	0.981	1.282	2.187	0.880	1.534	1.257	1.257	0.453	1.333	1.106	0.503	1.17	1.50
Nov	1.634	1.710	1.232	2.137	2.891	3.947	4.098	2.263	2.137	1.232	1.760	1.634	2.22	1.383	0.704	0.981	0.779	2.816	1.383	1.433	2.766	1.483	1.634	1.383	1.031	1.48	1.87
Dec	1.710	2.137	1.509	2.288	2.917	4.224	4.450	2.539	2.690	2.011	2.263	2.137	2.57	1.157	0.478	0.553	0.629	0.981	0.805	0.981	1.483	0.779	1.659	0.880	1.232	0.97	1.80
Jan	1.735	1.458	1.131	1.509	0.880	1.609	2.489	2.263	2.137	2.062	2.137	2.112	1.79	2.011	1.534	1.509	0.629	0.629	1.031	1.031	0.981	1.785	1.257	2.263	2.011	1.39	1.60
Feb	0.880	0.955	0.855	1.006	0.855	1.131	1.886	0.251	1.886	2.389	1.358	1.559	1.25	2.464	1.961	0.779	0.629	1.056	1.031	1.634	1.458	1.282	2.313	1.634	1.534	1.48	1.36
Mar	0.880	1.157	1.131	1.157	0.880	1.408	1.685	1.735	1.735	1.986	1.609	1.961	1.44	1.483	1.483	0.302	0.251	0.251	0.277	0.226	0.251	0.729	0.955	0.930	0.955	0.67	1.07
Apr	1.031	1.131	1.031	1.232	1.282	1.106	2.238	2.112	2.137	2.112	2.112	1.986	1.63	1.986	0.478	0.578	0.855	0.553	0.629	0.629	0.603	0.629	0.629	0.729	0.729	0.75	1.21
May	1.131	1.106	1.182	1.282	1.333	1.483	1.735	1.986	2.238	1.986	1.986	1.986	1.62	1.986	1.735	0.855	0.981	0.805	0.805	0.779	0.754	0.880	0.754	0.754	0.880	1.00	1.32
Jun	1.006	1.006	1.031	1.157	1.232	1.307	1.710	1.861	1.961	1.961	1.986	1.886	1.51	1.735	1.182	1.131	1.106	1.031	1.232	1.056	1.056	1.031	1.006	1.006	1.006	1.13	1.33
Jul	2.011	2.011	1.131	1.408	1.609	1.609	1.961	1.986	2.087	2.137	2.112	2.112	1.85	2.263	1.006	1.131	1.131	1.031	1.232	1.056	1.182	1.131	1.006	1.031	0.955	1.18	1.53
Aug	2.389	2.288	5.330	2.389	2.489	2.464	0.629	0.553	0.528	0.629	0.553	0.503	1.73	0.629	0.503	0.251	0.251	0.251	0.503	0.629	0.629	0.251	0.251	0.251	0.377	0.40	1.09
Sept	1.735	1.458	1.131	2.288	2.389	2.137	2.389	1.131	1.257	0.805	1.006	0.629	1.53	0.830	1.031	0.704	0.704	0.830	0.779	0.790	0.830	0.377	0.427	0.478	0.553	0.69	1.13
Oct	1.886	1.559	1.182	2.338	2.489	2.439	2.439	1.886	1.735	1.131	1.710	1.257	1.84	1.157	1.483	0.790	0.855	1.056	1.157	1.131	1.282	0.528	0.704	0.729	0.679	0.96	1.42
Nov	1.986	1.659	1.383	2.489	2.640	2.766	2.891	2.313	1.961	1.710	2.062	1.861	2.14	1.810	1.735	0.880	1.106	1.986	1.483	1.584	1.483	0.880	0.981	1.131	0.981	1.34	1.76
Avg	1.470	1.433	1.381	1.647	1.886	2.117	2.461	1.720	1.842	1.607	1.653	1.599	1.73	1.529	1.103	0.815	0.831	0.971	0.950	0.981	1.100	0.843	1.036	1.016	0.930	1.01	1.39

Table NO3-2: Monthly and stationwise variations in Nitrate nitrogen (mg/l) during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	0.779	0.126	0.302	0.025	1.986	1.634	2.489	1.634	1.634	0.754	0.729	1.232	1.11	0.503	0.503	0.729	0.277	0.251	0.302	0.528	0.277	0.251	0.226	0.503	1.006	0.45	0.79
Oct	1.383	1.659	1.031	2.238	2.565	2.338	3.243	2.263	2.263	1.257	1.031	1.433	1.89	0.251	1.282	0.251	0.855	0.503	0.327	1.458	0.830	1.006	1.056	0.603	0.352	0.73	1.33
Nov	1.534	1.584	1.333	2.439	0.302	0.402	3.998	2.539	2.263	1.383	1.634	1.735	1.76	2.213	1.358	1.257	2.766	1.106	2.843	1.131	2.615	1.735	1.358	1.659	2.162	1.85	1.80
Dec	1.483	2.213	1.659	2.464	0.304	4.400	4.551	2.766	2.766	2.263	1.961	1.961	2.40	1.031	0.880	1.559	0.729	0.603	0.981	0.629	0.855	1.659	0.679	1.986	1.358	1.08	1.77
Jan	1.861	1.760	1.182	1.634	1.886	1.584	1.835	2.011	2.037	1.936	1.986	1.810	1.79	1.886	1.282	1.383	0.478	0.553	0.880	0.955	0.880	1.634	1.131	1.659	0.880	1.13	1.48
Feb	0.754	0.805	0.654	0.855	0.603	1.081	1.735	0.201	1.609	2.037	1.333	1.458	1.09	2.037	1.333	1.056	0.981	1.106	1.131	1.383	1.634	1.056	2.414	1.081	1.207	1.37	1.23
Mar	0.629	1.131	0.930	0.855	0.629	1.106	1.760	0.176	0.226	1.634	2.238	1.131	1.04	2.062	1.157	0.226	0.201	0.226	0.226	0.251	0.277	0.905	1.157	1.106	0.905	0.72	0.89
Apr	0.981	1.081	1.182	1.257	1.584	1.131	2.112	2.037	2.062	1.835	1.760	1.810	1.57	1.634	0.503	0.478	0.779	0.453	0.503	0.528	0.503	0.629	0.578	0.679	0.629	0.66	1.13
May	0.955	1.182	1.006	1.257	1.509	1.307	2.037	1.886	2.087	1.634	1.634	1.634	1.51	1.509	1.157	0.629	0.880	0.629	0.629	0.453	0.478	0.830	0.654	0.855	0.880	0.80	1.17
Jun	0.955	1.307	0.830	1.333	1.483	1.559	2.037	2.162	1.634	1.358	1.433	1.157	1.44	1.383	1.232	1.081	0.830	0.830	0.880	0.880	0.704	0.779	0.729	0.754	0.704	0.90	1.18
Jul	1.911	1.886	3.143	3.143	1.634	1.458	1.710	1.886	2.112	0.880	1.458	0.754	1.83	0.880	0.830	0.830	0.880	0.930	0.754	0.855	0.930	0.930	0.805	0.880	0.855	0.86	1.37
Aug	2.741	2.037	9.278	2.464	2.766	3.998	0.176	0.151	0.101	0.302	0.025	0.327	2.03	0.302	0.251	0.176	0.226	0.176	0.151	0.126	0.126	0.151	0.151	0.151	0.126	0.18	1.14
Sept	1.886	1.634	1.358	2.464	2.464	2.263	2.514	1.483	1.483	1.307	1.408	0.754	1.75	1.056	1.232	0.880	0.805	1.081	1.081	1.131	1.131	0.528	0.729	0.503	0.629	0.90	1.34
Oct	2.011	1.886	1.383	2.766	2.715	2.514	2.715	2.263	1.961	1.408	1.810	1.383	2.07	1.333	1.810	1.006	1.081	1.358	1.383	1.483	1.383	0.805	0.754	0.754	0.729	1.16	1.63
Nov	2.464	1.810	1.710	2.816	2.791	2.967	3.017	2.640	2.313	1.76	2.213	2.011	2.38	2.062	2.087	1.106	1.609	2.137	1.710	1.861	1.685	1.056	1.031	1.182	1.006	1.54	1.98
Avg	1.488	1.473	1.799	1.867	1.681	1.983	2.395	1.740	1.770	1.450	1.510	1.373	1.71	1.343	1.126	0.843	0.892	0.796	0.919	0.910	0.954	0.930	0.897	0.957	0.895	0.96	1.348
Hi+Lt Avg	1.479	1.453	1.590	1.757	1.784	2.050	2.428	1.730	1.806	1.529	1.582	1.486	1.72	1.436	1.115	0.829	0.862	0.883	0.934	0.946	1.027	0.887	0.966	0.986	0.913	0.98	1.37

Fig. NO3 1: Stationwise average NO_3-N (mg/l) during High tide and Low tide in Ulhas river estuary and Thane creek.

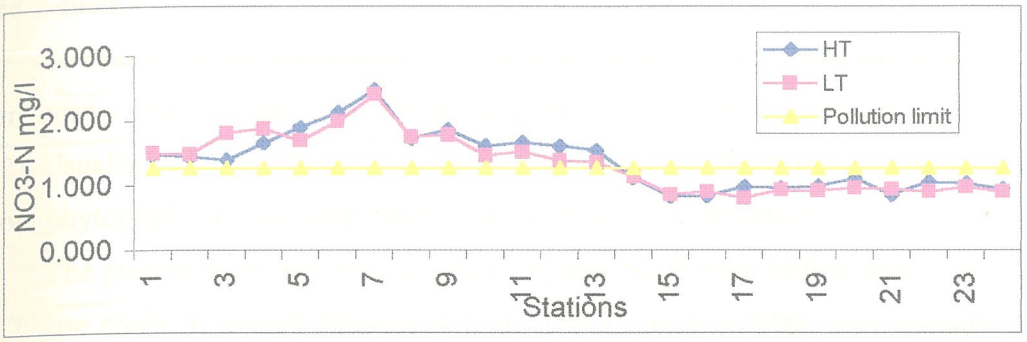


Fig. NO3 2: Monthly variations in NO_3-N (mg/l) during high tide in Ulhas river estuary and Thane Creek

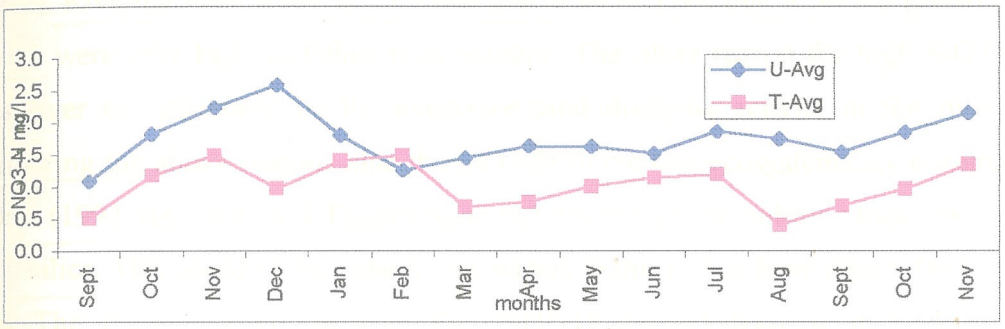


Fig. NO3 3: Seasonal variations in NO_3-N (mg/l) during high tide and low tide In Ulhas river estuary and Thane creek.

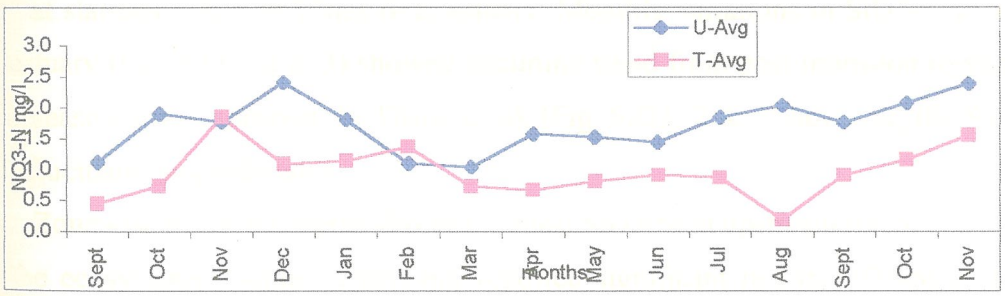


Fig. NO3 4: Zonewise annual average NO_3-N (mg/l) during high tide in Ulhas river estuary and Thane creek

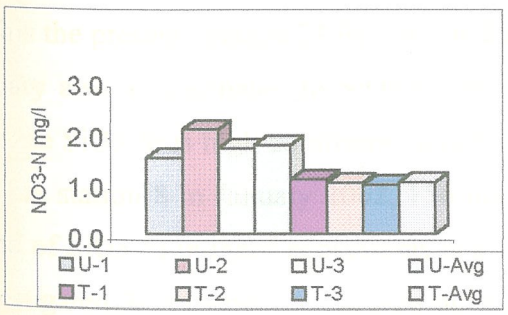
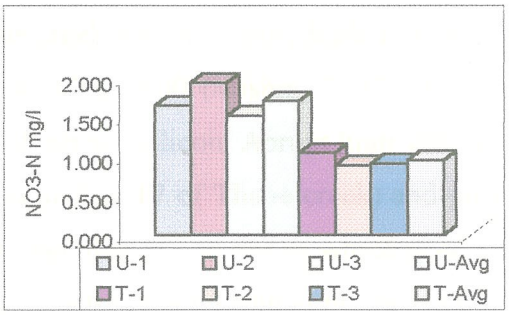


Fig. NO3 5: Zonewise variations in the annual average of NO_3-N (mg/l) during low tide in Ulhas river estuary and Thane creek



Silicate-silicon (SiO_3-Si)

Silicon is the most abundant element in the earths crust. It is essential for growth of organisms like diatoms and radiolarians which have shells made of silica (Alam, 1992). Usually high SiO3-Si leads to dominance of diatom phytoplankton whereas non-diatom phytoplankton dominate when there is low dissolved SiO3-Si.

The present study reports exceptionally high SiO3-Si in both Ulhas river estuary and Thane creek. It ranged between 4.13 to 163.35 mg/l in Ulhas river estuary (Avg. 36.65 mg/l), whereas 2.21 to 156.75 mg/l (avg. 21.91 mg/l) in Thane creek (Tables SiO3 - 1 & 2). Riverine fresh water is a known source of SiO3-Si due to which probably the silicates were very high in Ulhas river estuary. The other reason for high SiO3-Si in Ulhas river estuary could be the extensive sand dredging activity in the river bed. Considering the above reasons also the SiO3-Si in the two ecosystems are exceptional. Tandale (1993) has described Thane region to be derived from volcanic rocks, which are rich in silica. This could be the reason why waters in this region have high SiO3-Si.

The stationwise comparison (Fig. SiO3-1) showed decrease in SiO3-Si from riverine to seaward end, both in Ulhas river estuary and Thane creek, except very high values at stations 3 & 8 of Ulhas river estuary. Monthly variations in SiO3-Si in Ulhas river estuary (Fig. SiO3- 2 & 3) showed declining trend from post monsoon to summer and increase during monsoon. In Thane creek (Fig. SiO3- 2 & 3) however, the SiO3-Si values fluctuated unpredictably.

Zonewise trend in general, showed highest SiO3-Si in upstream riverine zone 1 of both the ecosystems. Goldin (2001) has reported significant rise in SiO3-Si in Thane creek during past 15 years. Accordingly average SiO3-Si levels in the creek were 4.08 mg/l in 1984 – 85; 8.76 mg/l during 1991 – 93; 15.3 mg/l in 1999 – 2000. As compared to this the present average 21.91 mg/l in Thane creek is significantly high. In Ulhas river estuary also as compared to SiO3-Si levels in 1999-2000 (Mishra, 2002) the present average SiO3-Si is high confirming build up of silicate silicon. Abrupt high values (163 mg/l at station 8 in January 2002, 156 mg/l at station 17 of Thane creek) and growing trend of SiO3-Si in these ecosystems is a very peculiar phenomenon which needs to be investigated. Is it related to any type of volcanic activity occurring at minor scale in the

river bed ? or movement of the earth strata ? It is essential that experts from concerned fields look into the matter. There is other probability that the silicates could be high due to sand dredging or solid waste dumping activities as mentioned earlier. Attempts should be made to find out the exact reason.

Table SiO3-1: Monthly and stationwise variations in Silicate silicon (mg/l) during high tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	79.53	78.87	77.55	73.76	69.14	73.76	58.74	88.77	83.33	65.18	53.79	42.08	70.37	13.20	33.17	63.36	62.37	31.02	33.33	38.78	37.46	41.91	36.63	38.61	38.78	39.05	55.34
Oct	53.63	60.72	73.76	65.84	70.13	57.42	62.21	73.26	72.11	53.63	51.98	38.78	61.12	38.78	42.08	30.53	18.15	49.83	14.85	22.28	13.20	6.77	9.08	9.08	23.10	23.14	42.89
Nov	49.34	45.87	65.18	61.88	56.93	56.93	51.48	60.23	62.37	47.69	45.38	42.08	53.78	30.03	38.12	63.53	22.28	17.33	14.85	16.50	8.25	9.57	3.47	6.60	3.30	19.48	37.32
Dec	37.13	34.98	47.03	43.73	47.03	37.13	46.37	49.17	45.38	42.08	34.82	33.33	41.51	28.88	45.87	32.18	33.99	16.34	31.19	31.19	2.48	15.51	18.15	25.41	8.25	24.12	33.16
Jan	10.23	27.23	33.83	5.78	14.52	15.02	16.34	163.35	22.28	22.28	18.48	16.50	30.48	20.63	23.76	28.88	27.23	16.50	18.98	18.15	15.02	14.85	9.74	14.36	11.06	18.26	24.62
Feb	5.28	4.13	31.19	11.39	12.87	9.41	14.52	14.52	14.69	16.01	32.67	16.34	15.25	23.93	20.63	25.91	16.50	20.79	21.78	16.50	16.50	15.68	10.73	12.87	12.87	17.89	16.52
Mar	6.11	6.27	75.24	20.63	14.85	15.68	18.98	20.46	14.85	15.68	42.24	16.50	22.29	20.63	12.87	14.03	27.23	22.28	22.44	14.85	14.85	15.02	15.68	15.68	15.68	17.60	20.04
Apr	6.11	6.27	35.48	8.25	9.08	38.78	6.11	90.75	12.38	14.85	20.63	16.50	22.10	16.50	16.34	12.38	47.03	156.75	138.60	15.84	15.84	11.55	15.18	12.38	14.85	39.44	30.42
May	7.43	8.58	38.78	8.58	11.06	23.93	11.88	13.53	13.53	12.21	10.56	10.56	14.22	9.08	12.38	12.38	30.53	20.63	16.50	16.50	16.50	4.13	16.50	7.43	9.90	14.37	14.29
Jun	8.25	11.55	23.10	13.20	11.55	11.55	9.90	14.85	18.15	12.87	13.86	14.69	13.63	14.85	27.23	30.53	39.93	30.53	27.23	16.50	156.75	33.00	33.00	30.53	30.53	39.22	25.91
Jul	16.50	28.88	25.74	22.28	23.93	37.13	4.13	18.98	29.37	14.03	23.93	12.87	21.48	7.43	9.24	20.63	20.13	21.78	16.50	15.84	15.02	15.51	16.34	16.01	15.18	15.80	18.75
Aug	24.26	30.86	57.59	32.34	30.53	47.69	18.98	28.38	33.00	16.50	27.23	16.50	30.32	32.67	23.93	24.26	20.46	20.46	16.50	18.48	16.34	14.03	8.91	9.08	11.55	18.05	24.43
Sept	37.13	34.98	47.03	45.87	33.83	60.72	73.76	65.84	70.13	37.13	46.37	49.17	50.16	34.82	33.33	28.88	23.93	20.63	25.91	27.23	16.50	18.98	18.15	9.57	9.57	22.29	36.78
Oct	49.34	45.87	65.18	47.03	43.73	47.03	65.84	70.13	57.42	37.13	46.37	43.73	51.57	36.30	34.32	32.18	25.41	27.72	29.37	29.21	15.84	16.01	17.82	18.98	27.56	25.89	39.24
Nov	56.93	62.70	67.98	53.63	47.03	51.48	66.00	67.65	62.37	45.87	47.03	45.38	56.17	37.46	35.48	32.67	33.99	28.05	30.53	30.53	16.50	19.64	18.15	19.80	22.77	27.13	42.23
Avg	29.81	32.52	50.97	34.28	33.08	38.91	35.01	55.99	40.76	30.21	34.35	27.67	36.96	24.34	27.25	30.15	29.94	33.37	30.57	21.89	25.14	16.81	16.50	16.42	17.00	24.12	30.80

Table SiO3-2: Monthly and stationwise variations in Silicate silicon (mg/l) during low tide in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											Total
	1	2	3	4	5	6	7	8	9	10	11	12	Avg	13	14	15	16	17	18	19	20	21	22	23	24	Avg	Avg
Sept	80.52	75.74	75.24	72.77	70.13	70.13	57.92	86.63	82.17	53.63	54.45	40.43	68.31	10.73	14.85	14.03	9.41	10.56	9.41	9.90	4.13	5.61	6.60	3.96	4.95	8.68	39.69
Oct	54.95	53.63	71.78	63.86	71.12	58.08	59.57	71.78	66.17	51.15	52.80	37.13	59.33	41.42	37.95	45.87	36.30	32.67	17.82	20.46	13.20	13.20	13.20	10.23	14.85	24.76	42.74
Nov	49.34	47.36	55.77	62.87	57.92	57.92	53.13	56.93	64.02	44.55	41.91	38.12	52.48	19.80	40.43	21.45	29.70	14.85	12.38	6.60	6.60	10.56	6.60	15.51	3.30	15.65	34.80
Dec	39.77	36.80	43.73	43.89	49.34	33.33	43.73	45.38	47.03	43.73	33.00	34.98	41.22	26.07	22.28	32.34	19.80	29.70	20.46	14.85	11.72	14.85	11.55	13.20	9.90	18.89	30.50
Jan	11.22	29.87	36.14	7.43	15.68	16.50	24.75	18.65	20.30	18.81	17.33	14.36	19.25	18.65	22.61	30.36	17.33	20.63	20.63	18.65	16.34	15.02	10.73	14.03	11.55	18.04	18.67
Feb	5.45	4.95	59.24	9.41	10.07	7.76	12.54	11.88	11.72	15.35	32.18	15.18	16.31	22.11	22.11	25.91	17.49	22.44	23.27	11.55	10.73	13.86	8.25	14.36	11.72	16.98	16.63
Mar	5.61	5.78	53.63	8.58	9.90	11.39	14.36	10.73	11.39	14.85	26.07	16.01	15.69	19.80	16.34	14.36	29.37	18.15	18.48	12.38	14.36	13.37	13.37	13.04	12.38	16.28	15.97
Apr	5.78	6.11	35.15	7.59	8.42	37.13	5.94	8.09	11.06	14.52	19.97	16.17	14.66	14.69	11.88	10.07	42.57	14.52	16.01	15.02	15.02	12.38	15.02	11.39	14.03	16.05	15.32
May	6.44	8.09	34.82	7.92	9.41	22.28	11.22	12.87	15.18	14.03	16.17	15.02	14.45	10.73	18.81	16.17	58.74	15.68	15.84	15.02	15.18	2.21	18.48	10.73	11.55	17.43	15.88
Jun	7.76	11.22	22.77	8.91	10.07	11.06	9.57	13.70	17.33	12.54	13.70	14.36	12.75	16.34	27.06	33.00	69.96	26.73	23.93	16.34	14.36	31.85	29.70	30.20	29.87	29.11	20.60
Jul	15.68	29.37	38.94	39.44	28.88	47.03	14.03	20.63	32.67	16.34	25.74	16.17	27.07	38.78	32.18	32.67	20.63	10.73	14.03	16.50	16.50	27.06	22.28	16.17	14.85	21.86	24.57
Aug	30.86	35.48	74.09	41.09	40.59	50.16	22.61	28.38	37.79	26.57	29.37	21.12	36.51	48.84	35.15	33.50	22.44	21.12	18.15	18.15	16.67	17.33	7.26	9.41	99.00	28.92	32.86
Sept	40.76	39.27	48.02	48.68	38.78	61.88	74.91	68.48	73.43	43.73	48.68	51.32	53.16	32.18	30.86	18.32	20.63	15.84	16.34	21.78	10.73	14.16	16.17	9.57	8.25	17.90	36.24
Oct	51.98	48.68	66.00	49.01	48.68	50.33	67.98	72.27	65.67	40.43	49.34	48.68	54.92	33.83	32.18	22.28	23.93	20.63	19.64	27.23	14.36	12.38	12.87	18.98	22.28	21.72	38.98
Nov	60.23	61.88	70.13	57.59	51.98	53.13	68.48	69.30	65.84	49.17	51.98	48.51	59.02	35.81	32.84	23.93	32.34	20.63	22.28	27.89	15.02	16.17	14.52	19.80	18.48	23.31	41.88
Avg	31.09	32.95	52.36	35.27	34.73	39.20	36.05	39.71	41.45	30.62	34.18	28.50	36.34	25.98	26.50	24.95	30.04	19.66	17.91	16.82	12.99	14.67	13.77	14.04	19.13	19.70	28.36
Ht+Lt Avg	30.45	32.73	51.67	34.77	33.90	39.06	35.53	47.85	41.10	30.42	34.27	28.08	36.65	25.16	26.87	27.55	29.99	26.52	24.24	19.36	19.06	15.74	15.14	15.23	18.06	21.91	29.58

Fig. SiO3-1: Stationwise average Silicates (mg/l) during high tide and low tide in Ulhas river estuary and Thane creek.

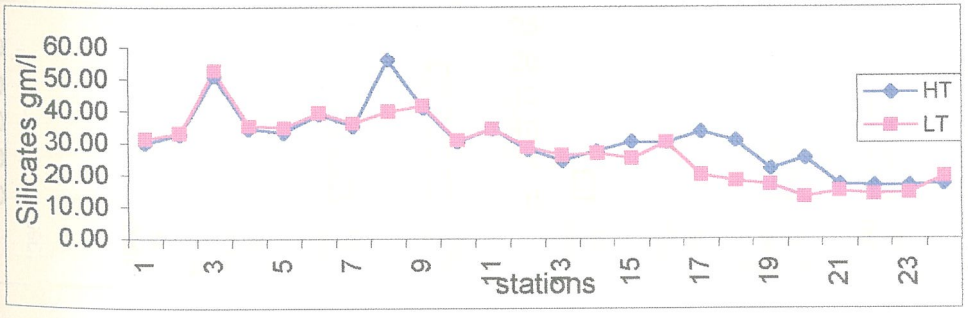


Fig. SiO3-2: Monthly variations in average SiO_3-Si (mg/l) during high tide in Ulhas river estuary and Thane creek

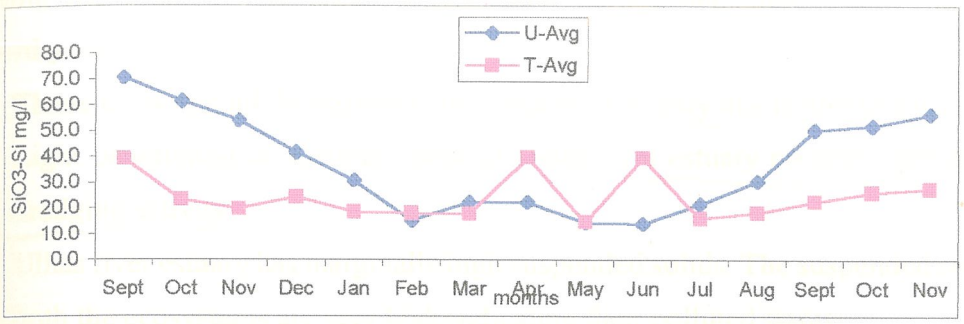


Fig. SiO3- 3: Monthly variations in average SiO_3-Si (mg/l) during low tide in Ulhas river estuary and Thane creek

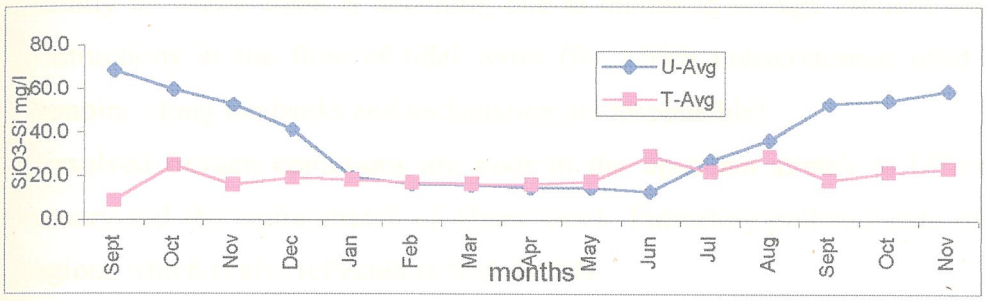


Fig. SiO3- 4: Zonewise variations in the annual average of SiO_3-Si (mg/L) during high tide in Ulhas river estuary and Thane creek

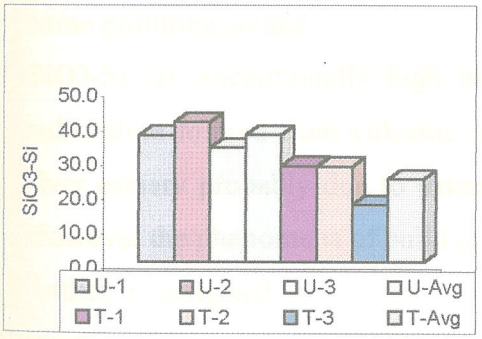


Fig. SiO3- 5: Zonewise variations in annual average SiO_3-Si (mg/l) during low tide in Ulhas river estuary and Thane creek

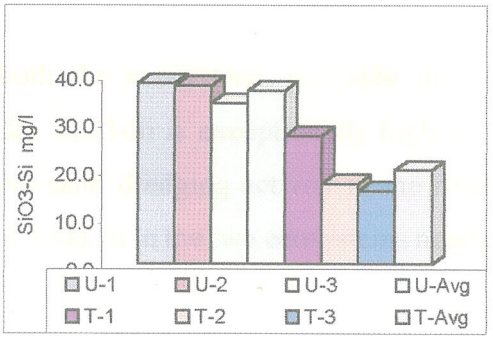


Fig SiO3- 6: Comparison of SiO_3-Si with past available data in Ulhas river estuary

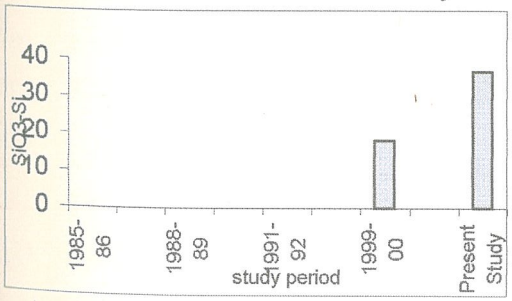
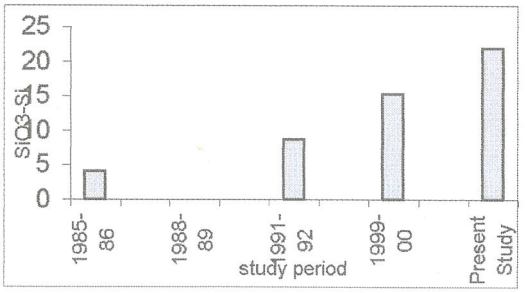


Fig SiO3- 7: Comparison of SiO_3-Si with past available data of Thane creek



Summary

Following hydrological characteristics of Ulhas river estuary and Thane creek are noteworthy.

1. Thane creek is slightly warmer than Ulhas river estuary due to shallow nature.
2. Light penetration is relatively poor in Ulhas river estuary probably due to sand dredging activity.
3. Ulhas river estuary has marginally high suspended solids. The suspended solids in both the ecosystems are very high indicating their polluted status.
4. Thane creek has higher salinity due to less fresh water inflow. However the salinity in Thane creek is declining due to increased sewage effluent load and obstructions in the flow of tidal water (for which indiscriminate solid waste dumping along the banks and reclamation are responsible).
5. Dissolved oxygen conditions are poor in the upstream stretch of Ulhas river estuary and the entire stretch of Thane creek. Indicating polluted state of these regions which is also reflected in high B.O.D.
6. PO4-P is higher in Thane creek due to sewage pollution.
7. NO3-N is higher in Ulhas river estuary probably due to agricultural runoff and some polluting source.
8. SiO3-Si are exceptionally high in both the ecosystems probably due to the substratum formed from volcanic rocks. SiO3-Si is exceptionally high in Ulhas river estuary probably due to extensive sand dredging activity in the river bed. However the phenomena of build up of SiO3-Si in the two ecosystems needs to be further investigated.

Chapter IV

Plankton

Introduction.

The word plankton is a Greek word meaning "wanderers or free floating". In aquatic ecosystem plankton means all those organisms which drift passively because they have no or insufficient power of locomotion. Krishnapillai (1986) has described different types of plankton such as Bacterioplankton (including bacteria), Phytoplankton (autotrophs) and Zooplankton (Heterotroph animals). The bacteria are responsible for the conversion of nutrients to their different forms and also decomposition of complex organic substances into simple ones. The phytoplankton act as primary producers, trapping the solar energy. They make this energy available to the primary consumers, the zooplankton, and also the consumers at other higher trophic levels such as fishes etc. The plankton mainly support the pelagic food chain and fishery (Lodh, 1990) and also play an indirect role in supporting the detritus food chain because many of them are short lived and their dead bodies settle down to form detritus. The estimates of plankton types (diversity) and quantity are useful in evaluating the health and productivity of an aquatic ecosystem and hence in the pollution monitoring surveys. In the present study, the phytoplankton and zooplankton diversity of Ulhas river estuary and Thane creek has been assessed during period September 2001 to November 2002.

Part I: Phytoplankton.

INTRODUCTION

In the pelagic realm, populations of photosynthetic species of prokaryotes and eukaryotes, taken as algae and plants respectively constitute the phytoplankton organisms. The phytoplankton are the primary producers of the aquatic food chain. They play a pivotal role in fixation of solar energy to make it available to the higher organisms thus forming an important link between the abiotic factors and the biota in the aquatic ecosystem. The planktonic flora of the water body is influenced by different environmental factors and show seasonal (temporal) and regional (spatial) variations. Through the study of phytoplankton one can assess the primary production at the 1st trophic level, based on which the secondary and tertiary productions can be estimated.

Some phytoplankton species are known to produce toxins which kill fishes and other organisms. Due to various anthropogenic activities there is tremendous pollution pressure on the waters of the creeks and estuaries, which affects the phytoplankton types and density. It is therefore, very important to study the phytoplankton.

Various workers like Krishnamurthy *et al.* (1974), Santhanam *et al.* (1975), Vijayalaxmi and Venugopalan (1975), Mani (1992), De *et al.* (1994), Ramaiah and Ramaiah (1998) have significantly contributed to the data on phytoplankton of coastal water bodies. This chapter describes the phytoplankton of Ulhas river estuary and Thane creek.

MATERIALS AND METHODS

The water samples for phytoplankton were collected from the intertidal region. The collected sample were fixed immediately after collection using Lugol's iodine and brought to the laboratory. The phytoplankton types were observed under trinocular light microscope. The density count was obtained by Lackey's drop method (Trivedy and Goel 1984). The genera observed were classified and the organic pollution indicators were listed according to Palmer (1969). The data was compared with the available past data from the Ulhas river estuary and the Thane creek.

Results and Discussion

The phytoplankton observed (Plate 9) in Ulhas river estuary and Thane creek included total 37 types belonging to classes Bacillariophyceae (22 types), Chlorophyceae (8 types), Cyanophyceae (6 types) and Xanthophyceae (1 type). Some important and dominant genera are described below.

Class : Basciallariophyceae.

Cyclotella spp. Cells discoid, about 25 um in diameter, valves circular with a central inflation and a broad intramarginal zone of radiate striae, 3 horseshoe like points in the inner part of the intramarginal zone of striae, central area small and hyaline.

Commonly seen in oligohaline creeks through out the year. It is a common planktonic and benthic form.

Thalassiosira spp. Cells discoid about 60um in diameter, valves circular with an intramarginal ring of striae, valves with an areolate structure, areolae relatively large in the center of the valve decreasing towards periphery. Observed in mesohaline creeks.

Nitzschia spp. Valves linear lanceolate, narrowing at the apices sometimes slightly dorsally constricted in the middle, cells rectangular in girdle view with rounded angles, Raphe marginal. Commonly occurs as planktonic and benthic form in euryhaline, brackish waters and common throughout the year in oligohaline creeks.

Navicula spp. Valves lanceolate with rostrate, capitate apices. Central area small, striae radiate convergent towards the end, clear terminal areas. Commonly seen throughout the year in oligo and mesohaline creeks.

Melosira spp. Cells cylindrical attached end to end in filaments, valve surface smooth or finely punctate. Common throughout the year mainly in oligohaline creeks. Planktonic or benthic.

Asterionella spp. Cells elongate, rectangular in girdle view enlarged especially at the basal poles. Frustules attached to each other with their basal poles forming a star shaped colony, valve linear, the end attached to other frustules is much larger. Sporadic in oligo and mesohaline creeks, Planktonic.

Skeletonema spp. Chain in girdle view, uppermost cells with two chloroplast (note that the linking structures may be much shorter and thinner) Intercalary valve with labiate process in the ring of marginal strutted processes. Cosmopolitan in occurrence.

Class : Chlorophyceae

Crucigenia spp. Coenobium consisting of 4 subspherical or rounded triangular or rounded narrow trapezoidal cells arranged around a small central space the outer free wall of the cells broadly convex. The lateral walls more or less straight, adjoined throughout their length with neighbouring cells and converging towards a bluntly rounded angle at the center of the colony, chloroplast a parietal plate with a central pyrenoid. Common in oligohaline creeks.

Scenedesmus spp. Cells arranged in series of 4 or 8 cells, inner cells spindle shaped tapering to sharply pointed apices, outer cells spindle shaped more or less curved to the

outer side, tapering to long slender acute apices. Chloroplast a parietal plate covering the whole cell except the apices, 1 pyrenoid.

Common throughout the year in oligohaline creeks.

Golenkenia spp. Cells spherical, solitary with long slender radiating setae, cells 14um in diameter. Sporadic in oligohaline creek, Planktonic.

Class Cyanophyceae

Oscillatoria spp. Trichomes straight or flexuous, tapering or not towards the apex, apical cells bluntly rounded, trichomes some times constricted at the cross walls, cell contents homogeneous. Very abundant throughout the year in many oligohaline creeks and with a sizeable development in the winter spring period in a mesohaline creek.

Anabaena spp. Trichomes spirally twisted, cells ellipsoid to barrel shape, pseudo vacoules present, heterocyst spherical. Abundant in many oligohaline creeks having optimal development at the end of summer and autumn.

Class Xanthophyceae

Tribonema spp. Filament straight and slender, Cells usually long, cylindrical with thin walls, sometimes slightly inflated, chromatophores 2-4, greenish parietal plates, sometimes small oil bodies present, cells forming H shaped pieces. Weakly euryhailne, planktonic.

The phytoplankton density in general was higher in Thane creek (Average 25155726/l) as compared to Ulhas river estuary (Average 22602107/l) (Table Phyto-1). The species number reduced from the riverine zone to the seaward zone. At least 12 genera from Thane creek and 20 from Ulhas river estuary showed bloom conditions. Both the ecosystems showed similar species diversity.

Of the different phytoplankton observed the diatoms dominated in both the ecosystems. Certain genera preferring low salinity were seen only at the riverine end, while others occurred only on the seaward side. The fresh water genera included the diatoms *Amphora spp., Biddulphia spp., Cosinodiscus spp., Gomphonema spp.* and *Leptocylindrus* spp; the chlorophyceans *Crucigenia spp.*and *Scenedesmus spp.* and the

cyanophyceae genera *Anabaena spp.* and *Oscillatoria spp.* These genera preferred the salinity range 0.389 ppt. to 18.51 ppt . *Volvox* a typical fresh water alga was seen only in the region with low salinity 0.389 to 0.73.ppt. Genera occurring on seaward end included the diatom *Triceratium spp.* and the Chlorophyceans *Koliella spp.* The other species occurred in all the zones due to their ability to tolerate changing salinities. Some of these species were dominant in both the ecosystems.

In Ulhas river estuary *Cyclotella spp.* was the most dominant phytoplankton followed by *Thalassiosira spp.*, *Asterionella spp.* and *Nitzschia spp.* (Fig. Phyto-5)The order of dominance was slightly different in Thane creek. *Melosira spp.* had the highest dominance and it occurred throughout the year. *Thalassiosira spp.* ranked 2nd followed by *Navicula spp.* and *Nitzschia spp.* Thus *Thalassiosira spp.* and *Nitzschia spp.* can be said to be most successful species because they flourish moderately in both the ecosystems (Table Phyto-1).

Monthly variations in the average total phytoplankton density (Table Phyto-2 & Fig. Phyto-1) showed in Ulhas river estuary, peaks of phytoplankton density in the months Feb 2002 and April 2002 i.e. in late post monsoon and summer (premonsoon). In the estuary, post monsoon of 2001 showed relatively higher population density as compared to similar period of 2002 (Fig Phyto-1). The monsoon season in general reduced the population density of phytoplankton. The monthly variations in Thane creek showed peak phytoplankton densities in April 2002 and August 2002. A smaller peak was also observed in Feburary 2002. Thus late postmonsoon and premonsoon months Feburary and April respectively were favourable for phytoplankton growth in case of both the ecosystems. In Thane creek however August 2002 showed additional peak whose main contributor genus was *Melosira spp.* Instead of phytoplankton density if one considers types of species occurring every month, then the trend was different. The maximum types in Ulhas river estuary were observed in November 2002 with further decreasing order as January 2002 > December > April, August, September (Table Phyto-2). In Thane creek the maximum species number was recorded in November 2002 followed by October 2002, September 2002 (Table Phyto-6). The lowest species number in both the ecosystems was observed in June i.e. onset of monsoon. Thus the monsoonal fresh water influx, by lowering the salinity, reduced the diversity. Whereas the recovery

period October - November and late postmonsoon period showed maximum diversity. Probably this period being of mixed salinity allowed growth of the freshwater as well as the marine water species; with growing salinity then some species got eliminated to reduce the number in summer.

Table Phyto-1 shows consolidated data on the zonewise average density of different phytoplankton types. From the total averages and the total number of species of different zones it is observed that both the density and species diversity declined from the riverine end zone 1 to seaward zone 3 (Fig Phyto-4). Overall diversity in both the system was same i.e. 31 species types. Thus the zone with moderate influence of marine water had the maximum diversity. Zonewise details of both the ecosystems are discussed below.

Ulhas river estuary

Zone 1 - Riverine zone (Stations 1 to 4)

This zone being away from the open sea had salinity in range 0.389 ppt to 18.5 ppt (Average 8.93 ppt.) The overall average density was 29219589/l (Table Phyto-3) Monthly variation in density showed peak densities in Feburary 2002 and September 2001 smaller peak was recorded in April 2002 (Fig Phyto-2). The density was in general low during monsoon. Thus the post monsoon and premonson periods were favourable for phytoplankton growth. The number of species occurring at every month also showed the same trend. Among the phytoplankton; organisms of Class Bacillariophyceae (diatoms, 19 genera) were more dominant (72 %) where as chlorophyceae (5 genera), Cyanophyceae (4 genera) and Xanthophyceae (1 genus) contributed 12 %, 12% and 4 % of the total population respectively (Table Phyto-10). *Cyclotella spp.* was the most dominant phytoplankton followed by *Thalosiosira spp. Crucigenia spp.* and *Anabaena spp.* The other significantly occurring genera were *Pleurosigma spp., Melosira spp. > Navicula spp.> Nitzschia spp. > Osciallotria spp.> Leptocylindrus spp.> Bidulphia spp.* Palmer has described 20 pollution indicator phytoplankton genera for freshwater of which 8 namely *Melosira spp., Navicula spp., Nitzschia spp., Pinnularia spp., Cymbella spp., Asterionella spp., Crucigenia spp.* and *Golenkenia spp.* were observed in Zone 1.

Zone 2 (Middle zone stations 5 to 8).

The salinity in this zone ranged between 0.73 ppt to 30 ppt. (average 15 ppt) thus showing more influence of marine water. The overall average density 28287123/l was slightly lower than zone 1. In this zone also Bacillariophyceae (14 genera) was the most dominant class constituting 80 % of the total phytoplankton. Chlorophyceae (3 genera), Cyanophyceae (4 genera) and xanthophyceae (1 genus) constituted 9 %, 4 % and 7 % respectively (Table phyto 10). Though the most dominant phytoplankton *Cyclotella* spp. was the same as Zone 1, others were different namely *Asterionela spp.* > *Volvox spp.* > *Tribonema spp.* The other important species included *Melosira spp.* > *Nitzschia spp.*> *Thalassiosira spp.* > *Navicula spp.* > *Biddulphia spp.* > *Oscillatoria spp.* The genera like *Thalassiosira spp., Pleurosigma spp.* and *Amphora spp* showed significant reduction in density in zone 2.

Monthly variations in this zone showed peaks of population density in September 2001 (Late monsoon) and April 2002 (Premonsoon). The species diversity however was the highest in November and December 2001. In general, the species diversity was the lowest in monsoon, and increased in the postmonsoon. In premonsoon, the diversity was lower as compared to zone 1. In zone 2 six of the Palmers pollution indicator genera were observed namely *Anabaena spp, Asterionella spp, Crucigenia spp, Melosira spp, Navicula spp, Nitzschia spp.*

Zone 3 (Seaward zone Stations 9 to 12).

This zone had higher salinity range from 1 ppt. to 35 ppt. (average 23 ppt.) The overall average of total phytoplankton was much lower 10299609/l than zone 1 & zone 2. There was total dominance of class Bacillariophyceae (diatoms) constituting 98 % of the total phytoplankton. Whereas the other classes namely chlorophyceae, cyanophyceae and xanthophyceae contributed less than 1 % (Table phyto 10). Therefore in this zone the most dominant species included all diatoms, *Skeletonema spp.* was the most dominant followed by *Thalassiosira spp., Nitzschia spp.* and *Asterionella spp.* The species diversity was lower than the earlier zones.

Monthwise variations in population density showed the maxima in Feburary and April (2002). In this zone five of the Palmers organic pollution indicator genera were recorded namely *Asterionella spp, Melosira spp, Navicula spp, Nitzschia spp, Pinnularia spp.*

In Ulhas river estuary thus, the population density of diatoms, species number and Palmers organic pollution indicator species decreased from riverine zone 1 to the seaward zone 3. The dominant genera also varied zonewise due to the difference mainly in the salinity.

Thane Creek

Zone 1 Riverine zone (Stations 13 to 16)

In this zone there was moderate influence of fresh water and the salinity ranged between 0.803 to 32.48 ppt (Avg. 19.67 ppt). The average count of phytoplankton was 34197392/l (Table phyto 7). In this zone also the members of class Bacillariophyceae dominated (91 %) with 19 generic types followed by Cyanophyceae (7.47 %) with 3 genera, Chlorophceae (1.43 %) with 3 genera (Table phyto 10). The diatom genus that dominated in this zone was *Thalassiosira spp* followed by *Melosira spp, Navicula spp* and *Nitzschia spp.* The least count was of *Gomphonema spp, Synedra spp*, and *Ankistrodesmus spp.* Cyanophyceae was dominated by *Oscillatoria spp* followed by *Anabaena spp.*. The Chlorophyceae members that dominated were *Scenedesmus spp.* and *Crucigenia spp.*

The pollution indicator genera (Palmer, 1969) included *Anabaena, Crucigenia, Lyngbya,Melosira, Navicula, Nitzschia, Pinnularia.* (Total 7).

Monthwise population density showed the peak population in April and August (Fig. Phyto 3). Whereas maximum species diversity was observed in postmonsoon months October - November 2002.

ZONE 2 (Middle zone, Stations 17 to 20)

In this zone the salinity ranged between 2.850 to 34.5 ppt (Avg.23.93 ppt). The average count of phytoplankton was 25901735/l (Table phyto 8). Of the different classes Bacillariophyceae dominated (96.15%) represented by 13 genera followed by Cyanophyceae (2.841 %) with 3 genera and Chlorophyceae (0.712 %) represented by a single genus *Crucigenia spp.* There was also sporadic occurrence of xanthophyceae genus *Tribonema spp.*

Of the Bacillariophyceae, the diatom that dominated in this zone was *Melosira spp* followed by *Thalassiosira spp, Navicula spp* and *Nitzschia spp.* Cyanophyceae had the dominant genus *Oscillatoria spp* followed by *Spirulina spp.*

Palmers' Pollution indicator genera included *Anabaena spp., Crucigenia spp., Cymbella spp., Melosira spp., Navicula spp., Nitzschia spp., Pinnularia spp., Oscillatoria spp.* (Total 8). The peak population density was observed in April 2002. A secondary peak was also noticed in February 2002 (Fig. Phyto-3). The species diversity was the lowest in monsoon months and the maximum in postmonsoon.

ZONE 3 (Seaward zone, Station 21 to 24)

In this zone the salinity was much higher ranging from 6.825 to 37.14 ppt. (Avg.27.55 gms/l) The average count of phytoplankton was comparatively less 15368050/l (Table Phyto 9) Bacillariophyceae dominated, being 91.19 % with 9 genera followed by Chlorophyceae 3.657 % with 3 genera, Cyanophyceae 4.793 % with 2 genera and 1 genus of Xanthophyceae (0.364 %) (Table Phyto 10). In this zone Chlorophyceae had relatively more density as compared to the seaward zone of Ulhas river estuary.

Of the Bacillariophyceae the diatom genera that dominated were *Melosira spp* followed by *Thalassiosira spp, Navicula spp,* while from Chlorophyceae there was dominance of *Golenkinia spp,* and *Oscillatoria spp* was dominant from Cyanophyceae

The Palmers pollution indicator species included *Anabaena spp, Golenkinia spp, Gonium spp, Melosira spp, Navicula spp, Nitzschia spp* (Total 6). Monthwise variations in population density (Table Phyto 9& Fig. Phyto 3) showed peak density in premonsoon month April 2002 and a secondary peak in August 2002. The overall species diversity in general was lower than the earlier zones. It was relatively better in postmonsoon months.

In Thane creek in general, there was more dominance of diatoms as compared to Ulhas river estuary. High occurrence of diatoms in both the ecosystems can be attributed to exceptionally high silicates in the water due to the volcanic origin of the rocks of this region (Blasco, 1975).

Comparison with past data.

Quadros (2001) while studying Thane creek in 1999-2000 recorded very high average population density of phytoplankton (60169 x 10^3/l) he reported maxima in August but the 2nd peak occurred in premonsoon months February and April instead of October. The decreasing trend from riverine to seaward end which he observed still persists. The population density has however got significantly reduced to 41 % of that observed in 1999 - 2000. Quadros (2001) also reported significant rise in phytoplankton density in comparison with that in 1985 and 1990. He reported 44 (+ 7 unidentified) genera of phytoplankton. The present study shows reduction in density as well as types of phytoplankton. If we try to find the causes of this, following things need to be considered. (1) There is reduction in phosphates and nitrates in the water probably due to closing of some of the industries in this region. (2) Significant increase in suspended solids is observed probably due to solid waste dumping, construction of bridges and reclamation. Though the nutrients phosphorus and nitrogen are reduced, silicon has increased and the nutrients in general being high cannot be limiting to the growth of phytoplankton. Increased suspended solids affect light availability. So one can say that the reduced phytoplankton could be due to these factors. However seeing the magnitude of the phytoplankton reduction we can not comment that they are the only reasons. It is probable that due to absence of proper check on the effluent quality, some toxic chemicals might have increased in the creek waters, affecting density and diversity of the phytoplankton.

In Ulhas river estuary also Mishra (2002) reported general trend of phytoplankton similar to the present one i.e. lowered density in monsoon, increasing trend in post monsoon and premonsoon; higher density on riverine side and decline towards the marine side. But she reported average density 107750 x 10^3/l which is much high (almost 5 times), as compared to the present observation. This also could be due to growing turbidity and pollution in water.

Thus decreasing phytoplankton in both Thane creek and Ulhas river estuary is an alarming signal indicating pollution. However it is based on comparison with the prior data which was collected by different researchers and intermittently. Such comparison

cannot be considered to be a fair comparison and it is in fact necessary to form a research cell which will regularly study the ecosystems and monitor the pollution status.

Conclusion

Though the species composition of Ulhas river estuary and Thane creek was similar, the trend of dominance was different in them

1) In Ulhas river estuary the proportion of phytoplankton was relatively more even, because the proportion of the first three most dominant phytoplankton was 20, 13, 11 percent. Whereas in Thane creek it was 34, 32 and 9 percent showing relative unevenness and dominance of a few species.
2) In Ulhas river estuary the most dominant phytoplankton were *Cyclotella spp.* > *Thalassiosira spp.* > *Asterionella spp.* Whereas in Thane creek they were *Melosira spp.* > *Thalassiosira spp.*> *Navicula spp.* In both the ecosystems *Thalassiosira spp.* was the most successful phytoplankton.
3) In both ecosystems the density and diversity reduced during monsoon and then increased in postmonsoon and premonsoon, April being the month of maximum growth.
4) Density was higher on riverine side and it declined seaward in both ecosystem.
5) Significant reduction in density and diversity of phytoplankton in both Thane creek and Ulhas river estuary as compared to the data from study period 1999-2000 (Quadros, 2001 and Mishra 2002) gives alarm signal indicating growing chemical pollution in the ecosystems.

However for fair comparison it is essential to collect the data every year and this should be done by a specially set research cell to study these ecosystems. It is infact not impossible for the BMC, TMC and KDMC, if they join hands on this issue.

Table Phyto 1- Zonewise average density (no./l) and % of Phytoplankton in Ulhas river estuary and Thane creek.

	Avg U-1	Avg U-2	Avg U-3	Avg U	Avg T-1	Avg T-2	Avg T-3	Avg T	% U-1	% U-2	% U-3	% U	% T-1	% T-2	% T-3	% T
Bacillariophyceae																
Cyclotella	6217367	6824660	551820	4531282	654479	649045	592669	632064	21.2781	24.1264	5.35768	20.0481	1.91383	2.5058	3.8565	2.5126
Gomphonema	40868	0	0	13622.76	81736.57	0	0	27245.52	0.13987	0	0	0.06027	0.23901	0	0	0.10831
Leptocylindrus	728445	572205.7	122604.9	474418.6	756121.2	510944.6	0	422355.3	2.493	2.02285	1.19038	2.099	2.21105	1.97263	0	1.67896
Melosira	1767202	1981491	326962.8	1358552	9413781	10763109	5170248	8449046	6.048	7.00492	3.17452	6.01073	27.5278	41.5536	33.6428	33.587
Navicula	1239759	956705.2	633566	943343.5	2983484	1614314	2268304	2288701	4.2429	3.38212	6.15136	4.1737	8.7243	6.23245	14.7599	9.09813
Pleurosigma	2358608	245226.3	286094.6	963309.7	381458.3	715054.3	326946.3	474486.3	8.07201	0.86692	2.77772	4.26204	1.11546	2.76064	2.12744	1.8862
Navicula closterium	122621	0	0	40873.8	0	0	0	0	0.41965	0	0	0.18084	0	0	0	0
Thalassiosira	5010485	1850638	2002778	2954634	12691951.95	8255775	3372374	8106700	17.1477	6.54233	19.4452	13.0724	37.1138	31.8734	21.9441	32.2261
Amphora	347455	490485.7	0	279313.5	326946.3	633523	122604.9	361024.7	1.18912	1.73395	0	1.23579	0.95606	2.44587	0.79779	1.43516
Biddulphia	717322	899188.4	449554.5	688688.3	408682.9	81736.57	0	163473.1	2.45494	3.17879	4.36477	3.04701	1.19507	0.31556	0	0.64984
Nitzschia	940120	1931214	1553054	1474796	1359050	1124408	551862.6	1011773	3.21743	6.82719	15.0788	6.52504	3.97413	4.34105	3.59097	4.02204
Pinnularia	40868	0	40868.29	27245.52	173719.2	122608.2	0	98775.79	0.13987	0	0.39679	0.12054	0.50799	0.47336	0	0.39266
Thalassionema	0	0	0	0	653925.7	0	0	217975.2	0	0	0	0	1.91221	0	0	0.8665
Rhizosolenia	40868	183965.2	327029.1	183954.2	408696.1	183965.2	306520.4	299727.3	0.13987	0.65035	3.17516	0.81388	1.19511	0.71024	1.99453	1.19149
Synedra	0	0	0	0	40868.29	0	0	13622.76	0	0	0	0	0.11951	0	0	0.05415
Coscinodiscus	204375	0	163489.7	122621.4	306586.6	143047.3	0	149878	0.69945	0	1.58734	0.54252	0.89652	0.55227	0	0.5958
Surirella	347438	81736.57	81739.88	170304.9	40868.29	0	0	13622.76	1.18906	0.28895	0.79362	0.75349	0.11951	0	0	0.05415
Cymbella	122605	0	0	40868.29	0	102228.7	0	34076.22	0.4196	0	0	0.18082	0	0.39468	0	0.13546
Chlorophyceae																
Skeletonema	623345	286144.2	2206987	1038825	183965.2	0	81736.57	88567.27	2.13331	1.01157	21.4279	4.59614	0.53795	0	0.53186	0.35208
Asterionella	81737	6375784	1062625	2506715	40868.29	0	0	13622.76	0.27973	22.5395	10.3171	11.0906	0.11951	0	0	0.05415
Triceratium	0	0	245209.7	81736.57	0	0	0	0	0	0	2.38077	0.36163	0	0	0	0
Gyrosigma	81737	102228.7	40868.29	74944.5	163489.7	0	0	54496.57	0.27973	0.3614	0.39679	0.33158	0.47808	0	0	0.21664
Tetraedron	81737	0	0	27245.52	0	0	0	0	0.27973	0	0	0.12054	0	0	0	0
Ankiistrodesmus	0	0	0	0	40868.29	0	0	13622.76	0	0	0	0	0.11951	0	0	0.05415
Crucigenia	2884939	122604.9	0	1002514	163473.1	184478.4	0	115983.8	9.8733	0.43343	0	4.43549	0.47803	0.71222	0	0.46106
Scenedesmus	183965	245209.7	81753.13	170309.4	327078.7	0	0	109026.2	0.62959	0.86686	0.79375	0.75351	0.95644	0	0	0.43341
Volvox	286095	2002563	0	762885.7	0	0	0	0	0.97912	7.07941	0	3.37529	0	0	0	0
Gonium	0	0	0	0	0	0	81736.57	27245.52	0	0	0	0	0	0	0.53186	0.10831
Koliella spiculiformis	0	0	0	0	0	0	531304.3	177101.4	0	0	0	0	0	0	3.4572	0.70402
Golenkenia	122605	0	0	40868.29	0	0	1471325	490441.5	0.4196	0	0	0.18082	0	0	9.57392	1.94962
Cyanophyceae																
Nostoc	0	81736.57	0	27245.52	0	0	0	0	0	0.28895	0	0.12054	0	0	0	0
Gleocapsa	81737	0	0	27245.52	0	0	0	0	0.27973	0	0	0.12054	0	0	0	0
Anabaena	2419919	204358	0	874759	81736.57	81736.57	40868.29	68113.81	8.28184	0.72244	0	3.87025	0.23901	0.31556	0.26593	0.27077
Oscillatoria	817468	613074	81736.57	504092.7	1287459	388306.7	286078	653947.8	2.79767	2.16733	0.79359	2.23029	3.76479	1.49915	1.86151	2.5996
Spirullina	163473	245226.3	0	136233.1	163473.1	265718.4	0	143063.8	0.55946	0.86692	0	0.60275	0.47803	1.02587	0	0.56871
Lyngbya	0	0	0	0	1021757	0	0	340585.6	0	0	0	0	2.98782	0	0	1.35391
Xanthophyceae																
Tribonema	1144428	1990678	40868.29	1058658	40868.29	81736.57	163473.1	95359.34	3.91665	7.0374	0.39679	4.68389	0.11951	0.31556	1.06372	0.37908
Total	29219589	28287123	10299610	22602107	34197392.9	25901735	15368050	25155726	100	100	100	100	100	100	100	100
Species no.	29	22	18	31	27	18	15	31								

Table Phyto 2 : Monthwise overall average density (no./l) of different phytoplankton species in Ulhas river estuary

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Bacillariophyceae																
Cyclotella	23116073.2	9702204.2	10855173.2	10826620.0	3454851.7	715228.1	1021789.9	204341.4	1021789.9	613040.9	817531.3	2350046.5	1533264.3	919908.9	817365.7	4531282
Gomphonema	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13623
Leptocylindrus	0.0	204341.4	613107.1	817531.3	613107.1	0.0	406200.0	1498503.9	817448.5	204341.4	817448.5	0.0	613107.1	511143.3	0.0	474419
Melosira	7148060.4	3250593.0	2043828.2	1430390.0	408765.6	953593.4	613024.3	0.0	613107.1	204341.4	1157934.8	204341.4	715484.7	1021707.2	613107.1	1358552
Navicula	613107.1	2228803.1	1021872.7	817448.5	1021872.7	1975325.4	613107.1	613024.3	613024.3	0.0	1771041.9	408682.9	1124250.3	715484.7	613107.1	943343
Pleurosigma	0.0	408682.9	613107.1	613107.1	1226462.4	7501292.2	2860945.6	204341.4	204341.4	0.0	204341.4	0.0	204341.4	0.0	408682.9	963310
Navicula closterium	408765.6	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40874
Thalassiosira	3474052.7	3474052.7	204341.4	408765.6	204341.4	2452200.7	4087077.0	10427719.7	1635228.1	11307472.1	1024355.6	510864.8	1737274.6	2349967.9	1021789.9	2954634
Amphora	817531.3	613107.1	613107.1	613107.1	204341.4	0.0	204341.4	0.0	0.0	0.0	204341.4	0.0	408682.9	306801.8	204341.4	279314
Biddulphia	411248.5	1024272.8	411248.5	204341.4	204341.4	0.0	0.0	1021723.7	1226462.4	1634748.0	1637297.1	0.0	613024.3	1430472.8	511143.3	688688
Nitzschia	408765.6	1226048.6	817448.5	1430555.6	204341.4	6130491.4	1021707.2	6488126.1	613107.1	0.0	204341.4	204341.4	715567.5	1532850.4	1124250.3	1474796
Pinnularia	0.0	0.0	0.0	0.0	204341.4	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27246
Thalassionema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Rhizosolenia	0.0	0.0	0.0	0.0	0.0	204341.4	204341.4	0.0	1022121.0	0.0	204341.4	0.0	408682.9	204341.4	511143.3	183954
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Coscinodiscus	0.0	0.0	0.0	0.0	817531.3	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	408682.9	0.0	408765.6	122621
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1634731.5	0.0	0.0	0.0	408699.4	0.0	204341.4	306801.8	170305
Cymbella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	204341.4	0.0	0.0	204341.4	40868
Chlorophyceae																
Skeletonema	0.0	0.0	0.0	0.0	408682.9	12720937.2	0.0	0.0	613107.1	0.0	0.0	0.0	613603.6	817365.7	408682.9	1038825
Asterionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36374679.1	0.0	0.0	613024.3	0.0	204341.4	0.0	408682.9	2506715
Triceratium	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	1021707.2	0.0	0.0	0.0	81737
Gyrosigma	0.0	0.0	0.0	0.0	0.0	204341.4	408682.9	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	306801.8	74945
Tetraedron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	27246
Ankiistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Crucigenia	613107.1	204341.4	408682.9	204341.4	613107.1	8721092.2	2433889.4	204341.4	204341.4	204341.4	204341.4	0.0	204341.4	613107.1	204341.4	1002514
Scenedesmus	204341.4	0.0	204341.4	204341.4	204341.4	0.0	0.0	0.0	0.0	0.0	817448.5	204341.4	511143.3	204341.4	0.0	170309
Volvox	8377998.9	817365.7	1226131.4	613107.1	0.0	0.0	0.0	0.0	204341.4	0.0	204341.4	0.0	0.0	0.0	0.0	762886
Gonium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Koliella spiculiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Golenkenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	408682.9	0.0	204341.4	0.0	40868
Cyanophyceae																
Nostoc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	27246
Gleocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	27246
Anabaena	204341.4	204341.4	613107.1	613107.1	2861028.4	7501292.2	204341.4	0.0	0.0	0.0	0.0	0.0	306801.8	408682.9	204341.4	874759
Oscillatoria	408765.6	817365.7	1021789.9	817531.3	204341.4	204341.4	408682.9	613024.3	613107.1	0.0	204341.4	1123931.7	408682.9	408682.9	306801.8	504093
Spirullina	204341.4	204341.4	204341.4	204341.4	408765.6	0.0	0.0	408682.9	204341.4	0.0	0.0	0.0	0.0	0.0	204341.4	136233
Lyngbya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Xanthophyceae																
Tribonema	2452262.8	1635145.3	2043414.4	1839072.9	204341.4	7501292.2	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1058658
Total	48862763	26219348	22915042	21862051	13673248	56785769	15101155	60510606	9605868	14372627	10290813	7049981	10731277	12057883	8993175	22602107
Species no.	15	16	16	17	19	14	16	17	14	7	16	11	17	17	20	31

Table Phyto.3: Monthwise average density (no./l) of different phytoplankton species in Riverine Zone 1 of Ulhas river estuary.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Bacillariophyceae																
Cyclotella	21529840.7	17765042.2	17238670.6	15326600.8	6686409.3	2145684.4	1226296.9	613024.3	1839321.2	1226098.3	1226296.9	3984869.0	613024.3	1226296.9	613024.3	6217367
Gomphonema	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Leptocylindrus	0.0	613024.3	1226296.9	1226296.9	613024.3	0.0	605575.7	2043414.4	1226296.9	613024.3	613024.3	0.0	1226296.9	920405.5	0.0	728445
Melosira	3065121.5	6686409.3	2452097.2	1839072.9	0.0	2247755.8	613024.3	0.0	1839321.2	613024.3	2247755.8	0.0	613024.3	3065121.5	1226296.9	1767202
Navicula	1226296.9	0.0	613024.3	613024.3	1226296.9	4699927.5	0.0	0.0	613024.3	0.0	4700101.3	1226048.6	1839321.2	613024.3	1226296.9	1239759
Pleurosigma	0.0	0.0	0.0	0.0	3066363.0	22503876.5	7356788.3	613024.3	613024.3	0.0	613024.3	0.0	0.0	0.0	613024.3	2358608
Navicula closterium	1226296.9	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	122621
Thalassiosira	9195861.2	9195861.2	0.0	0.0	0.0	4291356.4	9195861.2	20690625.6	1839321.2	10013226.9	1233745.6	919570.0	3065121.5	4290425.3	1226296.9	5010485
Amphora	1226296.9	613024.3	613024.3	613024.3	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	920405.5	0.0	347455
Biddulphia	1233745.6	1233745.6	1233745.6	613024.3	0.0	0.0	0.0	1226048.6	613024.3	613024.3	1233745.6	0.0	613024.3	1226296.9	920405.5	717322
Nitzschia	0.0	613024.3	1226296.9	1226296.9	613024.3	0.0	0.0	3984782.1	1226296.9	0.0	613024.3	613024.3	1226296.9	920405.5	1839321.2	940120
Pinnularia	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Thalassionema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Rhizosolenia	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Coscinodiscus	0.0	0.0	0.0	0.0	1226296.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	1226296.9	204375
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4291170.1	0.0	0.0	0.0	0.0	0.0	0.0	920405.5	347438
Cymbella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	613024.3	0.0	0.0	613024.3	122605
Chlorophyceae																
Skeletonema	0.0	0.0	0.0	0.0	0.0	7203470.1	0.0	0.0	1226296.9	0.0	0.0	0.0	920405.5	0.0	0.0	623345
Asterionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	81737
Triceratium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gyrosigma	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81737
Tetraedron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	81737
Ankiistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Crucigenia	1839321.2	613024.3	613024.3	613024.3	1839321.2	25550252.2	6688643.9	613024.3	613024.3	613024.3	613024.3	0.0	613024.3	1839321.2	613024.3	2884939
Scenedesmus	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	920405.5	613024.3	0.0	183965
Volvox	613024.3	613024.3	1226296.9	613024.3	0.0	0.0	0.0	0.0	613024.3	0.0	613024.3	0.0	0.0	0.0	0.0	286095
Gonium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Koliella spiculiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Golenkenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1226048.6	0.0	613024.3	0.0	122605
Cyanophyceae																
Nostoc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gleocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	81737
Anabaena	613024.3	613024.3	1226296.9	1226296.9	7356788.3	22503876.5	613024.3	0.0	0.0	0.0	0.0	0.0	920405.5	613024.3	613024.3	2419919
Oscillatoria	0.0	613024.3	1226296.9	1226296.9	0.0	613024.3	613024.3	1226048.6	613024.3	0.0	613024.3	3371795.1	613024.3	613024.3	920405.5	817468
Spirullina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1226048.6	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	163473
Lyngbya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Xanthophyceae																
Tribonema	7356788.3	3066363.0	3065121.5	2452097.2	613024.3	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1144428
Total	49738642	42851616	31960192	28201104	23240548	92372248	29364336	38979308	13488024	14304447	15545840	11954380	14409423	17473800	14409920	29219589
3zone avg.	48862763	26219348	22915042	21862051	13673248	56785769	15101155	60510606	9605868	14372627	10290813	7049981	10731277	12057883	8993175	22606107
No. of Spp.	12	13	12	13	9	10	12	15	13	7	13	7	14	13	16	30

Table Phyto 4 :Monthwise average density (no./l) of different phytoplankton species in zone 2 of Ulhas river estuary.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Bacillariophyceae																
Cyclotella	47205354.5	11341570.4	15326849.1	15926962.4	3065121.5	0.0	1839072.9	0.0	613024.3	0.0	0.0	1226098.3	3066363.0	920405.5	1839072.9	6824660
Gomphonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Leptocylindrus	0.0	0.0	613024.3	1226296.9	1226296.9	0.0	613024.3	1839072.9	613024.3	0.0	1226296.9	0.0	613024.3	613024.3	0.0	572206
Melosira	17766035.3	1839072.9	3066363.0	2452097.2	1226296.9	613024.3	613024.3	0.0	0.0	0.0	613024.3	0.0	920405.5	0.0	613024.3	1981491
Navicula	0.0	6686409.3	1226296.9	1226296.9	613024.3	613024.3	613024.3	1226048.6	613024.3	0.0	0.0	0.0	613024.3	920405.5	0.0	956705
Pleurosigma	0.0	613024.3	1226296.9	613024.3	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	245226
Navicula closterium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Thalassiosira	1226296.9	1226296.9	613024.3	1226296.9	613024.3	613024.3	1226296.9	2622969.4	0.0	14406816.1	613024.3	613024.3	920405.5	1839072.9	0.0	1850638
Amphora	1226296.9	1226296.9	1226296.9	1226296.9	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	613024.3	0.0	613024.3	490486
Biddulphia	0.0	1839072.9	0.0	0.0	613024.3	0.0	0.0	613024.3	3066363.0	1226098.3	1839072.9	0.0	613024.3	3065121.5	613024.3	899188
Nitzschia	1226296.9	2452097.2	613024.3	1839072.9	0.0	12260982.7	0.0	7509882.9	613024.3	0.0	0.0	0.0	920405.5	613024.3	920405.5	1931214
Pinnularia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Thalassionema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Rhizosolenia	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	613024.3	0.0	613024.3	0.0	920405.5	183965
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Coscinodiscus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	81737
Cymbella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Chlorophyceae																
Skeletonema	0.0	0.0	0.0	0.0	613024.3	919660.6	0.0	0.0	613024.3	0.0	0.0	0.0	920405.5	613024.3	613024.3	286144
Asterionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92571636.1	0.0	0.0	1839072.9	0.0	613024.3	0.0	613024.3	6375784
Triceratium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gyrosigma	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	920405.5	102229
Tetraedron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Ankiistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Crucigenia	0.0	0.0	613024.3	0.0	0.0	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	122605
Scenedesmus	0.0	0.0	613024.3	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	613024.3	613024.3	0.0	0.0	245210
Volvox	24520972.3	1839072.9	2452097.2	1226296.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2002563
Gonium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Koliella spiculiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Golenkenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Cyanophyceae																
Nostoc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	81737
Gleocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Anabaena	0.0	0.0	613024.3	613024.3	1226296.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	204358
Oscillatoria	1226296.9	1839072.9	1839072.9	1226296.9	613024.3	0.0	0.0	0.0	1226296.9	0.0	0.0	0.0	613024.3	613024.3	0.0	613074
Spirullina	613024.3	613024.3	613024.3	613024.3	1226296.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	245226
Lyngbya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Xanthophyceae																
Tribonema	0.0	1839072.9	3065121.5	2452097.2	0.0	22503876.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1990678
Total	95010574	33354084	33719565	32480108	12261479	38749641	6743516	107608683	7357781	15632914	7969564	2452147	11652179	11036176	8278435	28287123
No. of Spp.	8	12	15	14	12	9	8	8	7	2	8	3	13	11	10	23

Table Phyto 5: Monthwise average density (no./l) of different species in zone 3 of Ulhas river estuary.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Bacillariophyceae																
Cyclotella	613024.3	0.0	0.0	1226296.9	613024.3	0.0	0.0	0.0	613024.3	613024.3	1226296.9	1839172.2	920405.5	613024.3	0.0	551820
Gomphonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Leptocylindrus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	613024.3	0.0	613024.3	0.0	0.0	0.0	0.0	122605
Melosira	613024.3	1226296.9	613024.3	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	613024.3	613024.3	613024.3	0.0	0.0	326963
Navicula	613024.3	0.0	1226296.9	613024.3	1226296.9	613024.3	1226296.9	613024.3	613024.3	0.0	613024.3	0.0	920405.5	613024.3	613024.3	633566
Pleurosigma	0.0	613024.3	613024.3	1226296.9	613024.3	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	286095
Navicula closterium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Thalassiosira	0.0	0.0	0.0	0.0	0.0	2452221.4	1839072.9	7969564.3	3066363.0	9502373.3	1226296.9	0.0	1226296.9	920405.5	1839072.9	2002778
Amphora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Biddulphia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1226098.3	0.0	3065121.5	1839072.9	0.0	613024.3	0.0	0.0	449554
Nitzschia	0.0	613024.3	613024.3	1226296.9	0.0	6130491.4	3065121.5	7969713.2	0.0	0.0	0.0	0.0	0.0	3065121.5	613024.3	1553054
Pinnularia	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Thalassionema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Rhizosolenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3066363.0	0.0	0.0	0.0	613024.3	613024.3	613024.3	327029
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Coscinodiscus	0.0	0.0	0.0	0.0	1226296.9	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	163490
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1226098.3	0.0	0.0	0.0	81740
Cymbella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Chlorophyceae																
Skeletonema	0.0	0.0	0.0	0.0	613024.3	30039680.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1839072.9	613024.3	2206987
Asterionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15939376.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1062625
Triceratium	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	3065121.5	0.0	0.0	0.0	245210
Gyrosigma	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Tetraedron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Ankiistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Crucigenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Scenedesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1226296.9	0.0	0.0	0.0	0.0	81753
Volvox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gonium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Koliella spiculiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Golenkenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Cyanophyceae																
Nostoc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gleocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Anabaena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Oscillatoria	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81737
Spirullina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Lyngbya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Xanthophyceae																
Tribonema	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Total	1839073	2452346	3065370	4904939	5517715	39235418	9195613	34943826	7971799	13180519	7357037	6743416	6132229	7663673	4291170	10299609
No. of Spp.	3	3	4	5	7	4	8	7	5	3	7	4	8	6	5	19

Table Phyto 6: Monthwise overall average density (no/l) of different phytoplankton species in Thane creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Bacillariophyceae																
Cyclotella	0.0	817448.5	817365.7	0.0	817448.5	1634764.6	613107.1	0.0	408682.9	0.0	1024355.6	1405925.4	715567.5	817531.3	408765.6	632064
Gomphonema	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	27246
Leptocylindrus	204341.4	1021707.2	1021789.9	1430390.0	408765.6	0.0	408682.9	408682.9	408682.9	0.0	0.0	0.0	613603.6	204341.4	204341.4	422355
Melosira	8889390.4	7458834.8	1839072.9	2043828.2	817448.5	1634847.4	817696.8	39817406.0	7254907.2	5313042.8	2452180.0	40836405.2	2452097.2	2452097.2	2656438.7	8449046
Navicula	204341.4	2043497.1	4700018.5	8582671.3	1634814.2	2247788.9	1328260.7	6028320.6	1430390.0	204341.4	1123919.3	204341.4	1430390.0	1430390.0	1737026.3	2288701
Pleurosigma	204341.4	613107.1	1226131.4	1021707.2	613107.1	0.0	0.0	0.0	0.0	0.0	408765.6	2110308.7	511143.3	0.0	408682.9	474486
Navicula closterium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Thalassiosira	204341.4	1021872.7	817448.5	613107.1	1226131.4	6232769.7	2860780.1	92367245.0	2045980.0	7364865.9	1123919.3	2043480.6	1430721.1	1430472.8	817365.7	8106700
Amphora	0.0	613107.1	408765.6	408765.6	306553.5	613057.4	204341.4	0.0	613024.3	204341.4	204341.4	0.0	817365.7	613024.3	408682.9	361025
Biddulphia	204341.4	0.0	204341.4	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	817365.7	613024.3	204341.4	163473
Nitzschia	613107.1	613107.1	1634814.2	2043497.1	1124167.6	1021707.2	1226048.6	2758741.8	204341.4	0.0	1021872.7	255447.5	718050.3	919826.1	1021872.7	1011773
Pinnularia	0.0	0.0	0.0	0.0	0.0	817465.1	0.0	0.0	0.0	0.0	255488.9	0.0	0.0	204341.4	204341.4	98776
Thalassionema	0.0	0.0	0.0	0.0	0.0	3269628.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	217975
Rhizosolenia	0.0	0.0	0.0	0.0	715236.4	0.0	0.0	408682.9	204341.4	204341.4	0.0	1226114.8	919826.1	408682.9	408682.9	299727
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13623
Coscinodiscus	0.0	0.0	0.0	0.0	204341.4	408765.6	306553.5	0.0	204341.4	0.0	204341.4	204341.4	511143.3	204341.4	0.0	149878
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	13623
Cymbella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	306801.8	0.0	34076
Chlorophyceae																
Skeletonema	0.0	0.0	0.0	0.0	204341.4	0.0	204341.4	0.0	408682.9	0.0	204341.4	0.0	0.0	0.0	306801.8	88567
Asterionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	13623
Triceratium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gyrosigma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	408765.6	0.0	204341.4	0.0	204341.4	0.0	0.0	54497
Tetraedron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Ankiistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13623
Crucigenia	0.0	204341.4	411248.5	0.0	204341.4	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	204341.4	306801.8	204341.4	115984
Scenedesmus	204341.4	204341.4	204341.4	0.0	0.0	0.0	0.0	0.0	408765.6	0.0	0.0	0.0	0.0	306801.8	306801.8	109026
Volvox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gonium	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	27246
Koliella spiculiformis	0.0	0.0	0.0	0.0	0.0	2656521.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	177101
Golenkenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6743598.4	0.0	0.0	613024.3	490442
Cyanophyceae																
Nostoc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gleocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Anabaena	408682.9	204341.4	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	68114
Oscillatoria	408765.6	408765.6	1226048.6	613024.3	613024.3	0.0	613024.3	408682.9	408682.9	2452180.0	613024.3	613024.3	204341.4	613024.3	613603.6	653948
Spirullina	0.0	204341.4	408682.9	613107.1	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	0.0	306801.8	408682.9	143064
Lyngbya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5108784.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	340586
Xanthophyceae																
Tribonema	204341.4	204341.4	408682.9	408682.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204341.4	0.0	0.0	95359
Total	11750336	15633154	15328753	18187464	8889721	20945999	8787178	147715229	14409589	15947454	9045233	56051671	11958981	11342646	11342481	25155726
No. of Spp.	11	14	14	12	13	12	11	10	13	7	13	12	16	17	19	31

Table Phyto 7: Monthwise average density (no/l) of different phytoplankton species in zone 1 of Thane creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Bacillariophyceae																
Cyclotella	0.0	1226296.9	613024.3	0.0	1226296.9	0.0	613024.3	0.0	613024.3	0.0	1233745.6	1839172.2	1226296.9	1226296.9	0.0	654479
Gomphonema	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	81737
Leptocylindrus	613024.3	2452097.2	1839072.9	2452097.2	0.0	0.0	613024.3	1226048.6	613024.3	0.0	0.0	0.0	920405.5	613024.3	0.0	756121
Melosira	0.0	1839072.9	613024.3	613024.3	1226296.9	1839072.9	613024.3	3065121.5	1226296.9	7356540.0	3065121.5	111780806.1	3065121.5	3065121.5	1839072.9	9413781
Navicula	613024.3	1226296.9	3065121.5	11341570.4	3065121.5	1839072.9	1839072.9	12260982.7	613024.3	0.0	0.0	613024.3	3065121.5	1839072.9	3371757.8	2983484
Pleurosigma	613024.3	613024.3	1226296.9	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	2043480.4	613024.3	0.0	0.0	381458
Navicula closterium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Thalassiosira	0.0	1226296.9	613024.3	613024.3	1226296.9	613024.3	2452097.2	163686403.4	1839072.9	12898984.8	613024.3	3371733.0	0.0	1226296.9	0.0	12691952
Amphora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	613024.3	613024.3	0.0	1839072.9	613024.3	613024.3	326946
Biddulphia	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	2452097.2	1839072.9	613024.3	408683
Nitzschia	0.0	613024.3	1839072.9	1839072.9	613024.3	0.0	3065121.5	7356688.9	0.0	0.0	1226296.9	766342.5	920405.5	920405.5	1226296.9	1359050
Pinnularia	0.0	0.0	0.0	0.0	0.0	1226296.9	0.0	0.0	0.0	0.0	766466.6	0.0	0.0	0.0	613024.3	173719
Thalassionema	0.0	0.0	0.0	0.0	0.0	9808885.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	653926
Rhizosolenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	613024.3	0.0	0.0	3678344.5	0.0	613024.3	613024.3	408696
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Coscinodiscus	0.0	0.0	0.0	0.0	0.0	1226296.9	0.0	0.0	613024.3	0.0	613024.3	613024.3	920405.5	613024.3	0.0	306587
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	40868
Cymbella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Chlorophyceae																
Skeletonema	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	613024.3	0.0	613024.3	0.0	0.0	0.0	920405.5	183965
Asterionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	40868
Triceratium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gyrosigma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1226296.9	0.0	613024.3	0.0	613024.3	0.0	0.0	163490
Tetraedron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Ankiistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Crucigenia	0.0	613024.3	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	613024.3	163473
Scenedesmus	613024.3	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	1226296.9	0.0	0.0	0.0	0.0	920405.5	920405.5	327079
Volvox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gonium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Koliella spiculiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Golenkenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Cyanophyceae																
Nostoc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gleocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Anabaena	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81737
Oscillatoria	1226296.9	1226296.9	2452097.2	1839072.9	613024.3	0.0	613024.3	613024.3	613024.3	6743515.7	613024.3	613024.3	613024.3	613024.3	920405.5	1287459
Spirullina	0.0	0.0	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	613024.3	163473
Lyngbya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15326352.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1021757
Xanthophyceae																
Tribonema	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Total	4904443	12874504	13486783	19923911	8583085	16552649	11034438	205373695	10422158	28225089	10582801	125931976	16861024	14714818	13489514	34197392
3zone avg.	11750336	15633154	15328753	18187464	8889721	20945999	8787178	147715229	14409589	15947454	9045233	56051671	11958981	11342646	11342481	25155726
No. of Spp.	7	12	10	8	7	6	9	10	12	5	11	10	12	13	13	26

Table Phyto 8: Monthwise average density (no/l) of different phytoplankton species in zone 2 of Thane creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Bacillariophyceae																
Cyclotella	0.0	613024.3	1839072.9	0.0	613024.3	1839172.2	1226296.9	0.0	613024.3	0.0	1226296.9	539468.8	0.0	0.0	1226296.9	649045
Gomphonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Leptocylindrus	0.0	613024.3	1226296.9	1839072.9	1226296.9	0.0	613024.3	0.0	613024.3	0.0	0.0	0.0	920405.5	0.0	613024.3	510945
Melosira	11341570.4	9195861.2	3065121.5	2452097.2	613024.3	1839172.2	919660.6	96462813.4	9196606.0	6743515.7	3065121.5	9195786.7	1839072.9	2452097.2	3065121.5	10763109
Navicula	0.0	1839072.9	1839072.9	3065121.5	613024.3	3065121.5	613024.3	5210954.9	3065121.5	0.0	1839072.9	0.0	613024.3	1839072.9	613024.3	1614314
Pleurosigma	0.0	1226296.9	613024.3	613024.3	1226296.9	0.0	0.0	0.0	0.0	0.0	1226296.9	4287445.8	920405.5	0.0	613024.3	715054
Navicula closterium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Thalassiosira	613024.3	613024.3	613024.3	0.0	1839072.9	14406940.2	3065121.5	82762626.4	3065121.5	6130491.4	919660.6	919536.5	3371757.8	3065121.5	2452097.2	8255775
Amphora	0.0	1226296.9	1226296.9	1226296.9	919660.6	1839172.2	613024.3	0.0	613024.3	0.0	0.0	0.0	613024.3	613024.3	613024.3	633523
Biddulphia	0.0	0.0	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81737
Nitzschia	1226296.9	0.0	1839072.9	3065121.5	1839072.9	3065121.5	0.0	919536.5	613024.3	0.0	613024.3	0.0	1233745.6	1839072.9	613024.3	1124408
Pinnularia	0.0	0.0	0.0	0.0	0.0	1226098.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	122608
Thalassionema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Rhizosolenia	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	920405.5	0.0	613024.3	183965
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Coscinodiscus	0.0	0.0	0.0	0.0	613024.3	0.0	919660.6	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	143047
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Cymbella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	920405.5	0.0	102229
Chlorophyceae																
Skeletonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Asterionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Triceratium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gyrosigma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Tetraedron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Ankiistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Crucigenia	0.0	0.0	1233745.6	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	920405.5	0.0	184478
Scenedesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Volvox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gonium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Koliella spiculiformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Golenkenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Cyanophyceae																
Nostoc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gleocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Anabaena	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	81737
Oscillatoria	0.0	0.0	613024.3	0.0	613024.3	0.0	613024.3	613024.3	613024.3	613024.3	613024.3	0.0	0.0	613024.3	920405.5	388307
Spirullina	0.0	613024.3	613024.3	1226296.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	920405.5	613024.3	265718
Lyngbya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Xanthophyceae																
Tribonema	0.0	0.0	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81737
Total	13793916	15939625	15946825	14713080	11341570	27280798	8582837	186581980	18391971	13487031	9502497	15555262	11657890	13795654	11955091	25901735
No. of Spp.	4	8	13	9	12	7	8	6	8	3	7	5	10	10	11	18

Table Phyto 9: Monthwise average density (no/l) of different phytoplankton species in zone 3 of Thane creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Bacillariophyceae																
Cyclotella	0.0	613024.3	0.0	0.0	613024.3	3065121.5	0.0	0.0	0.0	0.0	613024.3	1839135.0	920405.5	1226296.9	0.0	592669
Gomphonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Leptocylindrus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Melosira	15326600.8	11341570.4	1839072.9	3066363.0	613024.3	1226296.9	920405.5	19924283.1	11341818.7	1839072.9	1226296.9	1532622.8	2452097.2	1839072.9	3065121.5	5170248
Navicula	0.0	3065121.5	9195861.2	11341322.1	1226296.9	1839172.2	1532684.9	613024.3	613024.3	613024.3	1532684.9	0.0	613024.3	613024.3	1226296.9	2268304
Pleurosigma	0.0	0.0	1839072.9	2452097.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	326946
Navicula closterium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Thalassiosira	0.0	1226296.9	1226296.9	1226296.9	613024.3	3678344.5	3065121.5	30652705.1	1233745.6	3065121.5	1839072.9	1839172.2	920405.5	0.0	0.0	3372374
Amphora	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	613024.3	0.0	122605
Biddulphia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Nitzschia	613024.3	1226296.9	1226296.9	1226296.9	920405.5	0.0	613024.3	0.0	0.0	0.0	1226296.9	0.0	0.0	0.0	1226296.9	551863
Pinnularia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Thalassionema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Rhizosolenia	0.0	0.0	0.0	0.0	1532684.9	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	1839072.9	613024.3	0.0	306520
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Coscinodiscus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Cymbella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Chlorophyceae																
Skeletonema	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	81737
Asterionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Triceratium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gyrosigma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Tetraedron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Ankiistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Crucigenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Scenedesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Volvox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gonium	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	81737
Koliella spiculiformis	0.0	0.0	0.0	0.0	0.0	7969564.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	531304
Golenkenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20230795.3	0.0	0.0	1839072.9	1471325
Cyanophyceae																
Nostoc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Gleocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Anabaena	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40868
Oscillatoria	0.0	0.0	613024.3	0.0	613024.3	0.0	613024.3	0.0	0.0	0.0	613024.3	1226048.6	0.0	613024.3	0.0	286078
Spirullina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Lyngbya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Xanthophyceae																
Tribonema	613024.3	0.0	613024.3	613024.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	613024.3	0.0	0.0	163473
Total	16552649	18085334	16552649	19925400	6744509	19004548	6744261	51190012	14414637	6130243	7050400	26667774	7358030	5517467	8582837	15368050
No. of Spp.	3	6	7	6	8	7	5	3	5	4	6	5	6	6	6	15

Table Phyto 10: Zonewise and overall percentage occurrence of the four phytoplankton classes along Ulhas river estuary and Thane creek.

	U-1	U-2	U-3	U	T-1	T-2	T-3	T
	%	%	%	%	%	%	%	%
Ba	71.95	80.42	98.02	79.43	91	96.15	83.23	91.19
Chl	12.13	8.655	0.794	8.964	1.435	0.712	13.56	3.657
Cya	11.59	3.751	0.794	6.686	7.471	2.841	2.127	4.793
Xant	-4.330	-7.174	-0.392	-4.920	-0.094	-0.297	-1.083	-0.360

Table Phyto 11:Monthwise percentage occuranceof the four phytoplankton classes in Ulhas river estuary and Thane creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
Ulhas river estuary																
Ba	74.49	85.19	75.03	79.44	67.12	57.86	78.47	97.3	87.24	97.16	86.1	75.36	86.67	83.05	89.77	79.63
Chl	18.82	3.897	8.026	4.674	5.978	15.36	16.12	1.013	4.255	2.843	11.91	8.695	6.667	10.17	2.272	8.986
Cya	1.673	4.676	8.026	7.479	25.41	13.57	4.059	1.688	8.51	0	1.986	15.94	6.667	6.779	7.956	6.703
Xant	-5.019	-6.236	-8.917	-8.412	-1.494	-13.21	-1.353	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-4.684
Thane creek																
Ba	89.57	90.85	82.65	91.01	90.81	85.37	90.7	96.26	94.33	83.34	93.22	86.88	93.17	86.48	79.27	91.17
Chl	1.739	2.614	4.016	0	2.299	13.66	2.325	0	2.837	0	0	12.03	1.709	5.41	11.71	3.656
Cya	6.957	5.229	10.66	6.742	6.896	0.976	6.976	3.735	2.836	16.66	6.777	1.094	3.417	8.109	9.013	4.793
Xant	-1.739	-1.307	-2.666	-2.247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-1.709	0.000	0.000	-0.379

Fig. Phyto.1- Comparison of average total Phytoplankton density (no/l) in Ulhas river estuary and Thane creek

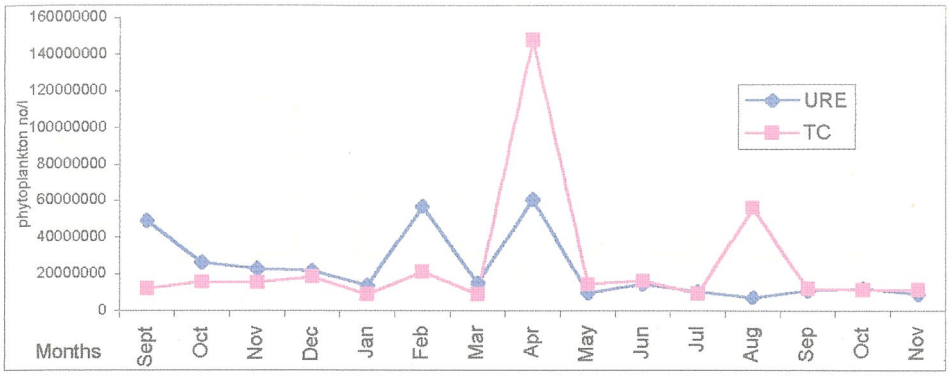


Fig. Phyto.2- Zonewise comparison of average total Phytoplankton density (no/l) in Ulhas river estuary.

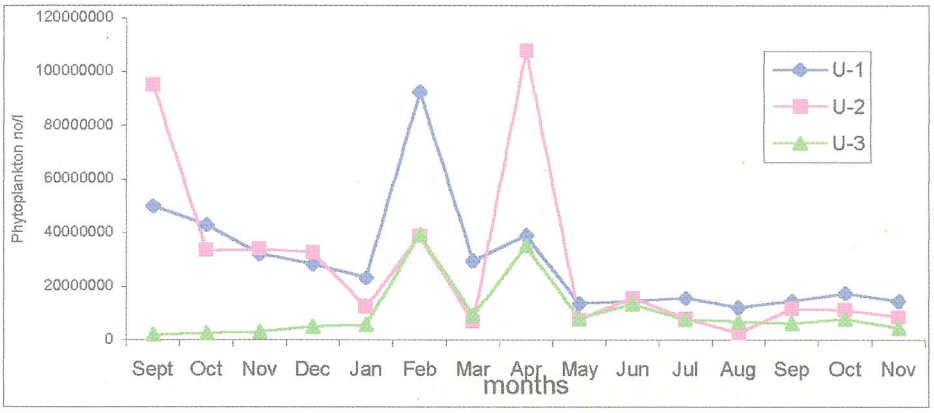


Fig. Phyto.3- Zonewise Comparison of average total Phytoplankton density (no/l) in Thane creek.

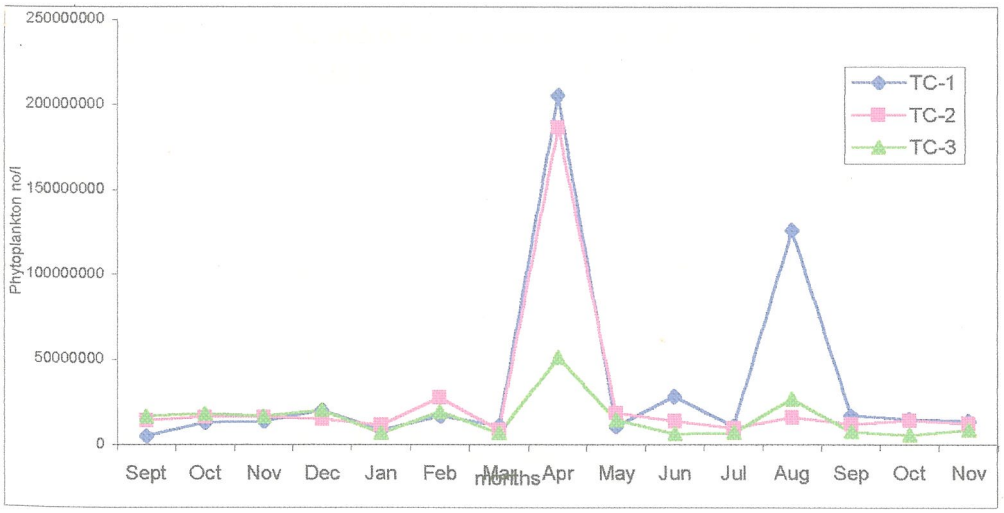


Fig. Phyto.4- Comparison of total zonewise annual average of total phytoplankton density (no./l) in Ulhas river estuary and Thane creek

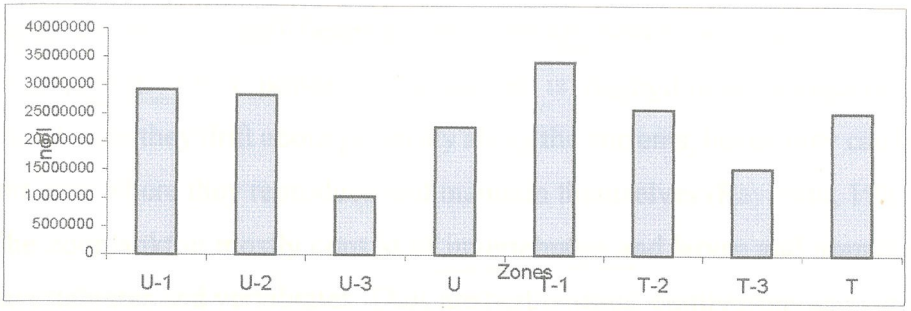


Fig. Phyto.5- Comparison of overall average phytoplankton densities of different genera inUlhas river estuary and Thane creek.

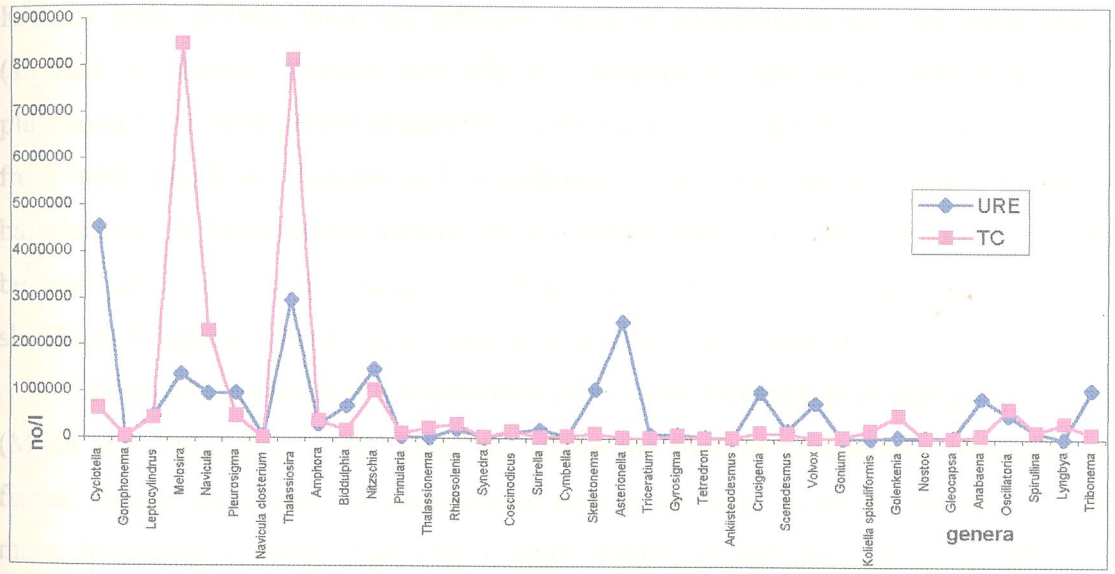
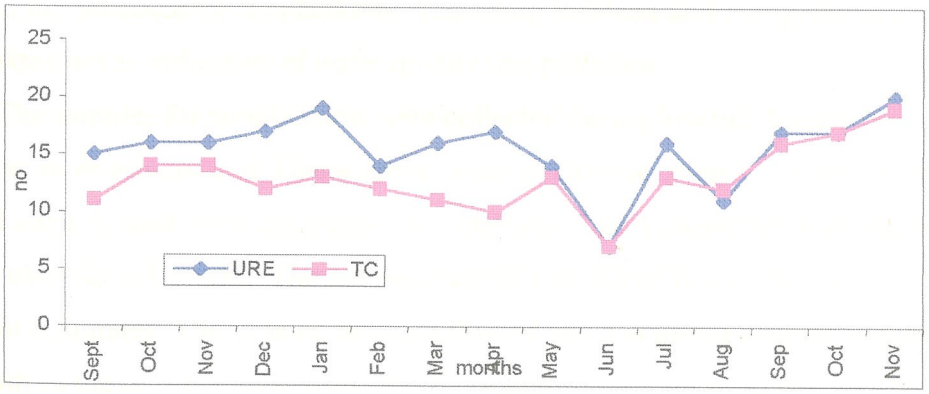


Fig. Phyto.-6: Monthwise species number of phytoplankton in Ulhas river estuary and Thane creek



Part II : Zooplankton

Zooplankton are small heterotrophic animals which occur at all depths of an aquatic ecosystems. Their power of movement is negligible as compared to water currents and hence they drift about passively along the currents, hence they can be carried beyond the area where they reproduce and maintain themselves (Raymont, 1983).

The zooplankton mostly consist of invertebrates and larvae and immature stages of both invertebrates and vertebrates. They are herbivorous, omnivorous and carnivorous. During phytoplankton blooms there is dominance of herbivorous and omnivorous zooplankton, which then changes to carnivorous zooplankton (Nair, 1980) According to Krishna Pillai (1986), there are different types of zooplankton such as holoplankton (animals planktonic through out life e.g. Copepods) and meroplankton (animals planktonic for a brief period of their life cycle e.g. Fish larvae). According to habitat the fresh water plankton is known as limnoplankton and that in marine water is known as haliplankton. In haliplankton there are types such as oceanic plankton (Plankton in water beyond continental shelf), Neretic plankton (plankton in water overlying continental shelf) and Brackish water plankton (plankton in creeks and estuaries).

Study of zooplankton is necessary as they form the vital link in pelagic food chain (Misra and Panigrahy, 1999). They contribute the food of crustaceans, mollusks and fishes. Hence, abundance of zooplankton acts as an index to assess fertility of water mass. According to Sarkar *et al* (1985), study of intensity and abundance of zooplankton in relation to environmental parameters is necessary for correct understanding of fishery resources. Some fishes exclusively feed on zooplankton hence their abundance is directly linked to the presence of zooplankton. According to Misra and Panigrahy (1999), some zooplankton act as indicators of water quality and pollution.

The samples for zooplankton were collected during low tide from 3 zones each of the Ulhas river estuary and Thane creek, namely riverine zone 1, Middle zone 2, and seaward zone 3; each zone consisting of 4 stations. Zooplankton net with mesh size 60 um was used for collection. The net was held at 1 m. depth below the water surface and towed for 5 minutes. The volume of water filtered was calculated considering the area of the mouth of the net and current speed. The samples collected were preserved in known

volume of 10 % formalin (made in filtered creek / estuarine water). Different types of zooplankton were identified by studying the 1 ml sub sample under trinocular microscope with built in illumination facility. Finally density / m^3 (i.e. per 1000 L) was calculated. Photographs were taken using Lynx microphotographic unit.

Results and discussion

Zone wise and monthwise data on zooplankton (no/m^3) in Thane creek and Ulhas river estuary is shown in Tables Z-1 to Z-10. In Ulhas river estuary the total monthly zooplankton density ranged from 13 no/m3 to 3055 no/m^3. The lowest 3 zone average 206 no/m^3 was observed in September 2002 and the highest 1303 no/m^3 in April 2002. and overall average was 517 no / m3. In Thane creek the total monthly zooplankton density ranged from 23 no/m^3 to 9350 no/m^3 the 3 zone monthly averages ranged from 196 no/m^3 (in November 2001) to 5615 no/m^3 (in April 2002) with overall average 1018 no/m^3. Thus the minima of averages were observed in late monsoon or postmonsoon and the maxima in premonsoon (summer) month in both the ecosystems. Goldin 2001 reported average zooplankton density in range 902 to 492100 no/m^3 and overall average 27917 no/m^3 in Thane creek in his study during 1999 - 2000. As compared to this the present averages are almost 1/27th indicating significant reduction in zooplankton density. Goldin (2001) has described increasing trend of average zooplankton density in Thane creek as 28 no/m^3 in 1977; 268 no/m3 in 1982; 4850 no/m^3 in 1990 and 27917 no/m^3 in 1999 - 2000. He commented that the zooplankton are not consumed (exploited) by fishes as they (the fishes) cannot enter the creek owing to pollution. The present data shows significant decline in zooplankton in past 2 years indicating death of zooplankton, suggesting pollution beyond tolerable limits. The average zooplankton density has got much lowered than most other Indian estuaries and creeks such as Vellar estuary, Cochin backwaters, Godavari estuary, Pitchavaram mangroves, Hooghly estuary etc. (Goldin 2001). This can be attributed to lower phytoplankton density. As the nutrient levels in the water and sediment are quiet high, they must not be limiting the phytoplankton growth. This leads to a conclusion that probably the reduction in plankton density (both Phyto and Zooplankton) has occurred due to some chemical pollution in the creek which needs to be traced by doing proper chemical analysis of water and sediment. In Ulhas

river estuary however increase in zooplankton density was observed as compared to the average 127no/m^3 observed by Mishra (2002) and decrease as compared to average 18969 no/m^3 reported by Mustafa *et al* (1999) thus zooplankton in Ulhas river estuary probably shows a fluctuating trend of density and they have not reached too much excessive growth probably due to moderate organic enrichment which has not gone beyond the tollerable limits. According to Nair (1975), Chaetognaths form an important constituent of zooplankton, which occur in estuaries during certain months. Nair *et al.* (1981) further pointed out that certain species of chaetognaths are sensitive to industrial pollution and reported their lowered density in Thane creek. Lodh (1990) also reported absence of certain chaetognaths species which were prevalent in past. Nair *et al* (1999) reported chaetognaths in zooplanktons of Ulhas river estuary. In the present study chaetognaths were not observed in Thane creek and Ulhas river estuary suggesting their polluted state.

Monthwise trend of overall total zooplankton in Thane creek and Ulhas river estuary (Fig Z-1) showed maximum density of zooplankton during period February to June i.e. premonsoon and the peak values coincide with the peak values of phytoplankton (Feburary and April in Ulhas river estuary and April in Thane creek)

The zooplankton of Thane creek and Ulhas river estuary belonged to different groups (total 10), namely protozoa, ctenophora, coelenterata, annelida, rotifera, mollusca, arthropoda, fish larvae and eggs which included 26 types of zooplankton (Plate 10). Arthropoda formed the most dominant group (60 % in Ulhas river estuary and 49 % in Thane creek) among the zooplankton. (Table Z-2) Arthropoda had positive relation with salinity showing increasing proportion towards the seaward zone (Table Z-2). The decreasing order of dominance in Thane creek was arthropoda > mollusca > annelida > eggs > rotifera > protozoa > coelentrata > nematoda. Where as in Ulhas river estuary it was arthropoda > rotifera > eggs > protozoa > mollusca > annelida. Thus in Thane creek molluscs and annelids followed arthropoda in dominance whereas in Ulhas river estuary rotifers and eggs ranked 2^{nd} and 3^{rd} in dominance. Higher number of rotifers in Ulhas river estuary could be due to its lower salinity. The same reason caused decreasing trend of rotifers from the riverine zone 1 to the seaward zone 3 in both the ecosystems. Among the protozoans Noctiluca occurred in higher density in Ulhas river estuary whereas

foraminiferans and tintinids occurred in higher density in Thane creek (Table Z 2 & 4). Ctenophora, coelenterates, fish larvae and nematoda were poorly represented in zooplankton. Annelids included oligochaetes and polychaetes of which polychaetes were dominant in both the ecosystems, however annelids were poorly represented in Ulhas river estuary (0.66 %) as compared to Thane creek (15%) Mollusca had a higher proportion in Thane creek (15 %) and showed dominance of gastropods in both the ecosystems. Proportion of eggs of different organisms was around 10 % in both the ecosystems.

Table (Z-2) shows percentage of different zooplankton organisms in Ulhas river estuary and Thane creek. In Ulhas river estuary there was dominance of Cyclopoid copepods (due to more fresh water conditions) followed by rotifera, calanoid copepods, nauplii, eggs, gastropods, noctiluca. In Thane creek calanoid copepod was the dominant zooplankton, followed by polychaetes, gastropods, nauplii, rotifer, cyclopoid copepods.

Average zooplankton in Ulhas river estuary (Table Z-1) showed the maximum density in riverine zone 1.which decreased slightly in zone 2 and significantly in zone 3. In Thane creek the riverine zone 1 had the minimum zooplankton density the middle zone 2 had the maximum density which reduced slightly in zone 3. Very low density in riverine zone of Thane creek could be due to high pollution in this zone. In zone 2 the organic pollutants probably get diluted thus boosting the plankton growth.

Table Z-2 and Z-5 to Z-7 show zone wise data on Ulhas river estuary which show special preference of different organisms. Rotifers and cyclopoid copepods preferred riverine zone, middle zone had mixture of calanoid and cyclopoid copepods due to intermediate salinity. Whereas in seaward zone 3, high salinity gave favorable environment for calanoid copepods and nauplii reducing cyclopoids and rotifers.

In Thane creek also zone 1 had dominance of rotifers but cyclopoid copepods were low. High rotifers were probably due to sewage pollution in this zone. As salinity in this zone was relatively high (as compared to Ulhas river estuary) cyclopoid copepods were low. The rotifers were followed by polychaetes and gastropods which could be due to high organic pollution in this zone. In zone 2 calanoids increased, followed by gastropods and polychaetes, whereas in Zone 3, high salinity favored calanoid copepods.

In general, high annelida and mollusca in Thane creek could be due to high pollution level in the creek as compared to Ulhas river estuary.

As seen from the zone wise comparison of annual total zooplankton in Ulhas river estuary the density was high in zone 1 (Table Z-2) probably due to higher organic enrichment in that zone. The density however declined in the downstream stretches i.e. zone 2 & 3 this can be due to 1) industrial chemical pollution near Kolshet, 2) heavy sand dredging activity and 3) diluted organic load. In Thane creek though zone 1 was sewage polluted. The pollution level being very high, anoxic conditions prevailed in this zone causing low zooplankton density. In zone 2 the organic load was diluted favorably boosting zooplankton density, which declined slightly in zone 3.

Summary

Total 10 groups and 26 types of zooplankton were recorded from Thane creek and Ulhas river estuary. Arthropoda was the most dominant group in both. Annelids (especially polychaeta) and mollusca were significantly higher in Thane creek owing probably to organic pollution.

In general zooplankton density in Ulhas river estuary and Thane creek was lower as compared to most Indian estuaries and creeks. During premonsoon months (February to June) the zooplankton growth was maximum in both the ecosystems. Increasing trend of zooplankton density in Thane creek has been reported in past studies. Present reduction in the density to 1/27th indicates some chemical pollution in the creek and also excessive organic enrichment.

In Ulhas river estuary the zooplankton showed fluctuating trend when compared to past, suggesting organic pollution within limits, which has not crossed the tolerance limits of the ecosystem probably due to higher water mass and regular dredging activity. However, it is also probable that the sand dredging activity is adversely affecting zooplankton density by making the water more turbid.

These conclusions are based on the sporadically available past data. In fact, there is a need to have an institution which will continuously study Thane creek and Ulhas river estuary, so that proper conclusions can be drawn and remedial measures implemented. Unfortunately this is being neglected in our system.

Table Z-1: Zonewise average density (no/m^3) of different zooplankton types and total zooplankton in Ulhas river estuary and Thane creek.

	U-1 Avg	U-2 Avg	U-3 Avg	U-avg	T-1 Avg	T-2 Avg	T-3 Avg	T-avg
Protozoa								
Noctiluca	1.933	46.73	0	16.22	0.733	0	0	0.244
Foraminifera	0	0.533	0.467	0.333	5.667	0.8	21.27	9.246
Tintinids	0	0.133	1.133	0.422	2	1.133	24	9.044
Ctenophore	0	0.6	0	0.2	0	0	0	0
Coelenterata	0.8	3.4	2.267	2.156	1.467	2.667	6.6	3.578
Rotifer	352.1	16.53	1.667	123.4	166.3	45.8	4.6	72.23
Nematode	0.6	0.467	0	0.356	7.6	1.667	1.533	3.6
Annelida								
Oligochaetes	0.267	0.333	0	0.2	0.067	0	0	0.022
Polychaetes	3.8	4.733	1.2	3.244	156.1	204.6	97.2	152.6
Mollusca								
Gastropods	12.87	5.533	10.07	9.491	24.13	224.5	93.27	114
Bivalves	3.933	0	5	2.978	5.533	63.8	48.6	39.31
Arthropoda								
Ostracod	2.467	2.467	0.467	1.8	0.267	0.133	3.067	1.156
Cypris	0	0.133	2.467	0.867	1.533	6.2	6.467	4.733
Cladocera	0	0.933	0	0.311	0.133	0	0	0.044
Nauplius	19.93	86.93	63.67	56.84	23.07	163.4	101.6	96.02
zoea	1.533	1	0.333	0.955	0.533	8.533	0.8	3.289
Cyclopoid copepods	200.3	140.3	33.07	124.6	15.2	43.87	63.07	40.71
Calanoid copepods	47	239.4	83.67	123.4	15.53	567.5	468.4	350.5
Harpactcoid copepods	0.267	0.933	0.933	0.711	1.667	0.867	6.933	3.156
Acetes	0.133	0	4.667	1.6	0	1.067	2.267	1.111
Acetes Larvae	0.133	0.133	0.133	0.133	0	4.133	4.333	2.822
Prawn Juveniles	0.2	0	0	0.067	0	0	0	0
Mites	0.067	0	0	0.022	0.333	0	0	0.111
other arthropods	0.267	0.067	0.333	0.222	0	0	0.467	0.156
eggs	42.67	71.8	25.13	46.53	13.13	92.67	223.9	109.9
Fish Larvae	0	0.133	0.067	0.067	0	0	0.067	0.022
Total	691.3	623.2	236.7	517.1	441	1433	1178	1017
3 zone avg.	517.1				1017.6			
no. of Spp.	19	21	19	26	20	18	20	24

Table Z-2: Proportion (%) of different zooplankton types and major groups in different zones of Ulhas river estuary and Thane creek.

	U-1 %	U-2 %	U-3 %	U-avg %	U-1	U-2	U-3	U-avg	T-1 %	T-2 %	T-3 %	T-avg %	T-1	T-2	T-3	T-avg
Protozoa																
Noctiluca	0.28	7.499	0	3.137					0.166	0	0	0.024				
Foraminifera	0	0.086	0.197	0.064	0.28	7.606	0.676	3.283	1.285	0.056	1.805	0.908	1.905	0.135	3.841	1.821
Tintinids	0	0.021	0.479	0.082					0.454	0.079	2.037	0.889				
Ctenophore	0	0.096	0	0.039	0	0.096	0	0.039	0	0	0	0	0	0	0	0
Coelenterates	0.116	0.546	0.957	0.417	0.116	0.546	0.957	0.417	0.333	0.186	0.56	0.352	0.333	0.186	0.56	0.352
Rotifer	50.93	2.653	0.704	23.87	50.93	2.653	0.704	23.87	37.7	3.195	0.39	7.097	37.7	3.195	0.39	7.097
Nematode	0.087	0.075	0	0.069	0.675	0.888	0.507	0.735	1.723	0.116	0.13	0.354	1.723	0.116	0.13	0.354
Annelida																
Oligochaete	0.039	0.053	0	0.039	0.589	0.813	0.507	0.666	0.015	0	0	0.002	35.415	14.27	8.248	15.002
Polychaete	0.55	0.76	0.507	0.627					35.4	14.27	8.248	15				
Mollusca																
Gastropods	1.861	0.888	4.252	1.835	2.43	0.888	6.364	2.411	5.472	15.66	7.915	11.2	6.727	20.11	12.04	15.06
Bivalves	0.569	0	2.112	0.576					1.255	4.451	4.124	3.863				
Arthropoda																
Ostracods	0.357	0.396	0.197	0.348					0.06	0.009	0.26	0.114				
Cypris	0	0.021	1.042	0.168					0.348	0.433	0.549	0.465				
Cladocera	0	0.15	0	0.06					0.03	0	0	0.004				
Nauplius	2.884	13.95	26.89	10.99					5.231	11.4	8.622	9.436				
zoea	0.222	0.16	0.141	0.185					0.121	0.595	0.068	0.323				
Cyclopoid copepods	28.98	22.51	13.97	24.09					3.447	3.06	5.352	4.001				
Calanoid copepods	6.799	38.41	35.34	23.86	39.4	75.78	80.15	60.23	3.522	39.6	39.75	34.44	13.21	55.52	55.79	49.51
Harpactcoid copepods	0.039	0.15	0.394	0.138					0.378	0.06	0.588	0.31				
Acetes	0.019	0	1.971	0.309					0	0.074	0.192	0.109				
Acetes Larvae	0.019	0.021	0.056	0.026					0	0.288	0.368	0.277				
Prawn Juvenile	0.029	0	0	0.013					0	0	0	0				
Mite	0.01	0	0	0.004					0.076	0	0	0.011				
other arthropod	0.039	0.011	0.141	0.043					0	0	0.04	0.015				
eggs	6.172	11.52	10.62	8.999	6.172	11.52	10.62	8.999	2.978	6.465	19	10.8	2.978	6.465	19	10.8
Fish Larvae	0	0.021	0.028	0.013	0	0.021	0.028	0.013	0	0	0.006	0.002	0	0	0.006	0.002
Total	100	100	100	100					100	100	100	100				

Table Z-3 : Monthwise overall average density (no/m3) of different zooplankton types and total zooplankton in Ulhas river estuary.

Total	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Protozoa																
Noctiluca	0	0	0	0	0.333	0	4	177	9.333	0	0	0	0	2.667	50	16.22
Foraminifera	0	0	0.667	0.667	0	0	0.667	0	0.667	2.333	0	0	0	0	0	0.333
Tintinids	0	0	0	0	0	0	1	0.333	0	0	0.667	0	1.667	0	2.667	0.422
Ctenophore	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0.2
Coelenterates	1.333	5	7.333	6.667	0	6	3	0	0	0	1.667	0	0.667	0	0.667	2.156
Rotifer	1.333	0.667	1.333	1.333	43.33	75.67	299.3	888	430.3	6.667	21.67	8	19	30	24.67	123.4
Nematode	0	0.667	0	0.667	0	0	2.333	0	0	0	0	0	1	0.667	0	0.356
Annelida																
Oligochaete	0	0	0	0	0	0	0	0	1	0	1.333	0	0.333	0.333	0	0.2
Polychaete	0	2	0.667	0	9.667	8.667	16.67	0	0.667	2.333	1.333	4.667	0.667	0.667	0.667	3.244
Mollusca																
Gastropods	0	0	2	0	2.667	0.667	1.333	22.67	1.333	26.67	2.333	58	11.67	8	5	9.489
Bivalves	1	0.667	2	1.333	8.667	14.67	5.667	0	2	2.333	2	0	0.667	3.667	0	2.978
Arthropoda																
Ostracods	1	0	0.667	0.667	0	19	0.667	0	0.667	0	0.667	0	2.667	0	1	1.8
Cypris	0	0	0	0	0	0	0	0.333	0.333	9	0	2.667	0.667	0	0	0.867
Cladocera	0	0	0	0	0	0	0	0	0	0	0	1.333	1.667	0.667	1	0.311
Nauplius	28	38	49	39.67	91.67	55.33	45.33	38.67	32.33	188.7	74.67	110	20.33	13.33	27.67	56.84
zoea	0	0	0	0	0	4	0.667	0	3	0	2.333	0	1.667	1.667	1	0.956
Cyclopoid copepods	19	136.3	78.33	121.3	0	749	329.3	4	50.67	137.7	91.67	8.667	38.67	60.33	43.33	124.6
Calanoid copepods	180.3	198.3	52.33	57.67	159	5.333	203.3	127.3	220	261	193	25	37	63	67.67	123.4
Harpactcoid copepods	0	0	0	0	0	3.667	1.667	0	0.667	0	0	0	1.667	2.333	0.667	0.711
Acetes	0.667	1.333	1.333	3	0	0	0	0	7.667	0	0	0	0	4	6	1.6
Acetes Larvae	0.667	0	0.667	0.667	0	0	0	0	0	0	0	0	0	0	0	0.133
Prawn Juvenile	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.067
Mite	0	0	0	0	0	0	0	0	0	0	0	0	0	0.333	0	0.022
other arthropod	0	0	0	0	0	1	0.667	0	0	0	0.667	0	0	0.667	0.333	0.222
eggs	48.67	36	28.33	25.67	44	300	0	44.67	7.667	6.667	7.667	31.67	66	29.33	21.67	46.53
Fish Larvae	0	0	0	0	0	0	0	0	0	0	0	0.333	0.333	0	0.333	0.067
Total	283	419	224.7	259.3	359.3	1246	915.7	1303	768.3	643.3	401.7	250.3	206.3	221.7	254.3	517.1
No. of Spp.	11	10	13	12	8	14	16	9	16	10	14	10	18	17	17	26

Table Z-4: Monthwise overall average density (no/m3) of different zooplankton types and total zooplankton in Thane Creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Protozoa																
Noctiluca	0	0	0	0	0	0	0	3.667	0	0	0	0	0	0	0	0.244
Foraminifera	8.333	7.667	8.333	18.33	7.333	0	23	10.67	30.33	4.333	0	0	7.667	11.67	1	9.244
Tintinids	0	0	0	0	0.667	0	0.333	84.33	0	0	0	0	41.67	0	8.667	9.044
Ctenophore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelenterates	6.333	7.333	11	7.333	6.667	0	4.333	6.667	0	0	0.333	0	0	3.667	0	3.578
Rotifer	8.667	2.333	1.333	0.667	2	0	0.667	0	0	0	184.3	728.7	115.7	29.67	9.333	72.22
Nematodes	0.333	5	3.667	3.667	4.667	4.333	7.333	0	9.333	0	5	0	6.667	3.333	0.667	3.6
Annelida																
Oligochaetes	0	0	0	0	0	0.333	0	0	0	0	0	0	0	0	0	0.022
Polychaetes	0	6	16.67	34.33	96	336.7	424.3	536	251.3	265.7	77.67	11	100.7	78	55.33	152.6
Mollusca																
Gastropods	12	10.67	14.33	11.33	40.67	98.33	148.3	301.7	171.3	393	296	84	60.33	38	29.33	114
Bivalves	4	2	3.667	3	20	49.67	16.33	46.67	71	168.3	102.3	42.67	36.67	16.67	6.667	39.31
Arthropoda																
Ostracods	14	0	1.333	0	0.333	0	0.333	0	0.333	0	0	0	0.667	0	0.333	1.156
Cypris	0	0	0	0	0	5.667	0	55.33	0	10	0	0	0	0	0	4.733
Cladocera	0	0	0	0	0	0	0	0	0	0	0	0	0.333	0.333	0	0.044
Nauplius	57	15.33	29.33	54.33	74	20	131.7	614.7	303.7	41.67	22	18.67	16.67	23	18.33	96.02
zoea	0	0	0	0	0	0	0	0	0	36.67	4	0	6	2.667	0	3.289
Cyclopoid copepods	108	14.33	13	9.667	64	70.33	108.7	63.33	63.67	0	15.33	3	30.67	20	26.67	40.71
Calanoid copepods	2.667	0.667	3	10.67	4.667	37.67	855	3792	191	44.33	52.33	3.333	48	136.7	75.67	350.5
Harpactcoid copepods	0	0	0	0	8.333	2.333	15.33	0	7.667	0	0	0	5	0	8.667	3.156
Acetes	0	0.667	4.333	0.667	0	0	3	0	1	0	0	0	0.667	5	1.333	1.111
Acetes Larvae	0	0	0.667	13	7.667	0	0	0	21	0	0	0	0	0	0	2.822
Prawn Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mite	0	0.667	0	0	0	0	0	0	0.333	0	0	0	0.667	0	0	0.111
other arthropod	0	0	0	0	2.333	0	0	0	0	0	0	0	0	0	0	0.156
eggs	299.3	218.7	85.33	86.67	71.67	135.7	202.3	100.7	127.3	0	125.7	21.33	69.67	77.33	26.67	109.9
Fish Larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0.333	0	0.022
Total	520.7	291.3	196	253.7	411	761	1941	5615	1249	964	885	912.7	547.7	446.3	268.7	1018
No. of Spp.	11	13	14	13	16	11	15	12	14	8	11	8	17	15	14	24

Table Z-5 : Monthwise average density (no/m3) of different zooplankton types and total zooplankton in zone 1 of Ulhas river estuary.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Protozoa																
Noctiluca					1				5					8	15	1.933
Foraminifera																0
Tintinids																0
Ctenophore																0
Coelenterates	0	2	4	4							2					0.8
Rotifers	2	2	2		130	227	875	2624	1256	20			20	65	58	352.1
Nematodes				2			5							2		0.6
Annelida																
Oligochaetes									1		2		1			0.267
Polychaetes		4			4	15	20				4	10				3.8
Mollusca																
Gastropods			2		8			58		80	5	20		12	8	12.87
Bivalves	2		2	2	1	44	2				2		1	3		3.933
Arthropods																
Ostracod	2		2	2		30							1			2.467
Cypris																0
Cladocera																0
Nauplius			4	4		51	32	58	4	20	51	40		3	32	19.93
zoea									9		5		5	3	1	1.533
Cyclopoid copepods	4	9	5	4		1848	965	12	23		12	10	32	23	58	200.3
Calanoid copepods	9	9	12	9	2	7	110	280	144	30	9		15	18	51	47
Harpactcoid copepods									2					2		0.267
Acetes	2															0.133
Acetes Larvae	2															0.133
Prawn Juvenile	3															0.2
Mite														1		0.067
other arthropod							2				2					0.267
eggs	23	28	25	19	107	315		23		20		10	35	25	10	42.67
Fish Larvae																0
Total	49	54	58	46	253	2537	2011	3055	1444	170	94	90	110	165	233	691.3
3zone avg.	283.0	419.0	224.7	259.3	359.3	1246.0	915.7	1303.0	768.3	643.3	401.7	250.3	206.3	221.7	254.3	517.1
No. of Spp.	9	6	9	8	7	8	8	6	8	5	10	5	8	12	8	

Table Z-6 : Monthwise average density (no/m3) of different zooplankton types and total zooplankton in zone 2 of Ulhas river estuary.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Protozoa																
Noctiluca							12	531	23						135	46.73
Foraminifera	0		2	2			2		2							0.533
Tintinids							1	1								0.133
Ctenophore						9										0.6
Coelenterates		9	9	4		18	9						2			3.4
Rotifer	2		2	4			23	40	35		65	4	32	25	16	16.53
Nematodes		2					2						3			0.467
Annelida																
Oligochaetes									2		2			1		0.333
Polychaetes			2		25	9	25		2			4		2	2	4.733
Mollusca																
Gastropods			2				2		2			67	8		2	5.533
Bivalves																0
Arthropods																
Ostracod						27	2						5		3	2.467
Cypris									1			1				0.133
Cladocera												4	5	2	3	0.933
Nauplius	64	85	95	88	125	37	37	58	64	413	125	24	32	25	32	86.93
zoea						9	2				2			2		1
Cyclopoid copepods	8	342	135	265		383			68	413	234	16	68	135	37	140.3
Calanoid copepods	471	510	85	78	250	9	265	100	471	620	512	8	51	85	76	239.4
Harpactcoid copepods						9							5			0.933
Acetes																0
Acetes Larvae			2													0.133
Prawn Juvenile																0
Mite																0
other arthropod															1	0.067
eggs	103	53	28	23		485		111	23			65	135	28	23	71.8
Fish Larvae												1	1			0.133
Total	648	1001	362	464	400	995	382	841	693	1446	940	194	347	305	330	623.2
No. of Spp.	5	6	10	7	3	10	12	6	11	3	6	10	12	9	11	

Table Z-7: Monthwise average density (no/m3) of different zooplankton types and total zooplankton in zone 3 of Ulhas river estuary.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Protozoa																
Noctiluca																0
Foraminifera										7						0.467
Tintinids							2				2		5		8	1.133
Ctenophore																0
Coelenterates	4	4	9	12							3				2	2.267
Rotifer												20	5			1.667
Nematodes																0
Annelida																
Oligochaetes																0
Polychaetes		2				2	5			7			2			1.2
Mollusca																
Gastropods			2			2	2	10	2		2	87	27	12	5	10.07
Bivalves	1	2	4	2	25		15		6	7	4		1	8		5
Arthropoda																
Ostracod	1								2		2		2			0.467
Cypris								1		27		7	2			2.467
Cladocera																0
Nauplius	20	29	48	27	150	78	67		29	133	48	266	29	12	19	63.67
zoea						3									2	0.333
Cyclopoid copepods	45	58	95	95		16	23		61		29		16	23	35	33.07
Calanoid copepods	61	76	60	86	225		235	2	45	133	58	67	45	86	76	83.67
Harpactcoid copepods						2	5							5	2	0.933
Acetes		4	4	9					23					12	18	4.667
Acetes Larvae				2												0.133
Prawn Juvenile																0
Mite																0
other arthropod						3								2		0.333
eggs	20	27	32	35	25	100					23	20	28	35	32	25.13
Fish Larvae															1	0.067
Total	152	202	254	268	425	206	354	13	168	314	171	467	162	195	200	236.7
No. of Spp.	7	8	8	8	4	8	8	3	7	6	9	6	11	9	11	

Table Z-8 : Monthwise average density (no/m3) of different zooplankton types and total zooplankton in zone 1 of Thane creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Protozoa																
Noctiluca								11								0.733
Foraminifera							12	32	23	13				5		5.667
Tintinids								13					5		12	2
Ctenophore																0
Coelenterates	2	4	9	4							1			2		1.467
Rotifers	1	2	2		5		2				378	1857	215	27	5	166.3
Nematodes		9	9	6	9	13	19		23		3		18	5		7.6
Annelida																
Oligochaetes						1										0.067
Polychaetes		18	23	92	215	320	233	98	67	760	135		85	164	132	156.1
Mollusca																
Gastropods	35	23	18	2		1	23	28	53	60	9	42	18	18	32	24.13
Bivalves	3					3	3				9	42	12	8	3	5.533
Arthropoda																
Ostracod					1		1						1		1	0.267
Cypris								3		20						1.533
Cladocera													1	1		0.133
Nauplius	3		2	69	45	33	23	11	11	67	12	8	23	27	12	23.07
zoea														8		0.533
Cyclopoid copepods	4			3	42	27	15		11		23	1	27	33	42	15.2
Calanoid copepods							12	18	23	67	56		6	18	33	15.53
Harpactcoid copepods					3	7	9						3		3	1.667
Acetes																0
Acetes Larvae																0
Prawn Juvenile																0
Mite		2							1				2			0.333
other arthropod																0
eggs	3	3	2	2		107	12	2	12				42		12	13.13
Fish Larvae																0
Total	51	61	65	178	320	512	364	216	224	987	626	1950	458	316	287	441
3 zone avg.	520.7	291.3	196.0	253.7	411.0	761.0	1941	5615.3	1249.3	964.0	885.0	912.7	547.7	446.3	268.7	1017.6
No. of Spp.	7.0	7.0	7.0	7.0	7.0	9.0	12.0	9.0	9.0	6.0	9.0	5.0	14	11	11	

Table Z- 9 : Monthwise average density (no/m3) of different zooplankton types and total zooplankton in zone 2 of Thane creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Protozoa																
Noctiluca																0
Foraminifera			2	2										5	3	0.8
Tintinids					2		1								14	1.133
Ctenophore																0
Coelenterates	13	9	15	3												2.667
Rotifer			2		1						157	325	132	62	8	45.8
Nematodes	1	4		2	5		3		5					5		1.667
Annelida																
Oligochaetes																0
Polychaetes			23	9	15	440	865	1250	325	30	23	33	42	12	2	204.6
Mollusca																
Gastropods	1	9	23	29	35	27	56	517	196	1110	856	208	148	96	56	224.5
Bivalves	1	4	9	9	15	13	23		78	430	245	83	23	15	9	63.8
Arthropoda																
Ostracod			2													0.133
Cypris								83		10						6.2
Cladocera																0
Nauplius	1	23	43		15	27	47	1333	768	40	36	33	27	15	43	163.4
zoea										110			18			8.533
Cyclopoid copepods	3				38	67	254	150	23		23	8	42	27	23	43.87
Calanoid copepods				2	9	13	2157	5717	365	50	78	8	38	67	9	567.5
Harpactcoid copepods							5								8	0.867
Acetes				2			9		3						2	1.067
Acetes Larvae				39	23											4.133
Prawn Juvenile																0
Mite																0
other arthropod																0
eggs	3	18	9	9	12		230	300	325		345	58	29	29	23	92.67
Fish Larvae																0
Total	23	67	128	106	170	587	3650	9350	2088	1780	1763	756	499	333	200	1433
No. of Spp.	7	6	9	10	11	6	11	7	9	7	8	8	9	10	12	

Table Z-10 :Monthwise average density (no/m3) of different zooplankton types and total zooplankton in zone 3 of Thane creek.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg
Protozoa																
Noctiluca																0
Foraminifera	25	23	23	53	22		57		68				23	25		21.27
Tintinids								240					120			24
Ctenophore																0
Coelenterates	4	9	9	15	20		13	20						9		6.6
Rotifer	25	5		2							18	4			15	4.6
Nematodes		2	2	3							12		2		2	1.533
Annelida																
Oligochaetes																0
Polychaetes			4	2	58	250	175	260	362	7	75		175	58	32	97.2
Mollusca																
Gastropods			2	3	87	267	366	360	265	9	23	2	15			93.27
Bivalves	8	2	2		45	133	23	140	135	75	53	3	75	27	8	48.6
Arthropoda																
Ostracod	42		2						1				1			3.067
Cypris						17		80								6.467
Cladocera																0
Nauplius	167	23	43	94	162		325	500	132	18	18	15		27		101.6
zoea											12					0.8
Cyclopoid copepods	317	43	39	26	112	117	57	40	157				23		15	63.07
Calanoid copepods	8	2	9	30	5	100	396	5640	185	16	23	2	100	325	185	468.4
Harpactcoid copepods					22		32		23				12		15	6.933
Acetes		2	13										2	15	2	2.267
Acetes Larvae			2						63							4.333
Prawn Juvenile																0
Mite																0
other arthropod					7											0.467
eggs	892	635	245	249	203	300	365		45		32	6	138	203	45	223.9
Fish Larvae														1		0.067
Total	1488	746	395	477	743	1184	1809	7280	1436	125	266	32	686	690	319	1178
No. of Spp.	9	10	13	10	11	7	10	9	11	5	9	6	12	9	9	

Fig Z-1: Comparison of monthly variations in zooplankton in Ulhas river estuary and Thane creek

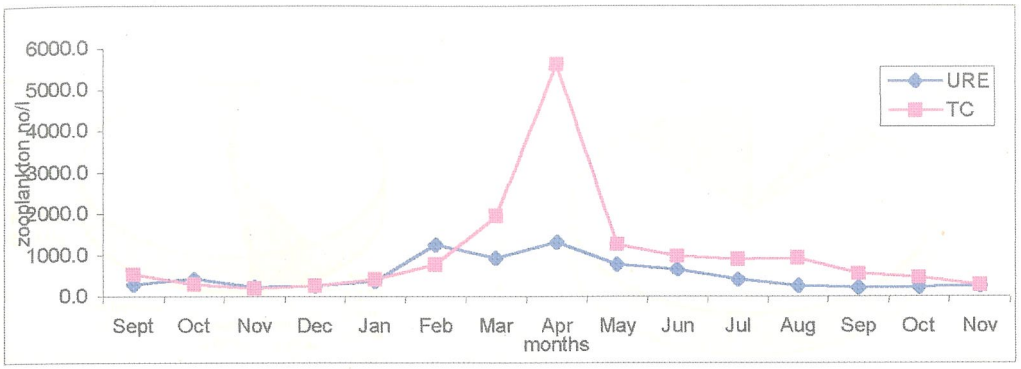


Fig Z-2: Comparison of zonewise monthly zooplankton variations in Ulhas River estuary

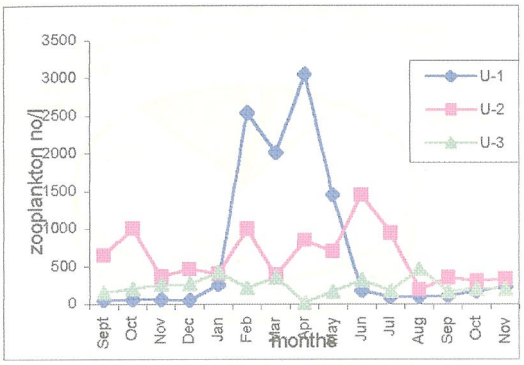


Fig Z-3 :Comparison of zonewise monthly variations in Zooplankton in Thane creek

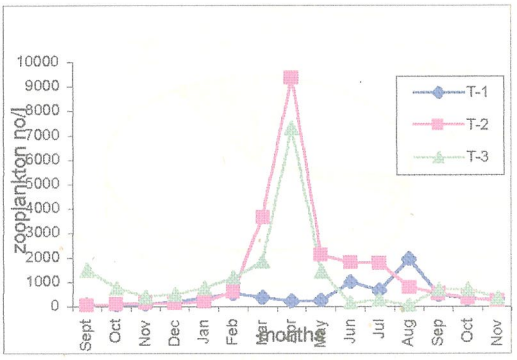


Fig Z-4: Zone wise comparison of Annual total zooplankton

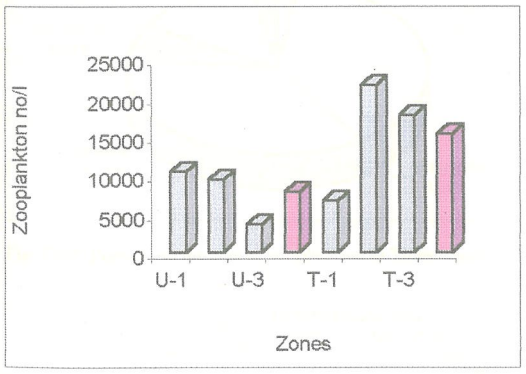


Fig Z-5: Comparison of monthly variations of zooplankton groups In Ulhas river estuary and Thane creek

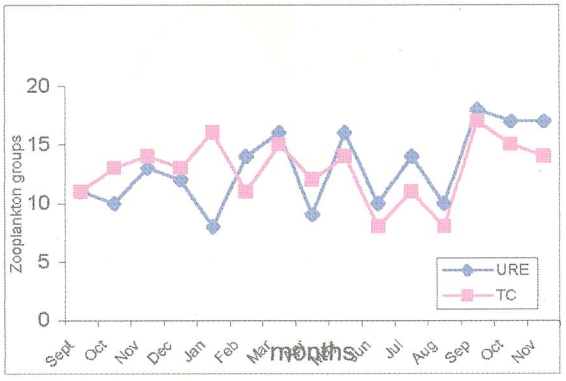


Fig. Z-6: Percent occurance of Zooplankton in Ulhas river estuary in Zone 1.

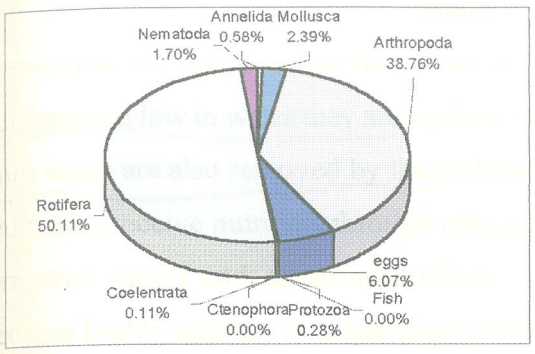


Fig. Z-7: Percent occurrance of Zooplankton in Ulhas river estuary Zone -2.

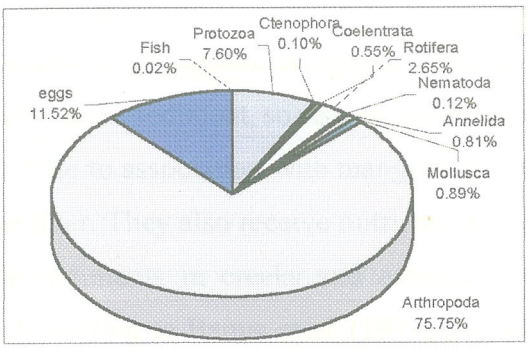


Fig. Z- 8 : Percent occurrance of zooplankton in Ulhas river estuary zone 3.

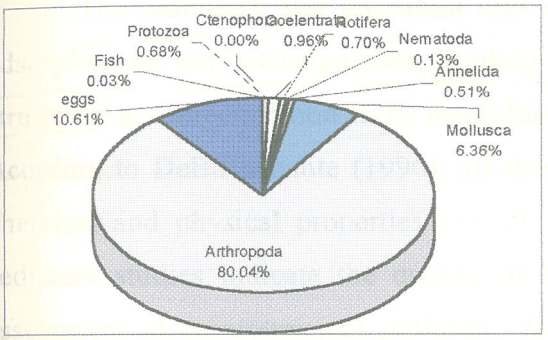


Fig. Z-9: Percent occurrance of Zooplankton in entire Ulhas river estuary.

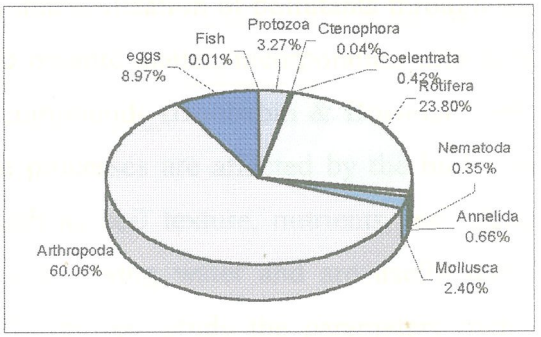


Fig. Z-10: Percent occurance of Zooplankton in Thane creek Zone 1.

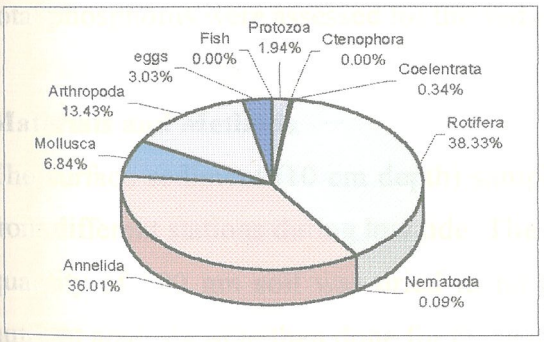


Fig. Z-11: Percent occurrance of zooplankton in Thane creek Zone 2

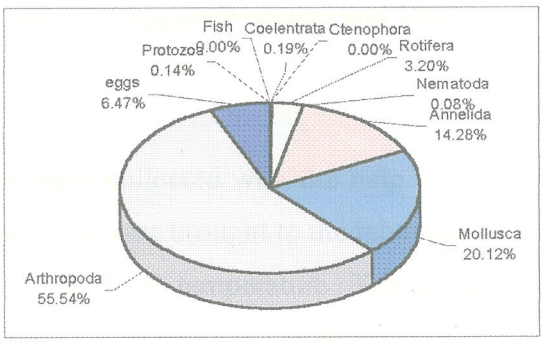
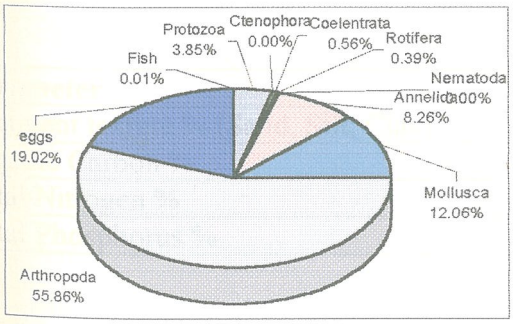
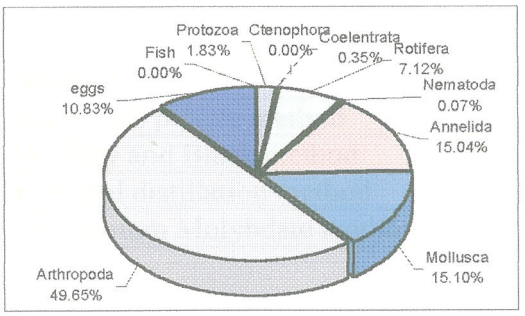


Fig. Z-12: Percent occurrance of zooplankton in Thane creek Zone 3.



Ffig. Z-13: Percent occurrance of Zooplankton in entire Thane creek.



Chapter V

Study of Sediment

The sediments act as reservoirs of nutrients in an aquatic ecosystem. Whenever nutrients are low in water they are replenished from the sediment, so also excess nutrients from water are also removed by the sediment. Due to association with mangroves, these sediments receive nutrients through mangrove litter. They also receive nutrients through terrestrial runoff and estuarine outflow. The sediments in creeks and estuaries thus become highly nutrient rich and productive. According to Banus *et al.* (1975) they also act as sink for heavy metals.

The sediments play important role in immobilization of pollutants through their adsorption on ion exchange sites, binding to organic matter, incorporation into lattice structures and precipitation in to insoluble compounds (Dunbabin & Bowmer, 1992). Acording to DeBustamante (1990), all these processes are affected by the biological, chemical and physical properties of soil such as soil texture, nutrients, etc. Hence, sediment studies indicate the quality of the overlying water and are useful tool in assessment of environmental pollution. In the present study the parameters such as texture (Percentage of Sand, Silt, Clay), nutrients - organic carbon, total nitrogen and total phosphorus were assessed for the sediments of Ulhas river estuary and Thane creek.

Materials and Methods

The surface sediment (10 cm depth) samples were collected with the help of a scoop, from different stations during low tide. The samples were brought to the laboratory and a quantity of 100 gm soil was dried in an oven at 70 C temperature. The texture and nutrient analysis were then done for these dried samples using the methods shown in the table below.

Parameter	Method
Sediment texture % (Sand, Silt, Clay)	Buchnan's pipette method
Organic Carbon %	Walkley and Black method
Total Nitrogen %	Kjeldhal distillation method
Total Phosphorus %	Ammonium Molybdate method

Sediment Texture

The monthwise and stationwise data on the proportion of sand, silt and clay has been presented in Tables Tex - 1, 2 & 3 respectively.

Sand : - In Ulhas river sand percentage in the sediment varied from 1.77 % (March, Station 2) to 35.4 % (May, Station 12). The average sand content was 12.59 %. In Thane creek the average sand content was lower than Ulhas river estuary (6.64 %) the range being from 0.1 to 15 %. The minima were observed in summer months, whereas the maxima in the post monsoon. The stationwise variation in the sand content was marginal in Thane creek whereas in Ulhas river estuary sand content gradually increased at the stations on the seaward end (Fig. Tex-1). This could be the effect of heavy sand dredging activity in the subtidal region of the middle zone of the estuary.

Seasonal variations in sand (Fig. Tex-2) showed different trends in Thane creek and Ulhas river estuary. The sand composition in Ulhas river estuary showed rising trend from March to August, whereas in Thane creek it decreased in premonsoon period and gradually increased from July to September during monsoon. As compared to Post monsoon of 2001, the sand component was lower in the corresponding period of 2002. Zonewise averages (Fig Tex- 5) showed rising trend of sand component from the riverine zone 1 to seaward zone 3. Higher average sand in Ulhas river estuary could be due to more influence of riverine flow as compared to Thane creek.

Silt (%) :- The silt component ranged from 28.25 % to 87.81 % (avg. 51 %) in Ulhas river estuary and 30% to 89.8 % (avg. 71%) in Thane creek indicating relatively higher proportion of silt in Thane creek. Stationwise trend (Fig tex - 1) showed high amount of silt at stations 1,2,3 and 8,9,10 of Ulhas river estuary, whereas in Thane creek silt was high through out the stretch showing marginal decline from the riverine to the seaward end. At station 24 however the silt was high as Station 1. The monthly trend (Fig. Tex-6) did not show significant fluctuations in Thane creek; in Ulhas river estuary the silt component was around 35 % in post monsoon months September to December 2001 which gradually increased up to 63 % in the following months upto July 2002, thereafter in period Aug to Nov. 2002 there was marginal decline up to 54 %. This showed relatively increased siltation in Ulhas river estuary. Zonewise average of sediment silt (Fig. Tex-9) showed the lowest average silt (45 %) in middle zone of the Ulhas river

estuary and high silt (approximate 63 %) in Zone 1. The maxima of Ulhas river estuary was the minima in Thane creek. The mudflats having high silt were found to be sinking type.

Clay (%) :- Clay component in the sediment is finer than silt. When suspended, it takes longer time to settle. High amount of clay in the sediment makes the substratum harder which is suitable for egg laying by prawns and fishes etc. Whereas high silt makes the substratum soft and sinking. On such substratum the eggs that are laid, get covered by silt leading to their death. Hence high clay percentage in sediment is better as compared to high silt.

In Ulhas river estuary the clay content ranged from 9.41% to 58.25 % (Avg. 36.38%) whereas in Thane creek the range was 5% to 60% (Avg. 22.26 %). Thus the clay component was much low in the sediments of Thane creek. The stationwise picture (Fig. Tex-1) showed low average clay at stations 1,2, 3 of Ulhas river estuary which increased up to station 5 and then gradually declined towards the seaward station 12. The trend was antagonistic to silt throughout the estuary and to sand in the downstream region. In Thane creek there was marginal increase in the clay component towards the seaward end of the creek except the drop at station 24. The clay component had inverse relation with silt. The zonewise average (Fig. Tex-13) showed high clay in the middle zone and lower in zone I and zone III of Ulhas river estuary, whereas increasing trend from zone I to zone III of Thane creek. Monthwise average of clay (Fig.Tex-10) showed in Ulhas river estuary significant decline from January to August and then increase again. In Thane creek however, the variations in the clay component were insignificant. The values fluctuated around 20 %.

Regarding the texture of the sediment it can be concluded that Ulhas river sediments had higher sand and clay component. Whereas Thane creek sediment showed predominance of silt. Parulekar *et al.* (1976) described the Bombay coastal sediments to be silty-clay (i.e. more clay and less silt). Athalye (1988) also observed silty-clay sediments in upstream stretch of Thane creek during 1984-85. As compared to these reports the present sediment texture shows clayey-silt nature (i.e. high silt and low clay). Thus the silt component of the Thane creek sediment has shown significant increase in past decade. Increased silt has led to many environmental problems such as

1. The sediments have become more sinking type. The mudflats which were harder before are extremely soft now.
2. This has probably produced adverse effect on fishery organisms especially prawns, mudskippers and others also because silty sediment is not ideal for egg laying. The eggs if laid can get covered by silt leading to their death.
3. This has also resulted in change of the benthic fauna.

The question which arises here is why such type of change in the sediment texture has occurred? And the probable reasons are -

1. Increase in the sewage effluent load. Gajbhiye *et al.* (1981) reported Thane creek to receive 27 mld of industrial waste water and 6 mld of sewage waste which according to TMC-ES report (2000) has increased to 294 mld and 145 to 260 mld respectively).
2. Solid waste dumping and reclamation along the banks of the creek. This has caused two things.

   A) Increase in the silt content of water.

   B) Obstruction (hindrance) in the tidal flow affecting flushing of sewage and other pollutants.

These observations corroborate with the hydrological change in salinity of the creek water discussed in earlier chapter III.

In Ulhas river estuary also the sediments in downstream zones (II & III) have more clay but in upstream zone I the silt proportion has increased significantly indicating siltation.

Table Tex-1: Monthly and stationwise variations in sand component (%) in Ulhas river estuary and Thane creek.

Sand %	Ulhas River													Thane Creek												
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg	Avg.
Sept	10	10	10	15	15	15	20	20	20	20	20	20	16.25	10	10	10	10	10	10	10	10	10	10	15	10	10.42	13.45
Oct	10	10	10	15	15	15	20	20	20	20	20	20	16.25	10	10	10	10	10	10	10	10	15	10	15	10	10.83	13.65
Nov	10	10	10	15	15	15	20	20	20	20	20	20	16.25	10	10	10	10	10	10	10	10	15	10	15	10	10.83	13.65
Dec	10	10	10	15	15	15	20	20	20	20	20	20	16.25	10	10	10	10	10	10	10	10	10	10	15	10	10.42	13.45
Jan	5	4.5	5	10	9.8	8.8	9.5	9.5	13.5	13	15	15	9.88	8.8	7.6	5.5	5.8	5.4	7.8	6.32	5.64	15	5.05	12.5	3.6	7.42	8.70
Feb	4.5	3.47	6.45	5.66	9.25	10.36	8.5	7.65	15	12.35	14.35	15	9.38	3.8	5.8	3.2	7.2	3.6	8.65	5	5.32	14.3	4.85	13.6	5	6.69	8.09
Mar	4.8	1.77	5	5.35	6.45	12.45	10.25	8.34	12.15	11.65	18	22	9.85	3.8	3.6	0.1	4.2	3.2	2.63	4.05	3.64	12.6	7.63	11.9	0.6	4.83	7.44
Apr	5.5	2.72	2.53	4.05	3.64	7.6	13.64	9.23	7.35	14.85	25	25	10.09	2.2	4.2	0.25	3.1	1.4	1.26	8.32	1.2	12	5.43	12.6	0.1	4.34	7.33
May	7.5	3.1	2.76	6.05	4.05	12.74	18.54	7.65	5.63	12.65	28.96	35.4	12.09	1.4	4	0.2	2	3.7	3.62	8	0.8	13.5	4.62	10	1.2	4.42	8.41
Jun	10	2.53	4.56	7.35	5.34	18.5	21.25	5.65	4.65	15.32	32.85	34.8	13.57	0.8	1.4	0.1	1.2	1.2	5.63	1.2	3.32	8.3	1.2	9	1.4	2.90	8.44
Jul	15.2	10	10	8.15	7.25	15.42	15.24	7.36	3.62	12.95	34.84	29	14.09	1.4	1.2	1.4	0.6	0.2	8.52	1.6	1.95	8.5	3.52	8.3	3.6	3.40	8.96
Aug	20	10	15	15	10	12.34	10.65	10	5	15	25.45	24	14.37	1.2	0.4	2	0.2	0.5	9.56	3.32	4.65	14	0.6	12	4.5	4.41	9.59
Sept	10	10	10	10	10	10	8	8	8	12.25	22	25	11.94	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8	8	7.58	9.85
Oct	8	7.5	7.5	7.5	5	6.25	10	7.5	5	10	20	22	9.69	5	5.4	5	5	5	5	5	5	10	5	10	7	6.03	7.93
Nov	7.5	7.5	7.5	5	5	5	7.5	7.5	5	7.5	20	22	8.92	4.5	5	4.5	3.8	4.5	4.5	3.8	5	5	4.5	7.5	8	5.05	7.06
Avg	9.20	6.87	7.75	9.61	9.05	11.96	14.20	11.23	10.99	14.50	22.43	23.28	12.59	5.36	5.74	4.65	5.37	5.08	6.98	6.27	5.60	11.38	5.99	11.69	5.53	6.64	9.73

Table Tex-2: Monthly and stationwise variations in silt component (%) in Ulhas river estuary and Thane creek.

Silt %	Ulhas River													Thane Creek												
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg	Avg
Sept	55	55	55	30	30	30	30	30	30	30	30	30	36.25	70	60	60	60	60	80	70	70	60	70	60	70	65.83	50.45
Oct	55	55	55	30	30	30	30	30	30	30	30	30	36.25	80	60	70	70	70	80	70	60	60	80	80	80	71.67	53.25
Nov	55	55	55	30	30	30	30	30	30	30	30	30	36.25	70	70	80	80	60	80	70	60	60	70	60	80	70.00	52.45
Dec	55	55	55	30	30	30	30	30	30	30	30	30	36.25	80	70	60	80	70	70	80	60	70	70	70	80	71.67	53.25
Jan	66.54	65.01	57.35	37.94	36.8	38.54	35.5	45.5	28.25	34.13	34.55	35.75	42.99	76.2	82.4	66.5	79.2	69.6	77.2	78.03	59.36	50	69.95	61.55	76.4	70.53	56.21
Feb	73.62	62.27	54.01	37.34	40.1	34.29	39.91	47.7	45.32	48.28	46.28	46.32	47.95	76.2	79.2	71.15	82.8	75.65	58.85	69.35	49.68	45.45	70.15	53.75	76.5	67.39	57.28
Mar	62.31	68.34	54.68	46.4	38.1	36.4	57.4	56.66	49.46	51.03	41.68	56.35	51.57	86.2	80.75	79.9	77.8	64.25	46.87	65.95	76.36	48.95	63.82	49.45	89.4	69.14	60.00
Apr	46.24	75.96	64.58	63.3	39.15	42.93	40.71	50.12	54.19	56.58	54.21	54.96	53.58	72.3	83.48	84.3	78.25	87.65	53.24	53.23	63.3	59.25	64.37	39.71	84.25	68.61	60.79
May	82.68	78.89	68.96	58.6	51.3	63.92	52.51	54.35	64.84	69.1	42.09	54.55	61.82	83.1	78	89.8	78	80.65	75.43	50	68.55	44.18	79.73	30	88.35	70.48	65.98
Jun	70.62	87.81	75.08	62.9	54.34	37.05	46.75	64	84.62	65.03	48.9	54.74	62.65	88.75	70.6	87.25	75.85	78.8	68.72	73.8	63.68	59.05	69.15	55.44	79.6	72.56	67.41
Jul	74.32	78.92	74.36	61.59	44.13	47.93	39.76	63.64	86.9	76.43	55.51	59.89	63.62	82.75	70.15	86.15	72.4	79.35	81.48	83.4	80.05	65.95	58.8	61.35	77.95	74.98	69.07
Aug	70.46	70.51	74.22	59.45	44.55	52.66	45.8	70.35	79.05	64.84	59.7	66.59	63.18	81.3	84.6	88	71.15	74.5	75.44	86.68	75.35	55.55	54.75	63	79.5	74.15	68.45
Sept	74.2	68.68	70.51	57.35	45.35	52	46.35	68.66	70.68	59.25	57.51	57	60.63	72.5	74.5	79.85	67	69.55	77.5	77.5	72.5	62.85	57.5	67	73.5	70.98	65.60
Oct	70.12	67.18	70.62	57	44.35	49.1	40.53	62.15	65.25	61	51.05	57.96	58.03	79.35	74.6	81	75	73	75.35	77.5	77	64.45	64.35	70	74.5	73.84	65.62
Nov	68.5	62.61	64.04	55	40	42.94	41.85	54.5	58.35	62.15	50.25	52.5	54.39	83	75.35	83	76.2	75.5	78	78.7	77.5	72.5	66.95	72.5	72	75.93	64.73
Avg	65.31	67.08	63.23	47.79	39.88	41.18	40.47	50.51	53.79	51.19	44.12	47.77	51.03	78.78	74.24	77.79	74.91	72.57	71.87	72.28	67.56	58.55	67.30	59.58	78.80	71.18	60.70

Table Tex-3: Monthly and stationwise variations in clay component (%) in Ulhas river estuary and Thane creek.

Clay %	Ulhas River													Thane Creek												
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg	Avg
Sept	35	35	35	55	55	55	50	50	50	50	50	50	47.50	20	30	30	30	30	10	20	20	30	20	30	20	24.17	36.30
Oct	35	35	35	55	55	55	50	50	50	50	50	50	47.50	10	30	20	20	20	10	20	30	30	10	5	10	17.92	33.30
Nov	35	35	35	55	55	55	50	50	50	50	50	50	47.50	20	20	10	10	30	10	20	30	30	20	25	10	19.58	34.10
Dec	35	35	35	55	55	55	50	50	50	50	50	50	47.50	10	20	30	10	20	20	10	30	20	20	15	10	17.92	33.30
Jan	28.46	30.49	37.65	52.06	53.4	52.66	55	45	58.25	52.87	50.45	49.25	47.13	15	10	28	15	25	15	15.65	35	35	25	25.95	20	22.05	35.09
Feb	21.88	34.26	39.54	57	50.65	55.35	51.59	44.65	39.68	39.37	39.37	38.68	42.67	20	15	25.65	10	20.75	32.5	25.65	45	40.25	25	32.65	18.5	25.91	34.63
Mar	32.89	29.89	40.32	48.25	55.45	51.15	32.35	35	38.39	37.32	40.32	21.65	38.58	10	15.65	20	18	32.55	50.5	30	20	38.45	28.55	38.65	10	26.03	32.56
Apr	48.26	21.32	32.89	32.65	57.21	49.47	45.65	40.65	38.46	28.57	20.79	20.04	36.33	25.5	12.32	15.45	18.65	10.95	45.5	38.45	35.5	28.75	30.2	47.69	15.65	27.05	31.88
May	9.82	18.01	28.28	35.35	44.65	23.34	28.95	38	29.53	18.25	28.95	10.05	26.10	15.5	18	10	20	15.65	20.95	42	30.65	42.32	15.65	60	10.45	25.10	25.62
Jun	19.38	9.66	20.36	29.75	40.32	44.45	32	30.35	10.73	19.65	18.25	10.46	23.78	10.45	28	12.65	22.95	20	25.65	25	33	32.65	29.65	35.56	19	24.55	24.15
Jul	10.48	11.08	15.64	30.26	48.62	36.65	45	29	9.48	10.62	9.65	11.11	22.30	15.85	28.65	12.45	27	20.45	10	15	18	25.55	37.68	30.35	18.45	21.62	21.97
Aug	9.54	19.49	10.78	25.55	45.45	35	43.55	19.65	15.95	20.16	14.85	9.41	22.45	17.5	15	10	28.65	25	15	10	20	30.45	44.65	25	16	21.44	21.96
Sept	15.8	21.32	19.49	32.65	44.65	38	45.65	23.34	21.32	28.5	20.79	18	27.46	20	18	12.65	25.5	22.95	15	15	20	29.65	35	25	18.5	21.44	24.57
Oct	21.88	25.32	21.88	35.5	50.65	44.65	49.47	30.35	29.75	29	28.95	20.04	32.29	15.65	20	14	20	22	19.65	17.5	18	25.55	30.65	20	18.5	20.13	26.45
Nov	24	29.89	28.46	40	55	52.06	50.65	38	36.65	30.35	29.75	25.5	36.69	12.5	19.65	12.5	20	20	17.5	17.5	17.5	22.5	28.55	20	20	19.02	28.21
Avg	25.49	26.05	29.02	42.60	51.07	46.85	45.32	38.27	35.21	34.31	33.47	28.95	36.38	15.86	20.02	17.56	19.72	22.35	21.15	21.45	26.84	30.74	26.71	29.06	15.67	22.26	29.61

Fig. Tex-1: Station wise variations in average Sand, Silt and Clay (%) in Ulhas river estuary and Thane Creek.

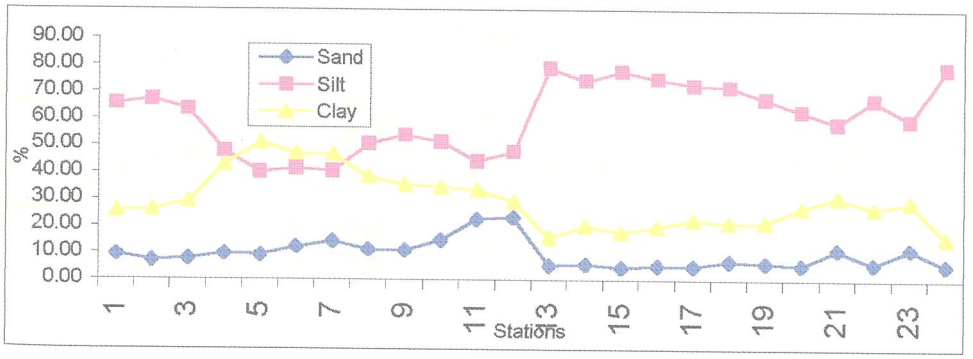


Fig. Tex-2: Monthly variations in Sand (%) in Ulhas river estuary and Thane Creek

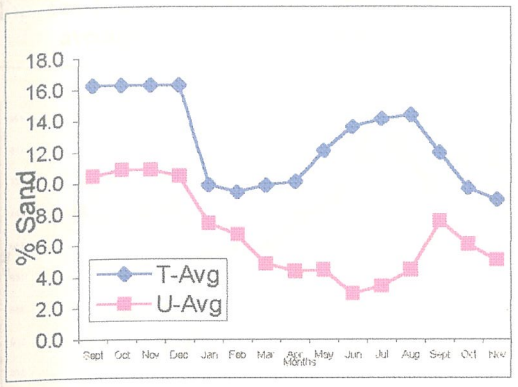


Fig. Tex-3: Zonewise monthly variations in average sand (%) in Ulhas river estuary

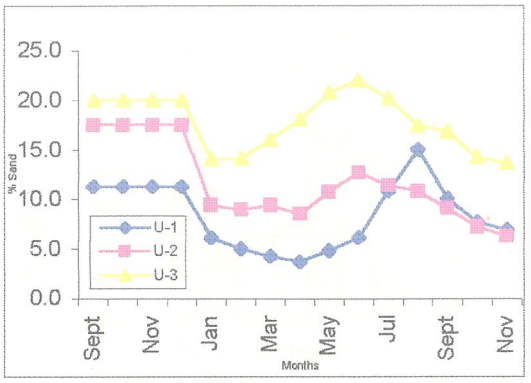


Fig. Tex-4: Zonewise monthly variations in average sand (%) in Thane creek

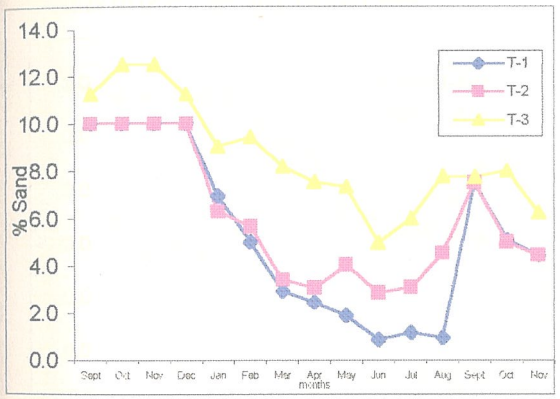


Fig. Tex-5: Comparison of Zonewise annual average of sand (%) in Ulhas river estuary and Thane creek

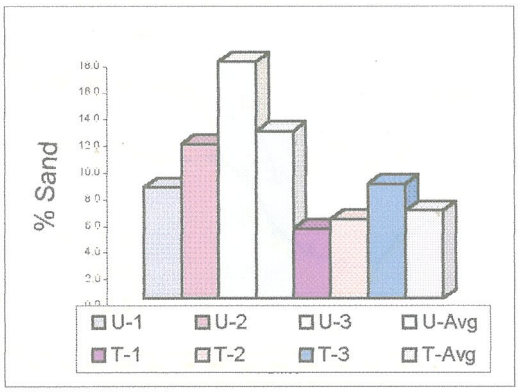


Fig. Tex-6: Monthly variations in silt (%) in Ulhas river estuary and Thane Creek

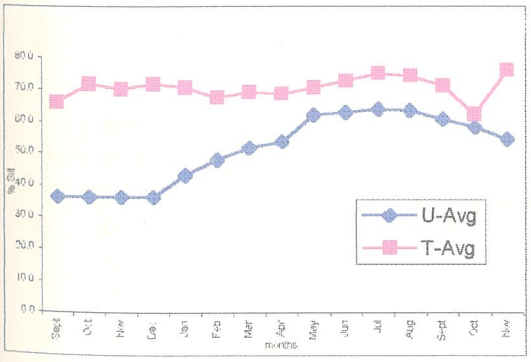


Fig. Tex-7: Zonewise monthly variations in average silt (%) in Ulhas river estuary

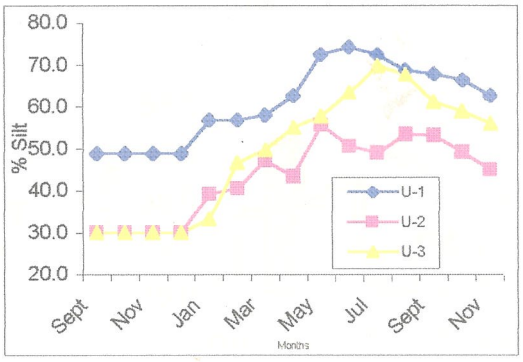


Fig. Tex-8: Zonewise monthly variations in average silt (%) in Thane creek

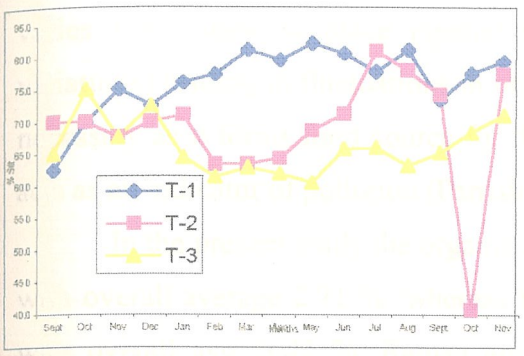


Fig. Tex-9: Comparison of Zonewise annual average of silt (%) in Ulhas river estuary and Thane creek

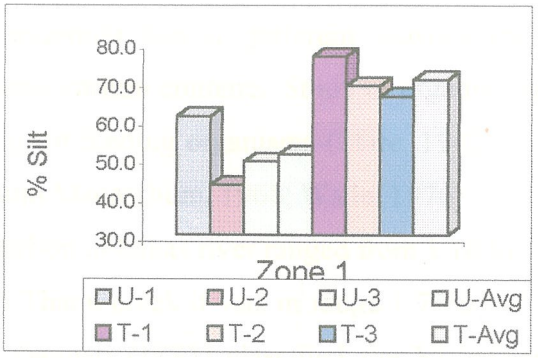


Fig. Tex-10 Monthly variations in clay (%) in Ulhas river estuary and Thane Creek

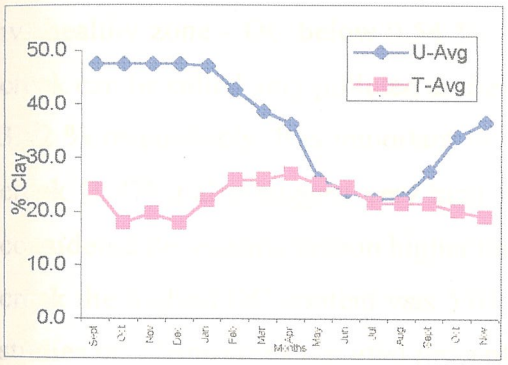


Fig. Tex-11: Zonewise monthly variations in average clay (%) in Ulhas river estuary

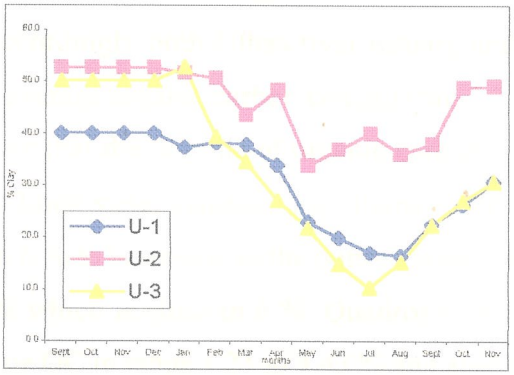


Fig. Tex-12: Zonewise monthly variations in average clay (%) in Thane creek

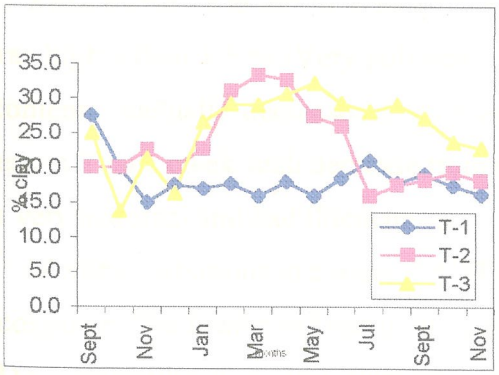
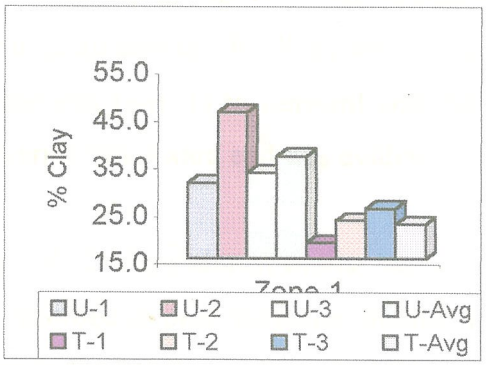


Fig. Tex-13: Comparison of Zonewise annual average of clay (%) in Ulhas river estuary and Thane creek



Organic Carbon (%)

Estuaries receive organic matter from different sources such as marine, terrestrial etc. (Canuel *et al.*, 1995). The quantity of organic matter received from these sources varies from place to place (spatial variations) and in different seasons (temporal variations) leading to fluctuations in organic carbon contents. Study of organic matter is necessary as it forms food source for deposit feeding organisms (Mare, 1942) and also acts as an indicator of pollution (Parrish and Macenthum, 1968; Wade, 1976)

In the present study the organic carbon in Ulhas river ranged from 1.18 to 4.61 % with overall average 2.71 %, whereas in Thane creek it was in range 1.77% to 5.03 % with overall avg. 3.42 %. Raman and Ganpati (1983) classified the Vishakapatnam harbour into 4 zones I) very polluted zone 1.47 - 4.24 % organic carbon ii) Polluted zone with organic carbon 1.22 - 1.47 % iii) semihealthy zone - Organic carbon 0.54 to 1.22% iv) healthy zone - OC below 0.54 %. Accordingly both Ulhas river estuary and Thane creek can be called very polluted as their average organic carbon contents are 2.71 % and 3.42 % respectively. It is important to note that the minima of organic carbon in Thane creek (1.77%) also suggest very high polluted state. Ganapati and Raman (1973) have considered the organic carbon higher than 6 % to be anoxic to the bottom fauna. In Thane creek the highest OC content was 5.03 % which is close to 6 %. Quadros (2001) in his studies on Thane creek reported percentage OC in range 1.21 to 4.43 % and average 2.63 %. **The present range and average show significant increase in organic carbon content in past 2 years which is alarming**.

Stationwise variation in average % OC is shown in Fig. OC-1 Accordingly avg. OC was higher than 1.5 % (Very polluted limit) at all stations. In Ulhas river estuary the OC contents gradually decreased from riverine end (Stn. 1) to seaward end (Stn. 12) whereas in Thane creek such decrease from riverine to seaward end was evident however it was very marginal and had fluctuations.

Monthly variations in average OC (Fig. OC-2) show almost similar trends in both the ecosystem The lowest sediment OC was recorded in post monsoon months Sept to Nov-Dec. Thereafter there was significant rise in the months January to May and then steady decline during monsoon and post monsoon months. Zonewise average trends (Fig

OC-5) showed decreased OC towards the seaward zone, thus zone being maximum polluted.

Table OC-1: Monthly and stationwise variations in Organic Carbon (%) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg	Avg
Sept	3.215	2.283	1.653	1.953	1.923	2.283	2.043	2.193	1.713	2.043	1.562	1.292	2.01	3.605	3.245	4.717	2.584	3.275	2.494	4.146	2.614	4.236	2.584	4.176	3.515	3.43	2.69
Oct	3.471	2.169	1.735	1.735	2.045	1.983	1.983	2.169	1.704	1.983	1.425	1.240	1.97	3.781	3.533	2.820	2.262	3.533	2.727	3.130	2.386	2.138	1.766	2.634	2.386	2.76	2.35
Nov	2.107	2.138	1.673	1.704	1.952	2.107	2.014	2.107	1.673	1.921	1.549	1.178	1.84	2.603	3.905	2.851	3.192	3.471	2.510	2.851	2.231	1.921	2.045	2.448	2.324	2.70	2.25
Dec	2.293	1.983	1.797	1.797	1.859	2.045	2.045	2.324	1.611	1.983	1.487	1.240	1.87	2.293	3.440	2.231	2.944	3.254	2.572	2.727	2.200	2.169	1.983	2.479	2.138	2.54	2.19
Jan	3.370	3.893	4.271	3.922	3.777	3.690	3.922	4.125	3.748	2.963	4.038	3.631	3.78	3.835	4.067	3.544	3.486	3.399	3.312	3.254	3.254	3.835	3.835	3.544	3.486	3.57	3.68
Feb	2.498	2.644	2.702	3.544	3.167	3.109	3.050	2.963	3.138	2.963	2.673	3.021	2.96	3.835	4.619	4.881	4.125	4.706	4.677	4.329	4.561	4.416	4.910	2.673	2.673	4.20	3.55
Mar	3.544	3.835	4.212	4.183	4.038	3.864	3.835	3.777	3.777	3.602	3.544	3.196	3.78	4.067	3.980	4.852	4.764	4.735	4.793	4.823	3.893	4.125	3.922	3.690	2.963	4.22	3.99
Apr	4.610	4.131	3.951	4.041	3.981	3.442	3.382	3.951	4.430	3.801	3.053	3.831	3.88	4.610	4.819	4.520	4.101	3.981	3.771	5.029	4.131	3.801	4.131	4.370	3.712	4.25	4.06
May	3.936	4.059	4.152	3.874	3.905	3.905	3.316	3.347	3.192	2.913	2.944	2.696	3.52	4.183	4.214	4.555	3.874	3.502	3.657	4.400	3.564	3.595	3.874	3.874	3.192	3.87	3.69
Jun	3.254	3.099	3.223	3.192	2.944	3.130	2.851	2.975	3.130	2.851	2.665	2.634	3.00	3.997	4.524	4.276	3.843	3.564	3.409	4.152	3.502	3.347	3.781	3.595	3.130	3.76	3.36
Jul	3.285	3.316	3.564	2.944	2.882	2.758	2.882	2.634	2.479	2.510	2.634	2.572	2.87	3.905	4.183	4.214	3.657	3.223	3.285	4.214	3.626	3.254	3.688	3.564	2.634	3.62	3.23
Aug	3.652	3.592	3.682	3.023	2.963	2.993	3.083	2.754	2.784	2.724	2.784	2.784	3.07	3.712	3.771	4.161	3.712	3.143	3.143	4.041	3.412	3.143	3.113	3.173	2.664	3.43	3.24
Sept	2.790	2.050	1.580	2.170	1.950	2.480	1.950	2.110	2.010	2.320	2.230	2.320	2.16	3.160	3.500	3.840	3.500	3.350	2.480	3.780	3.160	3.280	2.230	2.970	3.100	3.20	2.66
Oct	2.480	2.010	1.670	1.860	1.800	2.110	1.800	2.140	1.670	1.890	1.860	1.700	1.92	4.030	3.190	3.160	2.850	2.850	2.660	3.530	2.600	2.230	2.480	2.820	2.570	2.91	2.40
Nov	2.370	2.070	2.340	1.890	1.800	2.040	1.860	2.190	1.800	1.950	1.440	1.530	1.94	2.790	3.490	3.090	2.490	3.700	2.730	3.490	2.430	2.160	2.280	2.700	2.760	2.84	2.37
Avg	3.12	2.88	2.81	2.79	2.73	2.80	2.67	2.78	2.59	2.56	2.39	2.32	**2.71**	3.63	3.90	3.85	3.43	3.58	3.21	3.86	3.17	3.18	3.11	3.25	2.88	**3.42**	**3.05**

Fig. OC-1: Stationwise variations in average organic carbon (%) in Ulhas river estuary and Thane creek.

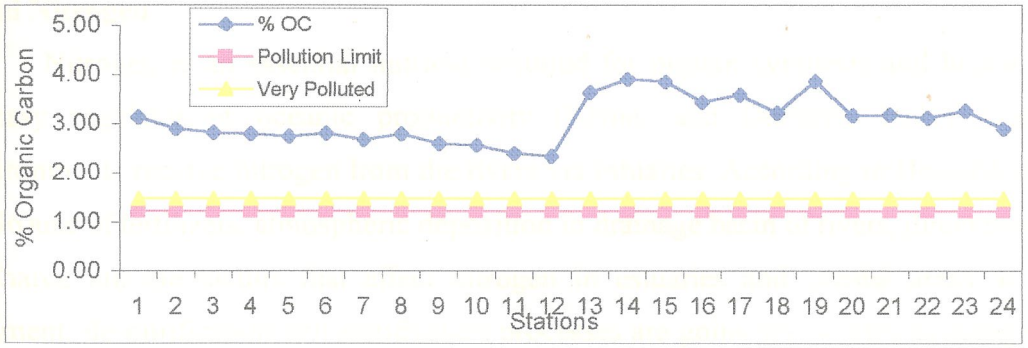


Fig. OC-2: Monthly variation in average Organic Carbon (%) in Ulhas river estuary and Thane creek.

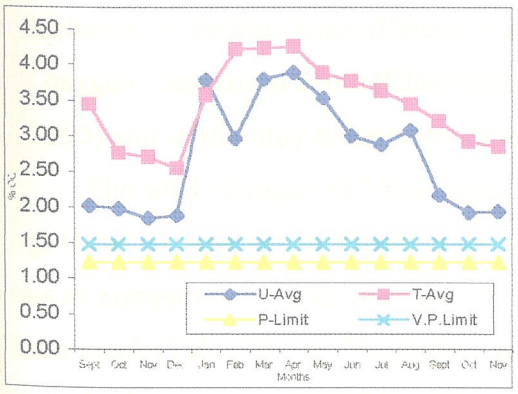


Fig. OC-3: Zonewise monthly variations in average Organic carbon (%) in Ulhas river estuary

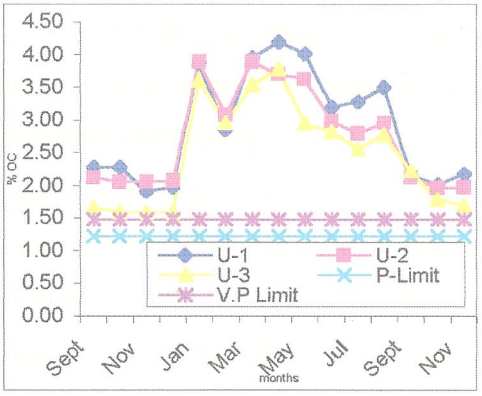


Fig. OC-4: Zonewise monthly variations in average Organic carbon (%) in Thane creek

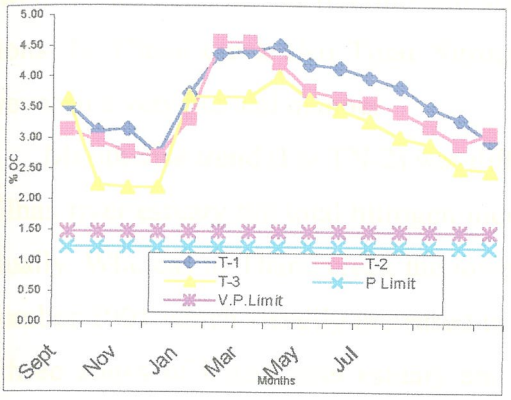
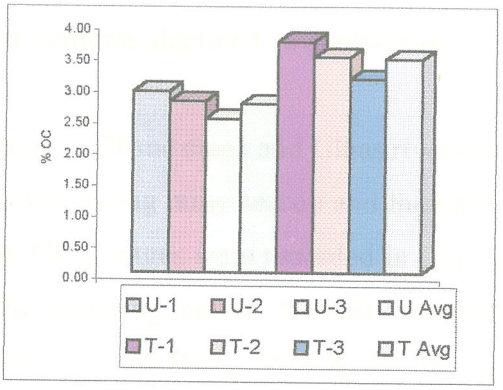


Fig. OC-5: Comparison of Zonewise annual average of organic carbon (%) in Ulhas river estuary and Thane creek



Total Nitrogen

Nitrogen is an essential nutrient required for protein synthesis and hence is a primary regulator of oceanic productivity (Ryther and Dunstan, 1971). Coastal environments receive nitrogen from the rivers via estuaries. According to Howarth *et al.* (1996)use of fertilizers, atmospheric deposition in drainage basin of rivers, direct sewage discharge are the factors that affect nitrogen in estuaries and coastal areas. In the sediment, de-nitrification and nitrification processes are going on, so also exchanges of nitrogen compounds with overlying water column take place. These processes are influenced by various factors such as fresh water flushing (Nixon *et al.*, 1996); bioturbation by benthic fauna (Pelegri *et al.*, 1994); nitrate concentration in water column and oxygen penetration depth (Christensen *et al.*, 1990); benthic microalgae (Rysgaard *et al.*,1995) and availability of ammonium and oxygen (Mackburn, 1996).

The total nitrogen in Ulhas river estuary varied between 0.098 % and 0.518 % (avg. 0.26 %), whereas in Thane creek it ranged from 0.126 to 0.518 % (avg. 0.25 %). Thus as compared to Ulhas river estuary the average total nitrogen was slightly lower in Thane creek (Table TN-1). The higher sediment nitrogen in Ulhas river estuary could be due to higher nitrates (NO3-N) in the overlying waters. Quadros (2001) reported avg.

total nitrogen in Thane creek to be 0.186 % during study period 1999-2000, which shows rise in the total nitrogen concentration in Thane creeek sediments during past 2 years.

Stationwise comparison (Fig.TN-1) of average total N in Ulhas river estuary showed higher contents on riverine end stations which decreased towards the seaward stations. In Thane creek also Total Nitrogen contents declined towards seaward end, however in a very gradual manner.

Monthwise trend (Fig TN-2) was different in Thane creek and Ulhas river estuary. In Ulhas river estuary the total nitrogen increased during rainy season and then lowered gradually. Whereas in Thane creek the lowest TN averages were recorded in October to December 2001 which steadily increased in the following months. Monthly variations in the three zones of Ulhas river estuary and Thane creek (Figs TN-3 & TN-4) showed trends similar to those of overall averages. Zonewise annual averages showed decline from riverine zone 1 to seaward zone 3 in both Ulhas river estuary and Thane creek (Fig.TN-5) but more sharp decline in Ulhas river estuary. Though most of the Indian estuaries and creeks have total sediment nitrogen similar to or lower than Thane creek and Ulhas river estuary, some ecosystems such as Goa estuaries, Asthamudi estuary, Mangrove strands of Madras Coast are reported to have higher total sediment nitrogen.

Table TN-1: Monthly and stationwise variations in Total Nitrogen (%) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg	Avg
Sept	0.364	0.308	0.287	0.308	0.266	0.280	0.196	0.266	0.238	0.280	0.168	0.168	0.26	0.182	0.329	0.518	0.378	0.343	0.245	0.301	0.329	0.308	0.266	0.336	0.154	0.31	0.28
Oct	0.308	0.280	0.252	0.238	0.210	0.266	0.210	0.252	0.210	0.294	0.154	0.196	0.24	0.294	0.280	0.245	0.217	0.294	0.210	0.224	0.196	0.161	0.126	0.175	0.140	0.21	0.23
Nov	0.266	0.252	0.252	0.238	0.252	0.280	0.182	0.280	0.224	0.280	0.168	0.168	0.24	0.189	0.294	0.252	0.238	0.301	0.210	0.224	0.175	0.154	0.161	0.168	0.154	0.21	0.22
Dec	0.294	0.196	0.280	0.294	0.252	0.266	0.196	0.266	0.266	0.266	0.154	0.182	0.24	0.196	0.315	0.182	0.196	0.252	0.210	0.210	0.182	0.168	0.154	0.182	0.140	0.20	0.22
Jan	0.224	0.196	0.266	0.280	0.210	0.294	0.210	0.238	0.210	0.238	0.140	0.154	0.22	0.210	0.308	0.294	0.210	0.266	0.224	0.238	0.182	0.210	0.210	0.203	0.168	0.23	0.22
Feb	0.210	0.210	0.266	0.294	0.196	0.322	0.224	0.238	0.196	0.238	0.112	0.140	0.22	0.238	0.294	0.308	0.238	0.322	0.224	0.266	0.196	0.238	0.238	0.203	0.161	0.24	0.23
Mar	0.238	0.224	0.280	0.294	0.196	0.294	0.252	0.210	0.196	0.280	0.112	0.140	0.23	0.245	0.294	0.280	0.238	0.308	0.245	0.266	0.217	0.266	0.245	0.217	0.161	0.25	0.24
Apr	0.224	0.224	0.252	0.238	0.182	0.280	0.294	0.196	0.182	0.266	0.105	0.098	0.21	0.252	0.301	0.308	0.266	0.336	0.238	0.259	0.245	0.273	0.259	0.252	0.168	0.26	0.24
May	0.280	0.252	0.350	0.252	0.182	0.266	0.294	0.182	0.154	0.280	0.098	0.098	0.22	0.266	0.308	0.280	0.322	0.350	0.203	0.252	0.266	0.280	0.273	0.266	0.175	0.27	0.25
Jun	0.448	0.406	0.462	0.280	0.266	0.322	0.280	0.266	0.252	0.322	0.126	0.098	0.29	0.280	0.280	0.266	0.336	0.294	0.224	0.266	0.280	0.280	0.168	0.266	0.126	0.26	0.28
Jul	0.406	0.406	0.490	0.308	0.294	0.308	0.266	0.322	0.308	0.280	0.154	0.196	0.31	0.294	0.322	0.266	0.350	0.280	0.231	0.294	0.294	0.294	0.182	0.280	0.133	0.27	0.29
Aug	0.490	0.448	0.518	0.280	0.280	0.308	0.252	0.280	0.294	0.294	0.182	0.168	0.32	0.266	0.308	0.238	0.378	0.280	0.238	0.294	0.280	0.294	0.126	0.322	0.126	0.26	0.29
Sept	0.406	0.378	0.476	0.238	0.266	0.294	0.238	0.224	0.266	0.280	0.168	0.182	0.28	0.280	0.280	0.308	0.350	0.252	0.238	0.266	0.280	0.294	0.252	0.210	0.140	0.26	0.27
Oct	0.448	0.350	0.378	0.280	0.238	0.294	0.252	0.238	0.238	0.266	0.168	0.168	0.28	0.294	0.294	0.322	0.294	0.294	0.210	0.252	0.266	0.280	0.238	0.266	0.154	0.26	0.27
Nov	0.476	0.252	0.280	0.294	0.280	0.322	0.280	0.280	0.294	0.280	0.154	0.182	0.28	0.294	0.294	0.378	0.322	0.301	0.203	0.259	0.308	0.301	0.259	0.322	0.168	0.28	0.28
Avg	0.339	0.292	0.339	0.274	0.238	0.293	0.242	0.249	0.235	0.276	0.144	0.156	0.26	0.252	0.300	0.296	0.289	0.298	0.224	0.258	0.246	0.253	0.210	0.245	0.151	0.252	0.25

Fig. TN-1: Stationwise variations in average total nitrogen (%) in the sediments of Ulhas river estuary and Thane creek.

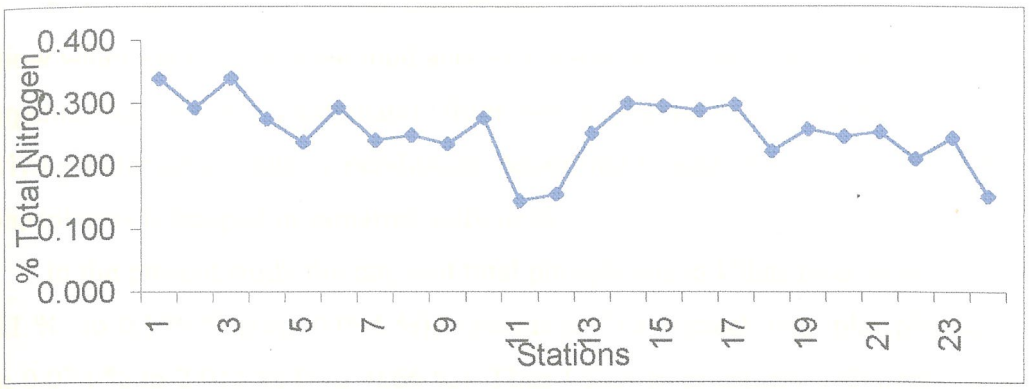


Fig. TN-2: Monthly variations in average Total Nitrogen (%) in the sediments of Ulhas river estuary and Thane creek.

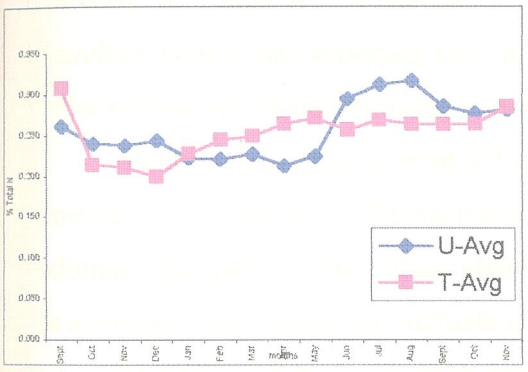


Fig. TN-3: Zonewise monthly variations in average Total Nitrogen (%) in Ulhas river estuary.

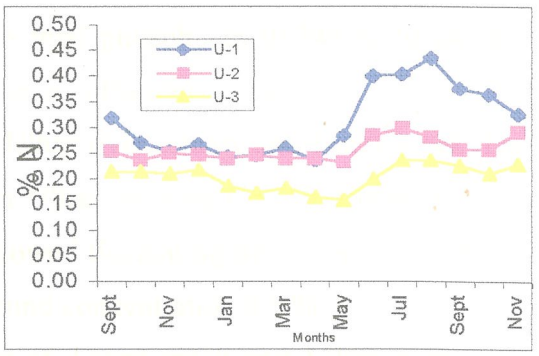


Fig. TN-4: Zonewise monthly variations in average Total Nitrogen (%) in Thane creek.

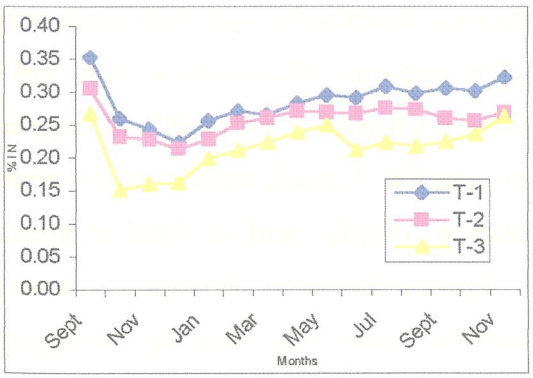
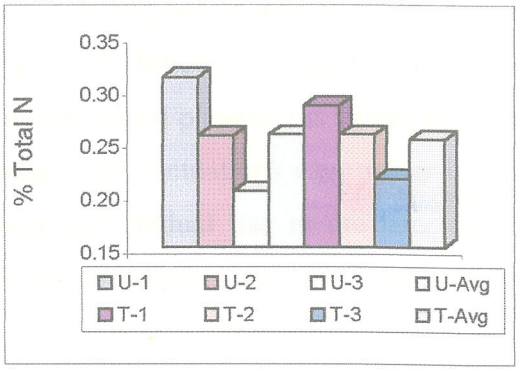


Fig. TN-5: Comparison of Zonewise annual average of Total Nitrogen (%) in Ulhas river estuary and Thane creek



Total Phosphorus (%)

Knowledge of phosphorus concentration in the mud is important especially in shallow water systems because mud acts as a reservoir of phosphorus in different forms (inorganic, organic and particulate), from which phosphorus is regenerated into the overlying water under suitable conditions. According to SaralaDevi *et al.* (1983) 80 to 90 % phosphorus is trapped in estuarine sediments.

In the present study the range of total phosphorus in Ulhas river estuary was from 0.021 % to 0.199 % (avg. 0.094 %), whereas in Thane creek total phosphorus ranged from 0.074 % to 2.915 % (avg. 0.66 %). Thus Ulhas river estuary sediments have very low total phosphorus as compared to Thane creek. The total phosphorus range of Ulhas river estuary is comparable to most other Indian estuaries whereas that of Thane creek is relatively very high which can be attributed to high sewage pollution in Thane creek. Chandran (1987) has reported very high total phosphorus (0.345 % to 28.816 %) in Vellar estuary which he attributed to proximity of sewage outlets.

Stationwise comparison of TP in Ulhas river estuary and Thane creek (Fig TP-1) showed very insignificant fluctuations in Ulhas river estuary. In Thane creek the high sediment total phosphorus values also showed fluctuating trend. As seen from Fig TP-1 the average values appear to fluctuate around concentration 0.6 %.

Monthly variations in each zone of Thane creek and Ulhas river estuary are shown in Fig TP-3 & TP-4. Which show similar trend of fluctuations in the three zones of Thane creek and different trends of fluctuations in the zones of Ulhas river estuary. In Thane creek high total phosphorus were observed during winter months which declined by May, increased in early monsoon, reduced in July followed by gradual rise in post monsoon. In Ulhas river estuary the monthly average total phosphorus values fluctuated around 0.1 % in zone 2 and 3. Whereas in zone I the fluctuations were wider with the maxima in April to June, decline in monsoon and gradual rise in the later months. Zonewise comparison of annual average of Total phosphorus (Fig. TP-5) showed high average total phosphorus in zone 2 of Thane creek and low and almost similar averages of all zones of Ulhas river estuary, where Zone 1 had marginally high total phosphorus (%).

Table TP-1: Monthly and stationwise variations in Total Phosphorus (%) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												
	1	2	3	4	5	6	7	8	9	10	11	12	U-avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg	Avg
Sept	0.049	0.043	0.049	0.037	0.080	0.086	0.092	0.101	0.052	0.095	0.110	0.101	0.07	0.199	0.175	0.233	0.132	0.169	0.196	0.147	0.144	0.123	0.144	0.123	0.138	0.16	0.12
Oct	0.080	0.077	0.049	0.049	0.089	0.092	0.080	0.095	0.058	0.101	0.101	0.083	0.08	1.393	0.657	2.209	1.945	2.369	1.675	0.792	0.528	1.737	0.804	0.571	1.283	1.33	0.68
Nov	0.086	0.086	0.114	0.052	0.086	0.101	0.101	0.101	0.064	0.110	0.107	0.089	0.09	0.865	0.859	0.804	1.381	0.871	1.111	0.890	0.663	0.761	1.117	0.878	0.921	0.93	0.49
Dec	0.095	0.101	0.110	0.092	0.117	0.114	0.110	0.117	0.089	0.117	0.120	0.110	0.11	1.817	2.111	2.025	2.614	2.117	2.209	1.921	1.982	2.369	1.669	2.099	1.859	2.07	1.05
Jan	0.107	0.092	0.089	0.046	0.092	0.089	0.089	0.092	0.055	0.107	0.184	0.077	0.09	0.414	0.292	0.660	1.013	0.752	0.875	0.752	0.752	0.813	0.445	0.914	0.813	0.71	0.39
Feb	0.101	0.098	0.083	0.077	0.089	0.092	0.089	0.092	0.083	0.169	0.138	0.031	0.10	0.402	0.350	0.350	0.690	0.853	0.598	0.414	0.608	0.881	0.402	0.690	0.445	0.56	0.32
Mar	0.129	0.126	0.107	0.061	0.089	0.092	0.098	0.089	0.089	0.184	0.153	0.021	0.10	0.457	0.230	0.292	0.347	0.301	0.270	2.915	0.301	0.295	0.230	0.292	0.506	0.54	0.31
Apr	0.187	0.184	0.135	0.077	0.071	0.110	0.089	0.083	0.107	0.086	0.077	0.046	0.10	0.433	0.074	0.110	0.156	0.206	0.169	0.166	0.187	0.123	0.132	0.138	0.460	0.20	0.15
May	0.181	0.184	0.114	0.074	0.068	0.107	0.098	0.092	0.101	0.086	0.107	0.061	0.11	0.721	0.107	0.239	0.301	0.227	0.184	2.393	0.230	0.230	0.199	0.245	0.537	0.47	0.28
Jun	0.199	0.187	0.110	0.068	0.077	0.095	0.098	0.107	0.098	0.092	0.092	0.055	0.11	0.675	0.138	0.166	0.239	0.292	0.242	2.915	0.350	0.344	0.239	0.350	0.292	0.52	0.31
Jul	0.107	0.089	0.061	0.055	0.083	0.089	0.092	0.104	0.061	0.089	0.117	0.077	0.09	0.371	0.107	0.199	0.196	0.353	0.338	0.445	0.506	0.445	0.350	0.405	0.350	0.34	0.21
Aug	0.089	0.086	0.055	0.052	0.068	0.092	0.086	0.098	0.058	0.092	0.114	0.092	0.08	0.298	0.092	0.239	0.270	0.506	0.405	0.506	0.608	0.598	0.384	0.436	0.644	0.42	0.24
Sept	0.095	0.095	0.077	0.055	0.068	0.095	0.092	0.095	0.058	0.064	0.077	0.095	0.08	0.433	0.292	0.292	0.307	0.537	0.506	0.522	0.638	0.614	0.402	0.473	0.669	0.47	0.27
Oct	0.129	0.120	0.110	0.052	0.089	0.101	0.098	0.092	0.077	0.074	0.107	0.077	0.09	0.414	0.307	0.506	0.537	0.752	0.598	0.568	0.690	0.660	0.457	0.546	0.752	0.57	0.32
Nov	0.147	0.150	0.135	0.061	0.101	0.117	0.107	0.110	0.095	0.107	0.095	0.083	0.11	0.457	0.304	0.608	0.601	0.881	0.752	0.611	0.721	0.675	0.598	0.690	0.878	0.65	0.37
Avg	0.119	0.115	0.093	0.060	0.084	0.098	0.095	0.098	0.076	0.105	0.113	0.073	0.094	0.623	0.406	0.596	0.715	0.746	0.675	1.064	0.594	0.711	0.505	0.590	0.703	0.661	0.366

Fig. TP-1: Stationwise variations in average total phosphorus (%) in the sediments of Ulhas river estuary and Thane creek.

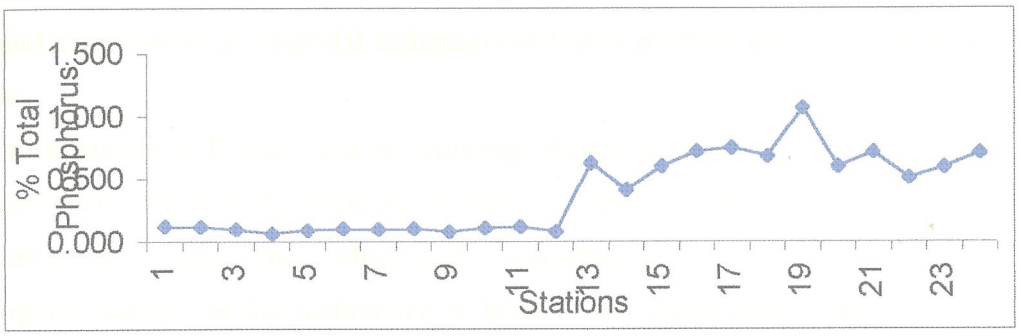


Fig. TP-2: Monthly variations in average Total Phosphorus (%) in the sediments of Ulhas river estuary and Thane creek.

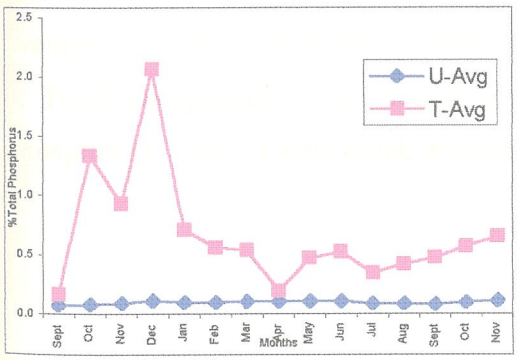


Fig. TP-3: Zonewise monthly variations in average Total Phosphorus(%) in Ulhas river estuary.

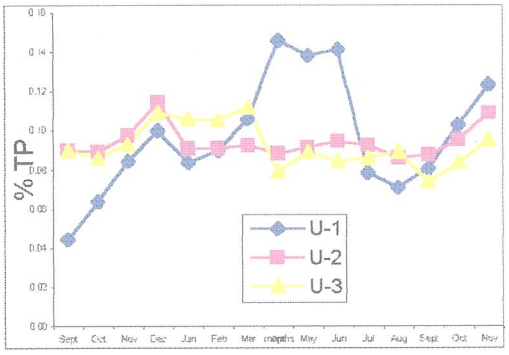


Fig. TP-4: Zonewise monthly variations in average Total Phosphorus (%) in Thane creek.

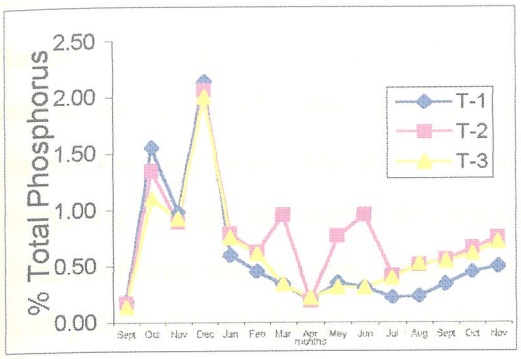
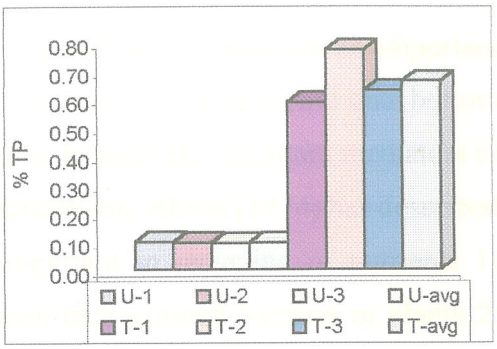


Fig. TP-5: Comparison of Zonewise annual average of Total Phosphorus (%) in Ulhas river estuary and Thane creek



Summary.

1. Sand component of intertidal sediments of Ulhas river estuary is higher than Thane creek.

2. Entire stretch of Thane creek is suffering siltation process. As the silt component in sediment has significantly increased in past 15 years. In Ulhas river estuary siltation is evident in the riverine zone 1 which is also spreading in the downstream region.

3. Organic carbon in the sediments of both Thane creek and Ulhas river estuary is significantly higher than 1.5 % (Limit of very polluted sediments) indicating organic pollution (caused by sewage) which is higher in Thane creek.

4. Total nitrogen in the sediments of both ecosystems declined seawards and the overall average was marginally higher in Ulhas river estuary.

5. Total phosphorus in the sediments is very high in Thane creek suggesting high phosphorus load in Thane creek, probably due to organic pollution by sewage load.

Chapter VI

Macrobenthos

Benthic organisms, those living in or on the sediment, constitute an important component of the food web. They convert detritus and small planktonic and bottom organisms into the food chain (Mann, 1976). Benthic infauna are important mediators of nutrient recycling from the sediments into the water column. Rhods (1974) has described 3 organisms-sediment mechanisms which are important in recycling of nutrients 1) ingestion of pellets (Coprophagy) which have been reconstituted bacteria or plants 2) vertical transport of organic detritus from below the redox potential discontinuity to the sediment water interphase and 3) resuspension of nutrient rich bottom mud into water column providing a potential food source for suspension feeders. Benthic infauna are important mediators of nutrient recycling through these and other mechanisms (Nowicki and Nixon, 1985)

The work on benthos was initiated in early 20th century Jones (1951-52 & 55-56) in UK., Sanders (1956 & 58) in US and Thorson (1950) have done pioneering work on the benthos in relation with the ecological parameters. In recent years more awareness regarding benthos has developed mainly due to their importance in pollution monitoring. According to Bilyard (1987), analysis of benthic macrofauna is a key element of many marine and estuarine monitoring programs. Benthic studies can indicate the magnitude, as well as well as spatial and temporal distribution of pollution in the environment Hartley (1982). Benthos are superior to other biological groups in indicating pollution stress because they are sedentary and must adapt to environmental stress or perish. Benthic organisms are very sensitive to habitat disturbance, including organic enrichment of the sediments and some species and communities of benthic fauna are often regarded as being the best indicators of organic pollution (Pearson and Rosenberg, 1978). In case of organic enrichment some species exhibit decreased abundance while others like *Capitella capitata* exhibit increased abundance (Ganapati and Raman, 1978). The species that show increased abundance (opportunistic species) can be used to help distinguish the effects of sediment organic enrichment from those of contamination by toxic substances. Among the benthos, macrobenthic organisms have their own importance. According to

Odum (1971), they make better pollution indicators than the small species. According to Duda *et al* (1982), monitoring of macrobenthic fauna provides the most accurate and reproducible information on the status of water quality.

The surface sediment samples (10 cm depth) for macrobenthic analysis were collected during low tide using a 10 cm x 10 cm metal scoop. Minimum 5 scoops were collected from mudflats at Low Water Level Mark (LWLM), Mid Water Level Mark (MWLM) and High Water Level Mark (HWLM), pooled together and 10 % $MgCl_2$ was added to sedate the organisms. The samples were then filtered through 0.5 mm sieve to retain the macrobenthos. The organisms were preserved using 10 % formalin prepared in filtered creek or estuarine water organisms were identified by studying under microscope. They were sorted, weighed to finally calculate density /m2 and biomass (wet wt.) in gm/m^2

In the present study the macrobenthos included 6 major animal groups (Plate 11, 12 & 13), namely Coelenterata (Seanemones) Nematoda, Plathyhelminthes, Annelida (Oligochaeta and Polychaeta), Mollusca, (Gastropoda and Bivalves) and Arthropoda (Crabs, balanus, insects and other crustaceans).

Figs Ma1 to Ma4 show percentage of major groups of organisms in Ulhas river estuary and Thane creek. Considering density Annelida was the largest group in Ulhas river estuary with (Polychaetes 51 % and Oligochaetes 23% followed by Nematoda 9%, Mollusca - Gastropoda 7 % and Bivalves 2%. However considering biomass Polychaetes (67 %) ranked first followed by gastropods 17 %, crabs 7% wheras oligochaetes, nematodes, bivalves etc. formed less biomass owing to small size.

Fig. Ma-1: Percentage of different macrobenthic groups in Ulhas river estuary based on density

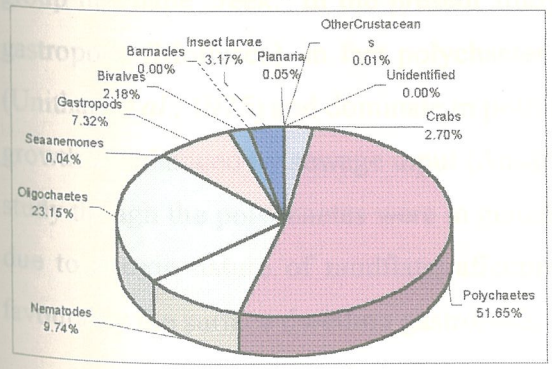


Fig. Ma-2: Percentage of different macrobenthic groups in Ulhas river estuary based on biomass

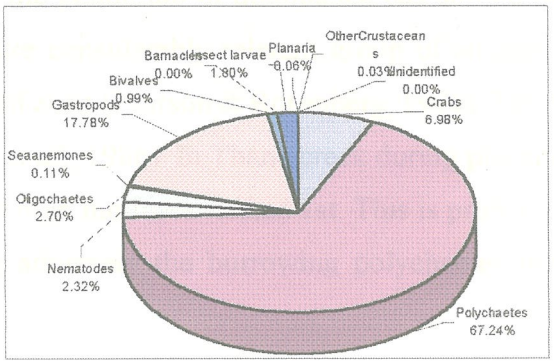


Fig. Ma-3: Percentage of different macrobenthic groups in Thane creek based on density

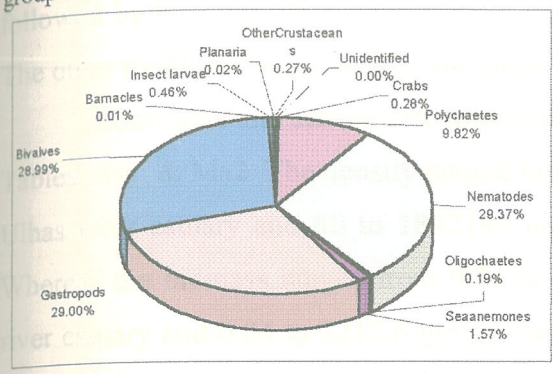
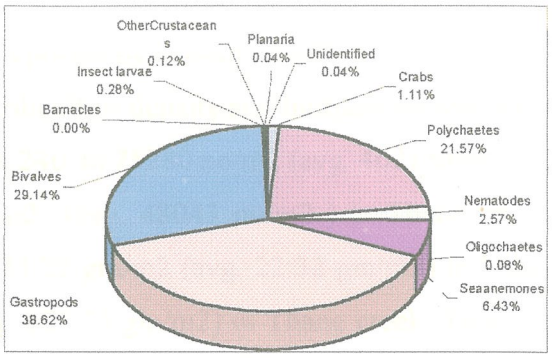


Fig. Ma-4: Percentage of different macrobenthic groups in Thane creek based on biomass



In Thane creek the dominance trend was different. Considering density the decreasing order of dominance was Nematoda (29.37 %)> Gastropoda (29 %) > Bivalves (28.99%) > Polychaetes (9.8%) > Seaanemones (1.57 %). The trend shown by biomass can be called as a correct picture as it is based on weight. Accordingly Mollusca was the most dominant group with Gastropoda (38%) and Bivalves (29 %) followed by Polychaeta (21%), Seaanemone (6%) Nematoda (2 %) and Crabs (1 %). Thus when polychaetes formed dominant macrobenthos in Ulhas river estuary, Mollusca (Gastropoda and Bivalve) formed their equivalent in Thane creek. This is probably due to organically enriched mudflat of Thane creek, which are getting anoxic.

In earlier studies on macrobenthos of Thane creek, Govindan *et al* (1976) observed bivalves as the most dominant group, Varsheney (1982) recorded foraminifera and polychaetes as the dominant taxa, Athalye (1988) reported mollusca and polychaeta as dominant. Thereafter since 1989 to 2000 Mathew (1989), Mukherje (1993), Gokhale & Athalye (1995) and Quadros (1999-2000) showed polychaetes as the most dominant group in Thane creek. In the present study the pendulum of dominance has shifted to gastropoda (Mollusca). In fact polychaetes are considerably tolerant group of animals. (Unithan *et al.*, 1975) and dominate in polluted zone (Pearson & Rosenberg, 1976). Their growth is enhanced by sewage input (Ansari *et al.*, 1986). In Thane creek during present study though the polychaetes were in general high mollusca ranked 1st. This is probably due to anoxic nature of mudflats, affecting adversely the burrowing polychaetes but favourably the surface dwelling gastropods.

In Ulhas river estuary Mishra (2002) has recorded polychaete dominance followed by bivalves, gastropods, crustaceans, etc. Thus except polychaetes ranking 1st The other trend was different than the earlier reported by Mishra (2002).

Monthwise and stationwise total macrobenthos density and biomass are shown in Tables Ma1 & Ma2. The density ranged from 240 to 75280 no/m2 (avg. 4621 no/m2) in Ulhas river estuary and 80 to 1892140 no/m2 (avg. 48043 no/m2) in Thane creek. Whereas the biomass ranged from 0.74 to 723.22 gm/m2 (avg. 22.32 gm/m2) in Ulhas river estuary and 0.04 to 2217.6 gm/m2 (avg. 173.25 gm/m2) in Thane creek. Thus the macrobenthic population was almost 10 times higher in Thane creek due to organically enriched environment caused by large mass of sewage released which is not diluted sufficiently due to less water mass as compared to Ulhas river estuary.

Mishra (2002) reported average macrobenthic density and biomass in Ulhas river estuary to be 3409 no/m2 and 79 gm/m2 respectively. Thus, there is increase in density and decrease in biomass of macrobenthos of Ulhas river estuary suggesting increase in small sized organisms. In Thane creek, Athalye (1988) reported average density 15000 no/m2 and biomass 111 gm/m2 in his study of 1984-85. In 1991-93 the average density was 5814 no/m2 and biomass 182.7 gm/m2 whereas as Quadros (2001) reported their averages to be 29583 no/m2 and 286 gm/m2 respectively. Thus in Thane creek also the macrobenthic density has increased and biomass has got reduced suggesting increase of small sized organisms.

Table Ma1: Stationwise and monthwise density (no/m2) of total macrobenthos in Ulhas river estuary and Thane creek.

	Ulhas River Total no/m2													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	3440	9660	1400	4580	6920	2720	1620	2760	500	380	460	860	2942	2360	4140	1740	10840	17740	9540	264540	9900	138780	61380	20660	1340	45247
Oct,01	3980	10360	1460	7020	7160	5080	1660	2840	500	300	560	700	3468	2280	6240	1660	11940	16620	12280	268900	10600	205300	68740	21360	1160	52257
Nov,01	4240	7920	1720	7340	6720	7720	1460	2600	1160	760	820	1240	3642	2500	10140	1620	12920	20880	16060	244880	15340	192860	48040	24380	1880	49292
Dec,01	3640	7660	1560	8020	10580	12780	960	2300	680	760	560	600	4175	3480	6440	2120	12580	22420	9740	229840	10520	124720	85020	21700	1420	44167
Jan,02	2660	15040	1640	240	3060	240	2980	2400	280	440	2240	1060	2690	2420	10220	1400	9080	20880	16020	258880	15340	202980	47840	24400	1680	50928
Feb,02	9060	19880	2660	12580	280	9340	5000	1240	1100	580	600	2180	5375	8680	7200	80	21400	1892140	83960	103280	92280	3340	63700	54260	280	194217
Mar,02	17020	11960	3300	10620	1760	5620	8440	1420	1460	780	940	1100	5368	12860	12640	140	23860	212620	88280	83700	90440	3480	46360	43480	540	51533
Apr,02	32060	45280	2120	75280	4000	2620	3500	1480	4980	760	920	1960	14580	2420	7680	120	10300	4540	8680	4280	3060	168280	17600	176400	560	33660
May,02	12780	21760	720	14320	7200	5500	5500	1400	4760	1440	1340	1980	6558	3200	3000	260	10760	4740	4500	4520	2120	111660	7000	68080	320	18347
Jun,02	4660	5080	2840	5220	3480	4840	3820	3760	5240	1040	1060	1880	3577	2380	20620	1240	75320	107120	90080	46600	83840	93520	49600	29580	440	50028
Jul,02	3380	5240	3140	2960	1780	1740	3400	2400	2940	1220	360	500	2422	2400	10060	1660	26700	37200	35460	12500	14200	16820	6280	8900	420	14383
Aug,02	2200	2140	1480	2160	3020	1260	2980	1640	280	440	780	400	1565	1300	2980	1300	10600	11820	6860	44000	10420	107380	39720	19160	1400	21412
Sep,02	3860	7340	2120	7440	8840	7300	1460	2600	880	760	900	1120	3718	2700	9340	1580	12920	21040	16160	244420	15160	192920	48040	25600	1900	49315
Oct,02	5120	22360	720	4020	4660	4840	4860	1400	4760	1440	1340	1980	4792	3200	3000	260	10760	4740	4500	4520	2120	20360	7000	28060	320	7403
Nov,02	10500	7960	3300	10060	1760	5620	8440	1420	1460	780	940	1100	4445	12860	12640	140	23860	72820	85820	79960	85240	3480	40580	43480	540	38452
Avg	7907	13309	2012	11457	4748	5148	3739	2111	2065	792	921	1244	4621	4336	8423	1021	18923	164488	32529	126321	30705	105725	42460	40633	947	48043

Table Ma 2: Stationwise and monthwise biomass (gm/m2) of total macrobenthos in Ulhas river estuary and Thane creek.

	Ulhas River gm/m2													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	7.06	21.34	20	4.28	29.46	8.38	4.84	24.62	1.406	0.74	1.06	7.26	10.87	7.1	15.24	2.92	258.54	159.36	57.36	204.84	169.88	278.48	381.76	229.84	12.16	148.12
Oct,01	8.46	25.02	18.9	7.42	29.96	31.16	9.12	29.22	5.88	1.2	0.96	6.24	14.46	8.4	19.56	2.8	226.4	182.2	79.66	158.36	191.66	295.6	369.54	212.76	14.16	146.76
Nov,01	8.4	19.58	27.84	12.2	30.14	29.8	16.4	22.66	6.68	1.4	2.26	6.8	15.35	19.52	17.82	3.76	241.54	156.08	72.9	188.92	157.68	272.38	420.98	299.6	12	155.27
Dec,01	11.76	15.24	24.72	15.2	23.6	26.16	11.56	19.82	5.4	4.18	3.04	15.6	14.69	18.3	23.12	5.16	207.72	139.78	62.78	179.1	137.8	248.3	274.44	203.14	13.26	126.08
Jan,02	1.8	59.8	38.46	1.2	14.74	1.56	11.62	4.06	0.96	4.3	4.68	5.82	12.42	19.56	17.98	4.48	241.54	159.78	73.26	188.92	157.68	272.38	420.98	299.6	12	155.68
Feb,02	9.34	32.32	5.32	43.6	14.83	17.3	12.8	3.38	2.44	1.32	1.07	6.18	12.49	16.88	18.64	0.04	852.36	634.84	977.38	1221.9	2217.6	944.2	320.1	1338.96	7.28	712.52
Mar,02	86.38	37.42	11.26	62.96	10.8	23.3	49.54	11.62	3.38	2.8	2.5	2.5	25.37	53.12	43.2	2.02	112.24	97.52	234.98	202.26	126.1	23.42	68.4	77.1	6.64	87.25
Apr,02	723.22	36.3	20.72	116.2	31.8	28	37.4	23.28	52.6	2.66	2	12.56	90.56	28.24	6.52	0.64	183.5	253.52	210.34	91.94	56.7	815.38	112.16	454.4	7.73	185.09
May,02	58.24	17.8	3.82	13.26	28	27.5	30.02	13.3	19.7	9.6	9	11.22	20.12	43.64	23.7	0.442	72.38	21.16	55.16	39.38	22.2	183.66	57.9	83.4	1.52	50.38
Jun,02	61.72	113.56	29.4	56.6	61.44	37.6	32	18.08	24.2	4.92	2.46	7.62	37.47	47.9	101.06	5.3	699.04	377.7	466.36	553.8	1726.96	467.8	370.08	255.1	3.8	422.91
Jul,02	27.3	17.52	12.7	22.96	23.3	21.24	32.32	20.56	8.4	9.3	2.82	2.42	16.74	11.58	37.82	10.08	117.94	103.7	253.36	90.4	114.86	118.2	60.66	88.5	4.34	84.29
Aug,02	13.36	4.3	6.58	11.46	42.48	4.56	14.82	2.56	0.96	20	2.16	2.06	10.44	9.3	33.52	3.62	108.8	51.62	108.242	128.49	102.42	164.62	55.02	81.84	26.89	72.87
Sep,02	8.4	19.58	27.84	12.2	29.34	27.42	12.8	22.66	6.68	1.4	2.26	6.8	14.78	20.52	18.06	3.76	217.52	141.08	72.36	163.8	130.58	264.3	344.06	264.36	12	137.70
Oct,02	43.16	17.8	3.82	13.26	28	27.5	28.22	13.3	19.7	9.6	9	11.22	18.72	43.64	23.7	0.442	72.38	21.16	55.16	39.38	22.2	143.66	57.9	83.4	1.52	47.05
Nov,02	39.92	29.48	11.26	56.56	10.8	23.3	49.54	11.62	3.38	2.8	2.5	2.5	20.31	34.4	35.2	2.02	108.44	67.3	143.02	132.1	121.96	23.42	49.9	77.1	6.64	66.79
Avg	73.90	31.14	17.51	29.96	27.25	22.32	23.53	16.05	10.78	5.08	3.18	7.12	22.32	25.47	29.01	3.17	248.02	171.12	194.82	238.91	363.75	301.05	224.26	269.94	9.46	173.25

Stationwise trend in Ulhas river estuary (Fig Ma-5) showed high abundance and biomass on the riverine end which reduces to the seaward end. Sewage polluted station 3 showed lower abundance and biomass whereas the nearby stations 2 & 4 had high abundance and biomass. This shows that excessive organic enrichment affects the macrobenthos adversely. In Thane creek (Fig Ma-6) the riverine end stations 13 to 15 being more organically polluted, showed low macrobenthic abundance and biomass. The biomass showed increasing trend up to station 20 and then declined towards seaward end. The abundance was the highest at station 17 and in general decreased to seaward end. The inverse biomass abundance trend in the middle zone of Thane creek suggest larger size organisms (Gastropods, bivalves and sea anemones).

Fig. Ma-5: Stationwise variations in average abundance and biomass in Ulhas river estuary.

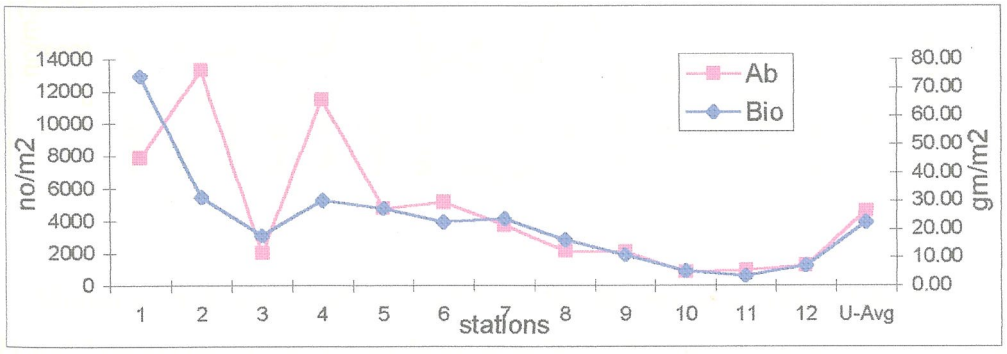


Fig. Ma-6: Stationwise variations in average abundance and biomass in Thane creek.

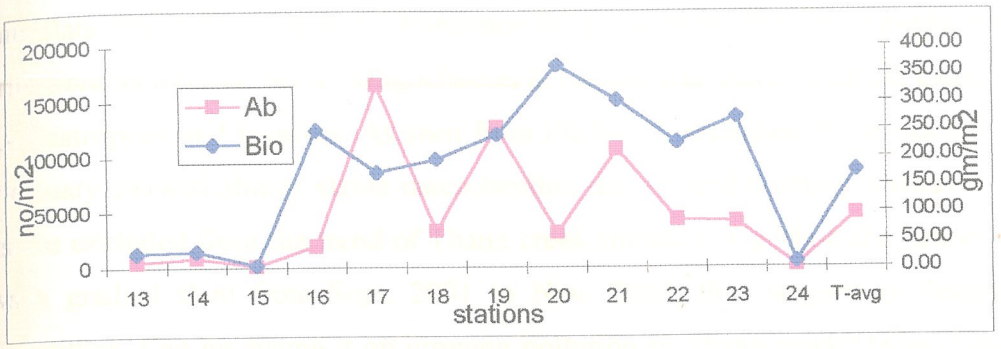


Fig. Ma-7: Monthly average variations in Abundance and Biomass in Ulhas river estuary

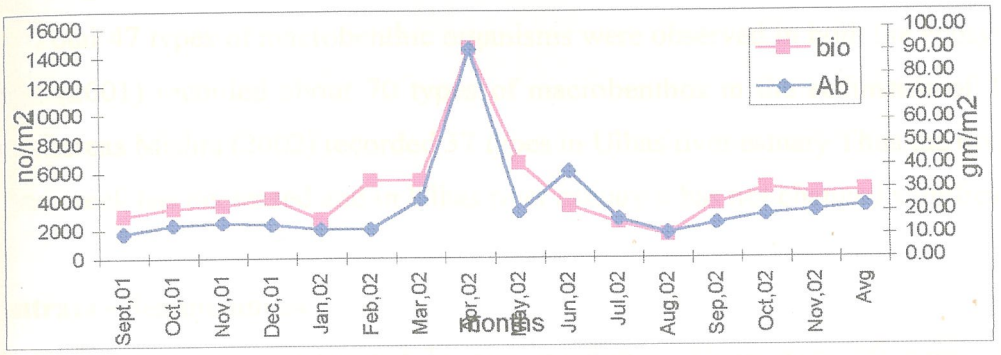
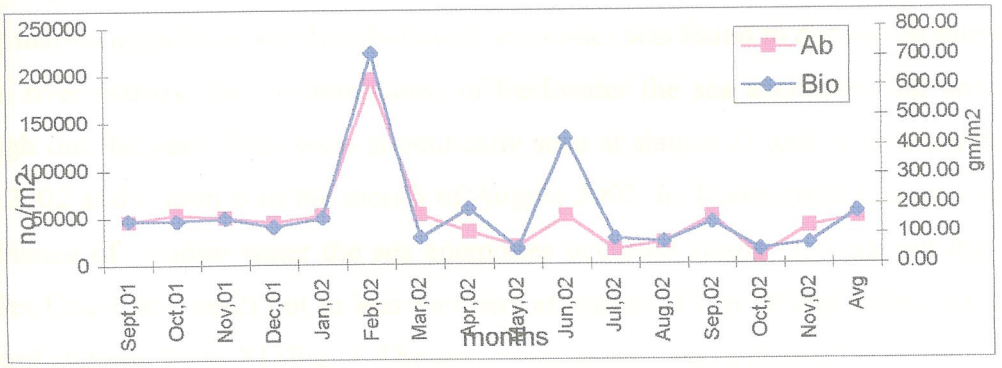


Fig. Ma-8: Monthly average variations in Abundance and Biomass in Thane creek



Monthly variations showed slightly different trends in Ulhas river estuary (Fig. Ma-7) and Thane creek (Fig. Ma-8). Peak population density and biomass were observed in April (Premonson) in Ulhas river estuary whereas in Thane creek the major peak was observed in Feb 02 and peaks of lower magnitude were recorded in April, June and

September. The peak in Feb was probably due to breeding of polychaetes forming a mat on mudflats (Plate 11) and high abundance of gastropods. The other peaks had the contributions as follows. April - Oligochaetes & Gastropods, June - Crabs & Gastropods, Sept.- Gastropods and bivalves. As seen from Fig Ma-7. excluding the peaks the Ulhas river estuary showed almost stable macrobenthic density and biomass. However, if the peaks are excluded from the trend of Thane creek shown in Fig.Ma-8 the general trend shows a gradual slant from Sept. 2001 to Nov. 2002, thus suggesting decrease in macrobenthos. Can we blame it on growing pollution in Thane creek? Does it indicate deterioration of creek ecosystem in spite of its high organic enrichment favoring population growth.

Total 47 types of macrobenthic organisms were observed in both the ecosystems Quadros (2001) recorded about 70 types of macrobenthos in the sediments of Thane creek, whereas Mishra (2002) recorded 37 types in Ulhas river estuary Thus the diversity in Thane creek has decreased and in Ulhas river estuary it has not changed significantly.

Coelentrata - Seaanemones

Coelentrata was represented by sea anemones. There were 20 types of sea anemones, however the identification being difficult, in the present study all are considered together. All the sea anemones were mud burrowing type. The coelentrata being marine organisms, the distribution of anemones was found to depend on salinity. In Ulhas river estuary, due to dominance of freshwater the sea anemones did not occur through out the year. They were sporadically seen at station 11 and 12 in the month of May 2002 and station 6 in the month of August 2002. In Thane creek however, due to dominance of marine water the sea anemones occurred almost through out the creek (Tables Coe-1 & Coe-2) but in less numbers at stations 13 to 18 and more numbers at seaward stations 19 to 24 (Fig). The maximum density was observed at station 21 and biomass at station 22. The occurrence was almost 5 to 6 times on the mudflats of east bank of Thane creek (East bank stations total 7726 no/m2; west bank stations total 1302 no/m2). The sea anemone density varied from 0 to 100 no /m2 (avg. 2 no/m2) in Ulhas river estuary and from 0 to 69400 no/m2 (avg. 752 no/m2) in Thane creek. Whereas biomass (gm wet wt./m2) varies from 0 to 1.6 gm/m2 (avg 0.21 gm/m2) in Ulhas river

estuary and 0 to 107.4 gm/m2 (avg. 11.15 gm/m2) in Thane creek. At the stations where organic pollution was very high due to proximity with the sewage reach, the sea anemone density was low. The anemone density has increased more than 10 fold in Thane creek as compared to that (71 no/m2) reported by Quadros (2001). In monthwise trend the anemones showed high density in August 02, Biomass was high especially during postmonsoon.

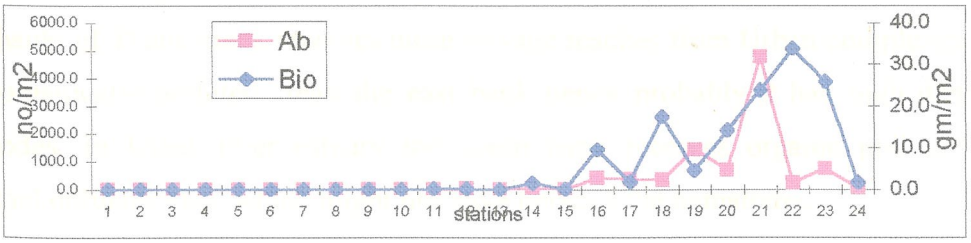
Table Coe-1: Monthwise & stationwise density (no/m2) of sea anemones in Ulhas river estuary and Thane creek

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	280	0	60	0	20	40	40	60	0	42
Oct,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	280	0	100	0	120	100	40	120	0	63
Nov,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	280	0	60	0	20	40	60	100	0	47
Dec,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	280	0	40	0	40	40	40	60	0	42
Jan,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	280	0	60	0	20	40	60	100	0	47
Feb,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	20	220	0	480	60	0	60	40	167
Mar,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	480	20	160	0	400	100	0	60	40	105
Apr,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	100	260	600	300	1200	100	227
May,02	0	0	0	0	0	0	0	0	0	0	40	100	12	0	0	0	0	0	160	160	160	560	40	480	0	130
Jun,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640	0	520	0	0	0	100	100	0	113
Jul,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	40	160	0	0	0	40	40	0	37
Aug,02	0	0	0	0	0	20	0	0	0	0	0	0	2	0	640	0	1320	5200	3020	21000	8300	69400	2480	8160	320	9987
Sep,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	280	0	60	0	20	40	60	100	0	47
Oct,02	0	0	0	0	0	0	0	0	0	0	40	100	12	0	0	0	0	0	160	160	160	560	40	480	0	130
Nov,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	480	20	160	0	400	100	0	60	40	105
Avg	0	0	0	0	0	1	0	0	0	0	5	13	2	0	43	0	392	353	340	1428	693	4779	220	745	36	752

Table Coe-2: Monthwise & stationwise biomass (gm/m2) of sea anemones in Ulhas river estuary and Thane creek

	Ulhas River		Seaanemones			gm/m2								Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	1.86	0	0.44	0	11.2	41.3	71.5	48.5	0	14.57
Oct,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	1.86	0	0.44	0	24.6	60.1	99.12	53.38	0	19.96
Nov,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	1.86	0	0.44	0	11.2	21.98	90.9	44.5	0	14.24
Dec,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	1.86	0	2.44	0	13	39.9	44.5	24.9	0	10.55
Jan,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	1.86	0	0.44	0	11.2	21.98	90.9	44.5	0	14.24
Feb,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	33.6	0.9	88.4	0	23.2	18.08	0	27.9	2.1	16.18
Mar,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	14.9	1.2	1.9	0	4.3	1.4	0	0.8	0.8	2.11
Apr,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	41.8	20.4	8	1.92	7	2.8	1.3	6.94
May,02	0	0	0	0	0	0	0	0	0	0	0.6	1.6	0.18	0	0	0	0	0	21.5	23.3	15.7	9.12	1.9	6.9	0	6.54
Jun,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	20.8	0	49	0	0	0	2.4	36.8	0	9.08
Jul,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	19.7	3.2	9.72	0	0	0	1.36	1.2	0	2.93
Aug,02	0	0	0	0	0	0.1	0	0	0	0	0	0	0.01	0	21.3	0	26.9	21	21.72	0.33	58.9	107.4	19.3	47.56	20.12	28.71
Sep,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	1.86	0	0.44	0	9.7	22.7	75.7	39.5	0	12.49
Oct,02	0	0	0	0	0	0	0	0	0	0	0.6	1.6	0.18	0	0	0	0	0	21.5	23.3	15.7	9.12	1.9	6.9	0	6.54
Nov,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	14.9	1.2	1.9	0	4.3	1.4	0	0.8	0.8	2.11
Avg	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.08	0.21	0.03	0.00	1.42	0.00	9.46	1.83	17.47	4.49	14.07	23.76	33.77	25.80	1.67	11.15

Fig. Coe-1: Stationwise variations in total abundance and biomass of Sea anemones in Ulhas river estuary and Thane creek.



Nematoda

Though there were different types of nematodes observed in the samples, they were not distinguished separately. The density and biomass (wet wt.) in Ulhas river estuary ranged between 0 to 17280 no/m^2 (avg. 450 no/m^2) and 0 to 9.60 gm/m^2 (avg. 0.52 gm/m^2) respectively. Whereas in Thane creek they were 0 to 1848000 no/m^2 (avg. 14110 no/m^2) and 0 to 432.96 gm/m^2 (avg. 4.45gm/m^2) respectively (Tables Ne-1 & Ne-2). Thus Thane creek showed almost 31 fold higher density of nematodes (9 fold high biomass) as compared to Ulhas river. This can be attributed to high level of organic pollution in Thane creek. According to Lambshed (1983), the nematode densities are very unpredictable and vary from place to place. Bouwmann (1983) has described them to be tolerant to different environmental stresses. According Moens and Vincx (1997), the nematodes can reach densities up to several million /m^2. Quadros (2001) observed average nematode density in entire Thane creek to be 404729 no/m^2. Mishra (2002) estimated the overall average nematode density in Ulhas river estuary to be 960 no/m^2 (Studied with Macrobenthos). The present study shows lowered densities in both the ecosystems.

Monthly variations in Nematode densities (Fig. Ne-2 & Ne-3) showed high densities in the months February, March and October - November. In general larger nematode were observed in May, June & October. Stationwise variations (Fig Ne-1) showed high nematode densities in the upstream zone of Ulhas river estuary (especially at station 2), probably due to high organic enrichment in this zone. But interestingly the nematode density was low at stations with close proximity of sewage reaches (Station 3, 6, 8, 10). In Thane creek (Fig. Ne-1) though the overall density was high the nematode peaks were observed at stations 17, 20, 23. Station 15 with proximity of sewage reach had lower density whereas station 17 with proximity of sewage and industrial effluent had very high density thus confirming unpredictable behaviour of nematodes. The north bank of Ulhas river and the west bank of Thane creek showed higher nematode densities. West bank of Thane creek receives more sewage reaches from Urban complexes and is more organically polluted than the east bank hence probably it had high density of nematodes. In Ulhas river estuary the south bank receives organic pollutants and industrial effluents also, which might not have boosted the nematodes.

Table Ne-1: Monthwise & stationwise density (no/m2) of nematodes in Ulhas river estuary and Thane creek

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	120	0	0	0	300	120	220	20	0	0	0	65	240	300	1080	0	5600	300	0	0	0	0	0	0	627
Oct,01	0	240	0	0	0	200	120	100	20	0	0	0	57	240	300	1080	0	3600	200	0	0	0	0	0	0	452
Nov,01	0	320	0	0	0	200	60	300	20	0	0	0	75	240	300	900	0	1360	300	0	0	0	0	0	0	258
Dec,01	0	100	0	0	0	240	120	220	20	0	0	0	58	80	300	1600	0	1600	300	0	0	0	0	0	0	323
Jan,02	0	0	1100	0	400	0	0	700	0	0	180	0	198	240	400	700	0	1360	300	0	0	0	0	0	0	250
Feb,02	3840	17280	1920	3200	0	0	460	0	440	40	0	0	2265	4500	2400	0	0	1848000	180	0	32000	0	0	33280	40	160033
Mar,02	5820	6960	1920	2960	0	0	460	0	360	40	0	0	1543	3700	3600	0	0	174700	1960	0	35540	0	0	19680	40	19935
Apr,02	0	0	0	0	1280	0	0	120	2200	80	0	0	307	100	0	40	1760	60	100	700	0	0	0	108800	40	9300
May,02	1360	0	0	0	1300	0	0	0	2200	500	0	0	447	120	0	120	1800	60	40	1500	0	0	0	28800	40	2707
Jun,02	700	360	300	0	180	0	100	140	0	0	0	0	148	640	5760	0	28160	44800	0	0	0	0	0	0	0	6613
Jul,02	0	200	1300	0	200	0	0	160	0	0	0	0	155	640	1320	100	1700	17100	0	0	0	0	0	0	0	1738
Aug,02	0	700	500	0	0	0	0	0	0	0	120	0	110	240	100	680	0	2800	300	0	0	0	0	0	160	357
Sep,02	0	320	0	0	0	160	60	300	20	0	0	0	72	240	300	900	0	1360	300	0	0	0	0	0	0	258
Oct,02	760	0	0	0	700	0	0	0	2200	500	0	0	347	120	0	120	1800	60	40	1500	0	0	0	2680	40	530
Nov,02	2700	2960	1920	2400	0	0	460	0	360	40	0	0	903	3700	3600	0	0	34700	1960	0	35540	0	0	19680	40	8268
Avg	1012	1971	597	571	271	73	131	151	524	80	20	0	450	1003	1245	488	2348	142477	419	247	6872	0	0	14195	27	14110

Table Ne-2: Monthwise & stationwise biomass (gm/m2) of nematodes in Ulhas river estuary and Thane creek

	Ulhas River				Nematodes gm/m2									Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0.06	0	0	0	0.12	0.08	0.14	0.006	0	0	0	0.03	0.04	0.16	1.16	0	3.7	0.36	0	0	0	0	0	0	0.45
Oct,01	0	0.18	0	0	0	0.12	0.08	0.14	0.02	0	0	0	0.05	0.1	0.16	0.5	0	3.7	0.18	0	0	0	0	0	0	0.39
Nov,01	0	0.1	0	0	0	0.12	0.08	0.14	0.02	0	0	0	0.04	0.04	0.16	0.72	0	3.7	0.36	0	0	0	0	0	0	0.42
Dec,01	0	0.06	0	0	0	0.12	0.08	0.14	0.02	0	0	0	0.04	0.04	0.16	0.6	0	3.7	0.36	0	0	0	0	0	0	0.41
Jan,02	0	0	0.7	0	0.7	0	0	0.36	0	0	0.02	0	0.15	0.04	0.16	0.72	0	3.7	0.36	0	0	0	0	0	0	0.42
Feb,02	1.8	9.6	1	2.4	0	0	0.24	0	0.1	0.06	0	0	1.27	1.06	0.4	0	0	432.96	6.4	0	12.8	0	0	19.2	0.1	39.41
Mar,02	9.56	7.5	1.96	1.56	0	0	0.08	0	0.1	0.02	0	0	1.73	4.44	3.9	0	0	21.6	1.9	0	21.9	0	0	22.3	0.02	6.34
Apr,02	0	0	0	0	0.6	0	0	0.1	0.8	0.06	0	0	0.13	1	0	0.06	2.4	0.1	0.12	2	0	0	0	53.76	0.02	4.96
May,02	4.3	0	0	0	5.7	0	0	0	6.3	2	0	0	1.53	0.02	0	0.02	1.3	0.04	0.02	0.18	0	0	0	1.5	0.02	0.26
Jun,02	0.4	0.3	0.4	0	0.2	0	0.06	0.06	0	0	0	0	0.12	6.5	2.4	0	44.8	23.04	0	0	0	0	0	0	0	6.40
Jul,02	0	0.4	1.5	0	0.18	0	0	0.16	0	0	0	0	0.19	1.8	1.96	0.04	1.9	2.7	0	0	0	0	0	0	0	0.70
Aug,02	0	0.8	0.36	0	0	0	0	0	0	0	0.02	0	0.10	0.4	0.02	0.2	0	1.9	0.3	0	0	0	0	0	0.1	0.24
Sep,02	0	0.1	0	0	0	0.12	0.08	0.14	0.02	0	0	0	0.04	0.04	0.16	0.72	0	3.7	0.36	0	0	0	0	0	0	0.42
Oct,02	4.3	0	0	0	5.7	0	0	0	6.3	2	0	0	1.53	0.02	0	0.02	1.3	0.04	0.02	0.18	0	0	0	1.5	0.02	0.26
Nov,02	3.1	3.3	1.96	1.56	0	0	0.08	0	0.1	0.02	0	0	0.84	1.78	3.9	0	0	21.6	1.9	0	17.76	0	0	22.3	0.02	5.77
Avg	1.56	1.49	0.53	0.37	0.87	0.04	0.06	0.09	0.92	0.28	0.00	0.00	0.52	1.15	0.90	0.32	3.45	35.08	0.84	0.16	3.50	0.00	0.00	8.04	0.02	4.45

Fig. Ne-1: Stationwise variations in the total density (no/m2) of Nematodes in Ulhas river estuary and Thane creek

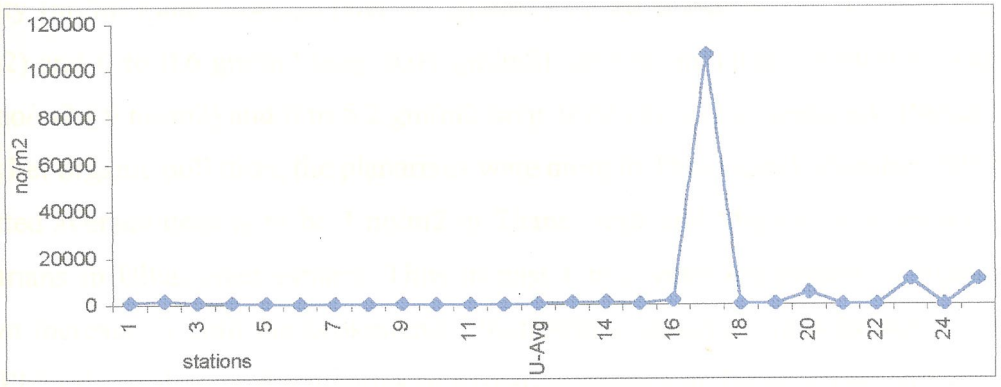


Fig. Ne-2: Monthly variations in Nematode density (no/m2) in Ulhas river estuary and Thane creek

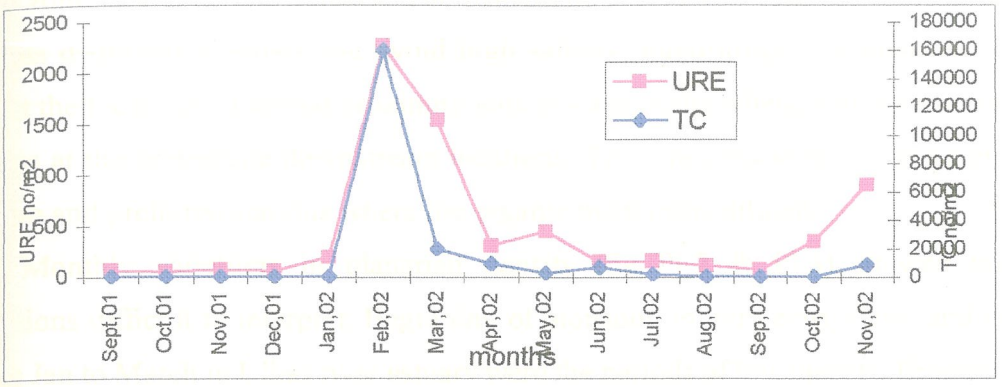
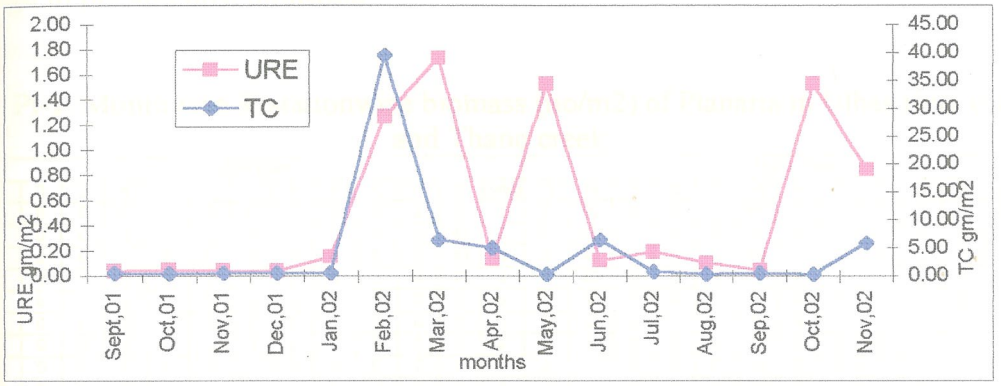


Fig. Ne-3: Monthly variations in Nematode Biomass (gm/m2) in Ulhas river estuary and Thane creek



Platyhelmenthes.

Mud dwelling planarians represented plathyhelminthes. In Ulhas river estuary density (no/m2) and biomass (wet wt. gm/m2) varied between 0 to 40 no/m2 (avg. 2 no/m2) and 0 to 0.6 gm/m2 (avg. 0.01 gm/m2) whereas in Thane creek they were 0 to 160 no/m2 (9 no/m2) and 0 to 5.2 gm/m2 (avg. 0.07 gm/m2) respectively. Probably due to higher organic pollution, the planarians were more in Thane creek. Quadros (2001) has reported average density to be 3 no/m2 in Thane creek and Mishra 2002 did not notice planarians in Ulhas river estuary. Thus in past 1 to 2 years the planarians number has shown increase in both the ecosystems. Stationwise variations in both the ecosystems (Fig Pl-1) showed more fluctuations in Planarian density in Thane creek. In Ulhas river estuary the density showed increasing trend towards the middle zone of estuary and then decrease. The highest density was observed at station 9. In Thane creek the planarian

density was higher on the upstream half which had brackish water conditions similar to middle zone of Ulhas river estuary. The planarians decreased seawards. They probably need less disturbed mudflats and avoid high salinity. Interestingly the planarians were lower at the locations in closed proximity with sewage outlet whereas they showed peak densities at the immediate downstream locations. Thus they avoided excessive organic pollution and preferred stations where the organic matter was diluted.

Monthly variations in planarian density (fig Pl-2 & Pl-3) showed uneven fluctuations difficult to interpret. Beginning of monsoon in both ecosystems and winter months Jan to March in Ulhas river estuary were the periods of low density. Biomass (Fig Pl-3) however was low during monsoon in Thane creek as well as in Ulhas river estuary and high in pre and post monsoon.

Table Pl-1: Monthwise & stationwise biomass (no/m2) of Planaria in Ulhas river estuary and Thane creek

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	40	3	0	40	0	0	0	60	0	0	0	0	0	0	8
Oct,01	0	0	0	0	0	0	0	0	0	0	0	40	3	0	40	0	0	0	60	0	0	0	0	0	0	8
Nov,01	0	0	0	0	0	0	0	0	0	0	0	40	3	0	40	0	0	0	60	0	0	0	0	0	0	8
Dec,01	0	0	0	0	0	0	0	0	0	0	0	40	3	0	40	0	0	0	60	0	0	0	0	0	0	8
Jan,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	20	0	0	0	0	0	0	5
Feb,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0	0	0	0	0	0	13
Mar,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0	0	20	0	0	0	15
Apr,02	0	0	0	0	0	0	40	0	0	0	0	0	3	0	0	0	0	0	60	0	0	0	0	0	0	5
May,02	0	0	0	20	0	0	40	0	0	0	0	0	5	0	0	0	0	0	20	0	0	0	100	0	0	10
Jun,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul,02	0	0	0	0	0	40	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	20	2
Aug,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	20	0	0	0	0	20	40	15
Sep,02	0	0	0	0	0	0	0	0	0	0	0	40	3	0	40	0	0	0	60	0	0	0	0	0	0	8
Oct,02	0	0	0	20	0	0	40	0	0	0	0	0	5	0	0	0	0	0	20	0	0	0	100	0	0	10
Nov,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0	0	20	0	0	0	15
Avg	0	0	0	3	0	3	8	0	0	0	0	13	2	0	16	0	39	0	29	0	0	3	13	1	4	9

Table Pl-2: Monthwise & stationwise biomass (gm/m2) of Planaria in Ulhas river estuary and Thane creek

	Ulhas River		Planaria	gm/m2										Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0.04	0.00	0	0.04	0	0	0	0.44	0	0	0	0	0	0	0.04
Oct,01	0	0	0	0	0	0	0	0	0	0	0	0.02	0.00	0	0.04	0	0	0	0.44	0	0	0	0	0	0	0.04
Nov,01	0	0	0	0	0	0	0	0	0	0	0	0.04	0.00	0	0.1	0	0	0	0.68	0	0	0	0	0	0	0.07
Dec,01	0	0	0	0	0	0	0	0	0	0	0	0.04	0.00	0	0.04	0	0	0	0.44	0	0	0	0	0	0	0.04
Jan,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.1	0	0	0	0.68	0	0	0	0	0	0	0.07
Feb,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	5.2	0	0	0	0	0	0	0	0	0.43
Mar,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0.4	0	0	0	0	0.6	0	0	0	0.08
Apr,02	0	0	0	0	0	0	0.1	0	0	0	0	0	0.01	0	0	0	0	0	1	0	0	0	0	0	0	0.08
May,02	0	0	0	0.4	0	0	0.6	0	0	0	0	0	0.08	0	0	0	0	0	0.04	0	0	0	0.2	0	0	0.02
Jun,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Jul,02	0	0	0	0	0	0.04	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0.04	0.00
Aug,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0.18	0	0.02	0	0	0	0	0.02	0.06	0.02
Sep,02	0	0	0	0	0	0	0	0	0	0	0	0.04	0.00	0	0.1	0	0	0	0.68	0	0	0	0	0	0	0.07
Oct,02	0	0	0	0.4	0	0	0.6	0	0	0	0	0	0.08	0	0	0	0	0	0.04	0	0	0	0.2	0	0	0.02
Nov,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0.4	0	0	0	0	0.6	0	0	0	0.08
Avg	0.00	0.00	0.00	0.05	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.03	0.00	0.41	0.00	0.30	0.00	0.00	0.08	0.03	0.00	0.01	0.07

Fig. Pl-1: Stationwise variations in average density of Planarians in Ulhas river estuary and Thane creek

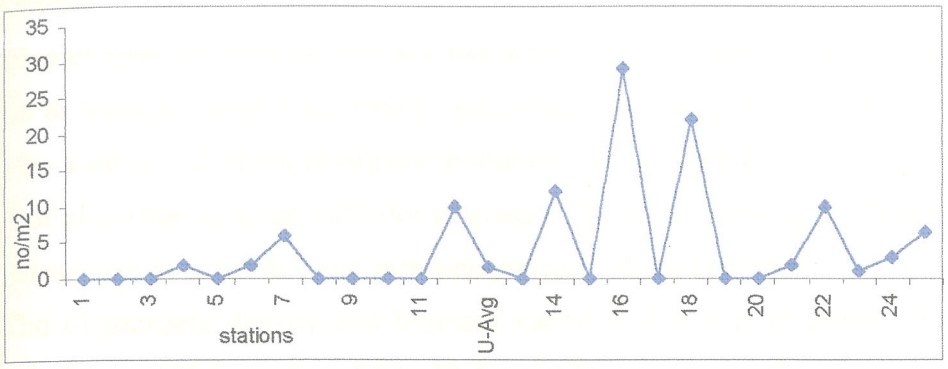


Fig. Pl-2: Monthly variations in average Planarian density (no/m2) in Ulhas river estuary and Thane creek

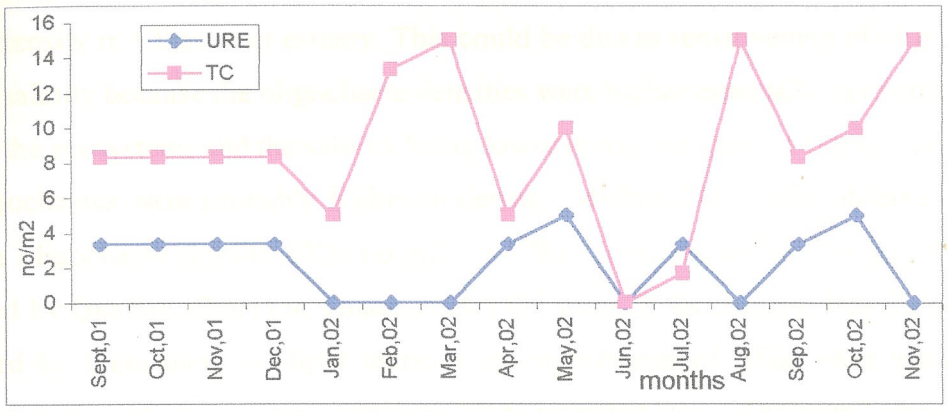
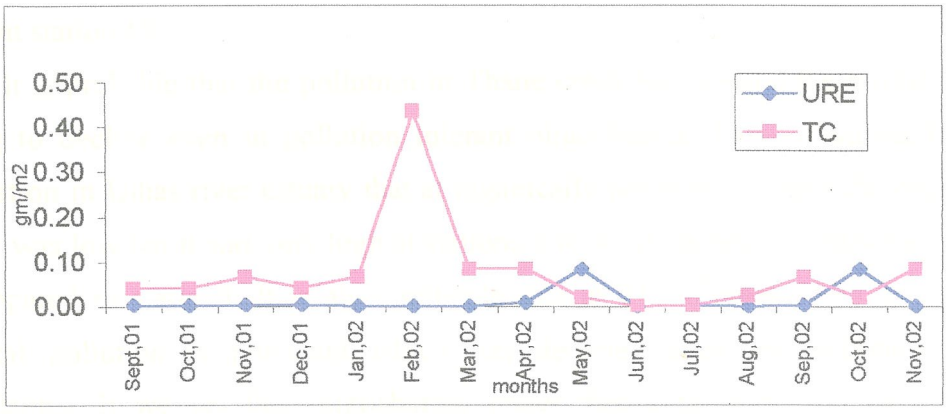


Fig Pl-3: Monthly variations in average Planarian Biomass (gm/m2) in Ulhas river estuary and Thane creek



Annelida

a. **Oligochaeta**

Oligochaetes can tolerate anoxic conditions and prefer sewage polluted locations (Subbarao & VenkateshwaraRao, 1980). According to Pearson and Rosenberg (1978), they can be used as indicators of organic pollution, whereas Srivastava (1962) consider presence of oligochaetes as an indicator of gross pollution. According to Parker (1980), oligochaetes occur at anaerobic and anthropogenically disturbed sites.

The oligochaete density and biomass varied in Ulhas river estuary from 0 to 74240 no/m2 (avg. 1070no/m2) and 0 to 38.4 gm/m2 (avg. 0.6gm/m2), whereas in Thane creek from 0 to 6720 no/m2 (avg. 93 no/m2) and 0 to 4.8 gm/m2 (avg. 0.14 gm/m2) respectively. Thus though Thane creek is more polluted organically, oligochaetes showed higher density in Ulhas river estuary. This could be due to sensitiveness of oligochaetes to high salinity because the oligochaete densities were higher especially in riverine zones of both the ecosystems and the salinity being lower in riverine zone of Ulhas river estuary the oligochaetes were probably higher in density. Mishra (2002) also observed higher average oligochaete density (726 no/m2) in Ulhas river estuary as compared to that recorded by Quadros (2001) in Thane creek (337 no/m2). As compared to the densities observed by them there is slight increase in oligochaetes of Ulhas river estuary and decrease in case of Thane creek. Athalye (1988) recorded avg. 2400 no/m2 oligochaetes at a sewage polluted station, whereas no oligochaetes at relatively unpolluted location. In present study though the oligochaete density is lower, they occur almost at all stations except at station 19.

It is probable that the pollution in Thane creek has crossed the tolerable limits leading to decline even in pollution tolerant oligochaetes. This is evident from the observation in Ulhas river estuary that at organically polluted station 3 the oligochaete density was low but it was very high at stations 2 & 4, where organic matter got diluted as compared to station3. It is also probable that in Thane creek some sort of toxic chemical pollution is prevalent which has declined even the pollution tolerant oligochaetes. If we say that oligochaetes prefer freshwater condition then monthly variations in the oligochaetes (Fig. Ol-2 & 3) showed different picture. The oligochaetes decreased during monsoon months and peak densities were observed usually in pre and

post monsoon months. Probably the turbulance in monsoon caused destabilization of the mudflats reducing the oligochaetes. Thus the oligochaetes were higher on riverine end but got washed during monsoon.

In the study though different types of oligochaetes were observed, their species level identification was not possible, hence they are considered together.

Table Ol-1: Monthwise and stationwise variations in oligochaete density (no/m2) in Ulhas river estuary and Thane creek.

	Ulhas River		Oligochaetes		no/m2									Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan,02	2500	7200	0	100	0	0	0	120	0	0	60	0	832	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb,02	0	0	0	0	0	0	0	40	0	0	0	0	3	360	0	0	0	0	0	0	0	960	0	0	0	110
Mar,02	360	0	480	0	100	0	0	40	200	40	0	0	102	300	0	0	0	0	0	0	0	760	0	0	0	88
Apr,02	0	44800	160	74240	0	0	0	0	0	0	0	80	9940	60	6720	20	320	120	0	0	0	0	0	0	20	605
May,02	1100	20700	160	13000	0	0	0	0	0	0	0	80	2920	300	1120	20	400	180	0	0	0	0	0	0	20	170
Jun,02	0	0	0	0	0	0	0	0	0	0	40	120	13	240	0	0	0	0	0	0	0	0	0	0	0	20
Jul,02	0	0	0	0	0	0	0	0	0	0	40	0	3	900	0	20	0	0	0	0	0	0	0	0	0	77
Aug,02	1760	560	200	120	0	0	0	120	0	0	60	0	235	0	0	360	280	0	60	0	20	40	40	60	0	72
Sep,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct,02	500	19300	160	2700	0	0	0	0	0	0	0	80	1895	300	1120	20	400	180	0	0	0	0	0	0	20	170
Nov,02	360	0	480	0	100	0	0	40	200	40	0	0	102	300	0	0	0	0	0	0	0	760	0	0	0	88
Avg	439	6171	109	6011	13	0	0	24	27	5	13	24	1070	184	597	29	93	32	4	0	1	168	3	4	4	93

Table Ol-2: Monthwise and stationwise variations in oligochaete biomass (gm/m2) in Ulhas river estuary and Thane creek.

	Ulhas River		Oligochaetes		gm/m2									Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Nov,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Dec,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Jan,02	1.3	0	0.7	0	0.7	0	0	0.36	0	0	0.02	0	0.26	0.04	0.16	0.72	0	3.7	0.36	0	0	0	0	0	0	0.42
Feb,02	0	0	0	0	0	0	0	0.02	0	0	0	0	0.00	0.16	0	0	0	0	0	0	0	0.7	0	0	0	0.07
Mar,02	0.7	0	0.6	0	0.18	0	0	0.02	0.1	0.02	0	0	0.14	0.1	0	0	0	0	0	0	0	1.1	0	0	0	0.10
Apr,02	0	25.6	0.1	38.4	0	0	0	0	0	0	0	0.34	5.37	0.14	4.8	0.42	0.8	0.6	0	0	0	0	0	0	0.01	0.56
May,02	1	7.5	0.1	7.1	0	0	0	0	0	0	0	0.02	1.31	0.02	0.5	0.002	0.08	0.02	0	0	0	0	0	0	0.02	0.05
Jun,02	0	0	0	0	0	0	0	0	0	0	0.14	0.56	0.06	1.6	0	0	0	0	0	0	0	0	0	0	0	0.13
Jul,02	0	0	0	0	0	0	0	0	0	0	0.12	0	0.01	1.92	0	0.04	0	0	0	0	0	0	0	0	0	0.16
Aug,02	4	0.3	0.32	0.2	0	0	0	0.18	0	0	0.3	0	0.44	0	0	2.5	1.9	0	0.12	0	0.02	0.1	0.16	0.14	0	0.41
Sep,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Oct,02	1	7.5	0.1	7.1	0	0	0	0	0	0	0	0.02	1.31	0.02	0.5	0.002	0.08	0.02	0	0	0	0	0	0	0.02	0.05
Nov,02	0.7	0	0.6	0	0.18	0	0	0.02	0.1	0.02	0	0	0.14	0.1	0	0	0	0	0	0	0	1.1	0	0	0	0.10
Avg	0.58	2.73	0.17	3.52	0.07	0.00	0.00	0.04	0.01	0.00	0.04	0.06	0.60	0.27	0.40	0.25	0.19	0.29	0.03	0.00	0.00	0.20	0.01	0.01	0.00	0.14

Fig. Ol-1: Stationwise variations in the average density (no/m2) of oligochaetes.

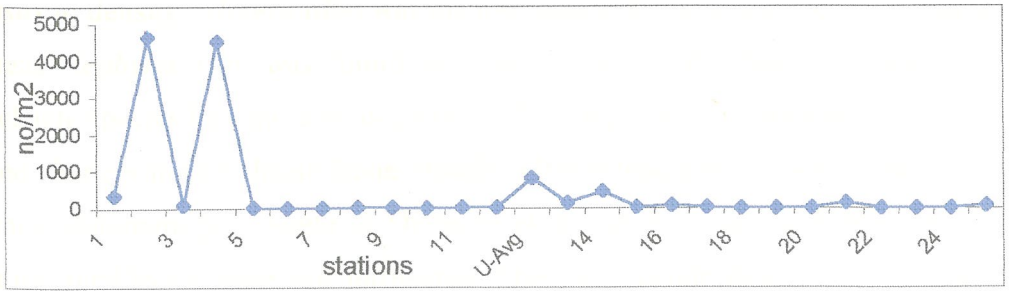


Fig. Ol-2: Monthly variations in average oligochaete density (no/m2) in Ulhas river estuary and Thane creek

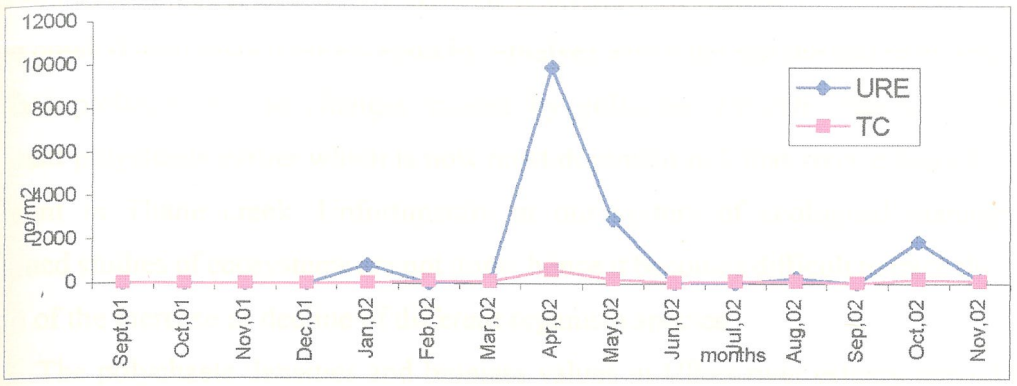
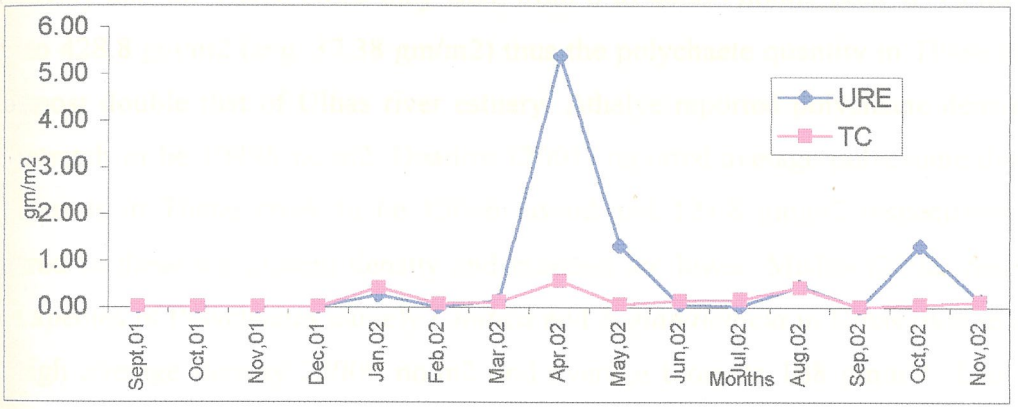


Fig. Ol-3: Monthly variations in average oligochaete biomass (gm/m2) in Ulhas river estuary and Thane creek



b) **Polychaetes.**

Polychaetes formed major group in both Ulhas river estuary and Thane creek. Total 11 species of Polychaetes were observed (Table Poly-1) the dominant species were different in Ulhas river estuary and Thane creek. *Lycastis indica* was the most dominant polychaete in Ulhas river estuary which ranked 2nd in Thane creek where *Ceratonereis burmensis* was predominant through out the creek. *Nereis glandicincta* was next to *Lycastis* in density. *Glycera alba* was mainly recorded in lower stretches of Thane creek whereas *Nephytes spp.* was found in lower stretches of Ulhas river estuary. Other polychaete species had sporadic occurrence. It is important to note that the pollution has caused changes in polychaete fauna. Athalye (1988) reported *Lycastis ounaryensis* to be the most dominant polychaete in Thane creek during his study of 1984 - 85. This has been replaced by *Ceratonereis burmensis*. The main reason for this apart from pollution

could be the changed sediment texture which has changed from silty clay to clayey silt. In 1984 -85 studies the polychaete *Polydora tentaculata* occurred in upper stretches of Thane creek (Unpublished observation by Athalye) which has got pushed to downstream stretches probably due to changes caused by pollution. *Lycastis indica* was not a dominant polychaete earlier which is now most dominant in Ulhas river estuary and 2nd dominant in Thane creek. Unfortunately in our system of ecological management continued studies of ecosystems are not done, hence it becomes difficult to trace the exact reason of the increase or decline of different organism species.

The polychaete densities and biomass values in Ulhas river estuary ranged from 40 to 32000 no/m2 (avg. 2387 no/m2) and 0.16 to 723.2 gm/m2 (Avg. 15.01gm/m2) respectively and for Thane creek they were from 0 to 44000 no/m2 (avg. 4719 no/m2) and 0 to 428.8 gm/m2 (avg. 37.38 gm/m2) thus the polychaete quantity in Thane creek was almost double that of Ulhas river estuary. Athalye reported polychaete density in upper stretch to be 10495 no/m2. Quadros (2001) reported average polychaete density and biomass in Thane creek to be 15066 no/m2 and 121.8 gm/m2 respectively. As compared to these the present density and biomass are lower. Mishra (2002) reported only 2 species of Polychaetes namely *L.indica* and *N.glandicincta* in Ulhas river estuary with high average density 23000 no/m2 and average biomass 188 gm/m2. Thus the polychaete density and biomass in Ulhas river estuary have lowered than that in 2000-2001.

Stationwise variation in Polychaete biomass and number has been shown in Fig. Poly-1 In Ulhas river estuary a decreasing trend from the riverine side to seaward side was observed. Significant drop in polychaete fauna at station 3 could be due to excessive pollution caused by proximity with sewage reach (a major outlet from Dombivili Urban area) This organic pollution however boosted fauna at station 2 and 4. In Thane creek the middle zone had high polychaete population. The riverine zone being highly polluted had lower density and biomass. The population density was low especially at station 15 which was in close proximity with effluent outlets from Thane. The polychaete fauna declined towards seaward end probably due to higher salinity, harsher condition and dilution of organic nutrients in the downstream stretches. In Ulhas river estuary the north bank had

marginally higher polychaete population whereas in Thane creek the east bank showed higher polychaete density and biomass.

Monthly variations in Polychaetes are shown in Fig. Poly-2 and 3 the trends are different in Thane creek and Ulhas river estuary. High density and biomass of polychaetes in premonsoon, their decline in rainy season and again gradual increase in post monsoon was seen in Ulhas river estuary. This is probably because the dominant polychaete *L.indica* preferred brackish water conditions in Ulhas river estuary but strong floods in rainy season destabilized the mudflats reducing their population. In Thane creek the number was high in Feburary - March but the biomass was lower suggesting young polychaetes. During this period layers of polychaetes were found on the mudflats (Plate 11), which were probably the breeding stages, the heteronereid. The population reached a peak in June, declined in rainy season and again increased in post monsoon. September to Jan. was growth phase of polychaetes when biomass was higher than the number. In Ulhas river estuary the maximum polychaete growth occurred in March, April May (premonsoon) and breeding probably occurred in post monsoon. Stationwise observation of different species of polychaetes is shown Table. Poly-1.

Glycera alba had very sporadic occurrence at stations 21 to 23 in Thane creek probably due to its preference to higher salinity. Quadros (2001) reported this polychaete in low salinity at seaward station of Thane creek.

Fig. Poly-1: Comparison of stationwise variations in the average abundance (no/m2) and average biomass (gm/m2) of Polychaetes in Ulhas river estuary and Thane creek

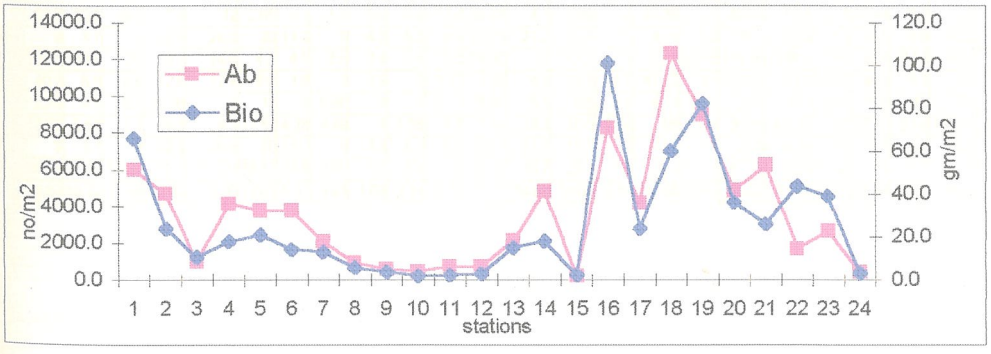


Fig. Poly-1: Stationwise variations in the density (no/m^2) of polychaete species in Ulhas river estuary and Thane creek during the 15 month study period.

	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg
Glycera alba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0
Dendronereis heteropoda	74	45	7	93	250	80	149	0	0	0	1	0	58	33	117	0	246	74	72	80	13	16	48	27	0	61
Nereis glandicincta	919	146	82	561	1052	110	52	13	12	0	1	3	246	564	714	7	751	531	908	222	149	366	112	265	0	382
Ceratonereis	1460	45	0	219	29	23	23	0	0	0	0	0	150	222	2324	188	3950	2151	7979	4626	4118	2492	1108	1507	340	2584
Sigambra bassi	0	0	5	0	0	0	0	5	24	24	57	72	16	0	27	4	85	294	1165	146	106	55	122	654	7	222
Lycastis indica	3519	4393	878	3401	2240	3221	1091	295	97	57	100	68	1613	1152	1369	11	1718	571	882	645	277	55	68	53	53	571
Lycastis ounaryensis	0	32	0	0	0	0	33	0	3	0	0	0	6	0	85	0	192	11	0	0	0	21	0	0	0	26
Nephthys spp	0	5	0	33	0	0	541	480	394	319	481	573	236	0	0	0	0	0	0	0	0	0	0	0	0	0
Boccardia tricuspa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	314	80	137	41	1940	35	215	0	231
Polydora tentaculata	0	0	0	0	0	0	0	0	5	4	0	3	1	0	117	0	1044	186	705	2806	96	17	13	86	0	423
Tube Polychaete	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	492	0	0	48	144	0	0	60
Total	5973	4667	972	4308	3571	3434	1889	794	535	404	641	718	2326	1971	4785	209	8000	4131	12283	8662	4800	5011	1652	2809	400	4559

Table Poly-2: Monthwise and stationwise variations in Polychaete density (no/m^2) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek												
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	3400	9460	940	4560	5280	2360	1440	520	420	360	360	260	2447	1300	2500	540	6000	4860	1380	4400	1420	940	2400	2800	480	2418
Oct,01	3900	10040	1100	6900	5500	1300	1280	600	420	200	360	160	2647	1440	4500	500	5300	5500	3380	3900	3280	1200	3200	2700	600	2958
Nov,01	4200	7480	1480	7120	5500	2500	1280	720	880	720	720	480	2757	880	8500	400	7300	6840	700	3960	1280	640	2400	2480	880	3022
Dec,01	3500	7480	1100	6000	8520	8480	540	1240	240	560	320	320	3192	1600	4400	240	7280	6840	1600	6480	2400	1280	1600	4800	560	3257
Jan,02	160	7460	400	40	2500	160	2700	1340	280	340	1900	900	1515	800	8500	400	3300	6840	700	3960	1280	560	2200	2480	680	2642
Feb,02	5120	2600	740	9280	120	9240	3300	1040	600	460	540	1860	2908	2900	4800	60	8000	120	33280	11540	4480	1060	200	0	100	5545
Mar,02	10520	4900	900	7300	1280	5280	5300	1280	840	480	600	900	3298	6900	8800	100	9600	480	39560	13700	7700	1660	700	0	300	7458
Apr,02	32000	460	1920	580	2720	2320	760	720	460	360	900	1140	3695	1700	80	0	5280	700	7120	2500	1460	20300	720	8660	240	4063
May,02	9000	900	520	600	5900	5300	2000	900	800	400	1200	1100	2385	2040	960	0	6500	960	3560	2100	1100	14900	400	4800	160	3123
Jun,02	2380	2640	980	2900	2800	4500	820	740	700	240	220	620	1628	1160	6560	60	25600	10880	35200	44000	29120	26880	3360	20	60	15242
Jul,02	1300	1560	600	1600	800	1500	700	200	240	360	220	400	790	240	3300	240	9160	6300	17000	11520	7700	9160	1960	360	200	5595
Aug,02	380	540	600	180	2540	1100	2700	1340	280	340	500	240	895	900	1900	140	6900	3720	1500	7300	1500	1340	2200	2200	700	2525
Sep,02	3800	6900	1920	7120	7700	2200	1280	720	600	720	800	360	2843	1080	7700	360	7300	7000	800	3500	1100	700	2400	3700	900	3045
Oct,02	3040	2900	520	600	3960	4640	1360	900	800	400	1200	1100	1785	2040	960	0	6500	960	3560	2100	1100	10900	400	4800	160	2790
Nov,02	7120	4900	900	7300	1280	5280	5300	1280	840	480	600	900	3015	6900	8800	100	9600	480	35300	13700	7700	1660	700	0	300	7103
Avg	5988	4681	975	4139	3760	3744	2051	903	560	428	696	716	2387	2125	4817	209	8241	4165	12309	8977	4841	6212	1656	2653	421	4719

Table Poly-3: Monthwise and stationwise variations in Polychaete biomass (gm/m2) in Ulhas river estuary and Thane creek.

	Ulhas River			Polychaetes gm/m2										Thane Creek												
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	5.52	18.48	5.94	4.08	19.8	6.26	4.04	1.26	0.84	0.6	0.7	0.16	5.64	3.3	6.3	1.68	150.8	22.3	29.1	117.84	3.38	17.74	98.9	65.56	3.1	43.33
Oct,01	7.12	19.78	6.9	5.9	19.8	8.04	8.04	1.98	5.12	0.7	0.66	0.24	7.02	4.5	9.1	2.22	134.8	50.7	47.28	71.36	13.5	22.5	88.9	51.36	3.1	41.61
Nov,01	6.5	12.96	8.58	11.1	20.1	8.88	15.12	4.28	4.48	1	1.56	1.7	8.02	12.3	10.26	2.88	114.8	37.5	40.1	112.44	11.3	19.98	109.9	114.56	4.02	49.17
Dec,01	9.32	9.98	12.56	8.04	13.76	12.28	9.34	6.12	4.08	2.48	2.04	4.9	7.91	11.22	8.5	4.48	114.8	44.5	30.9	92.9	5.76	17.76	91.9	55.7	4.22	40.22
Jan,02	0.5	57.98	30.66	0.5	12.5	0.5	9.8	2.92	0.96	1	3.8	0.82	10.16	12.3	10.26	2.88	114.8	37.5	40.1	112.44	11.3	19.98	109.9	114.56	4.02	49.17
Feb,02	7.36	22.72	4.32	40.08	7.8	12.1	6.8	2.96	2.14	0.9	1.04	1.16	9.12	12.46	18.24	0.02	62.3	0.84	288	44.82	11.2	19.36	0.3	0	1	38.21
Mar,02	72.7	28.7	8.7	59.72	6.7	21	29.16	10.8	2.96	1.5	1.9	2	20.49	35.76	37.3	1.9	40.7	2	17.72	55.9	41	3.9	5.7	0	2.3	20.35
Apr,02	723.2	10.3	20.5	16.4	31.2	12	2.66	4.1	1.3	0.6	0.5	11.4	69.51	4.1	0.06	0	47.36	5.1	45.88	11.4	16.8	30.44	3.7	17.32	2.3	15.37
May,02	31	9	3.7	3	22.3	26.5	20	11.2	9	4.3	6.5	6.3	12.73	21.7	15.7	0	41.9	7.3	26.5	9.16	1.5	53.5	6.9	20.8	1.3	17.19
Jun,02	46.5	104.5	20.6	29	59.7	24.6	4.2	4.8	3.8	0.4	0.4	0.3	24.90	37	63.2	1	428.8	37.76	114.56	334.4	288	38.4	9.24	0.32	1.3	112.83
Jul,02	9.7	10.3	6.5	12.9	12.6	17.9	6.9	1.8	2	3.9	2	1.72	7.35	4.5	28.5	8.7	47.72	41	112.64	61.6	55.72	49.5	5.3	3.3	1.9	35.03
Aug,02	9.2	2.76	4.8	5.2	39.06	3	13	2	0.96	1	1	0.16	6.85	6.5	8.5	0.9	40.1	28.7	24.5	52.8	28.7	19.6	15	13.6	6.5	20.45
Sep,02	6.5	12.96	8.58	11.1	19.3	6.5	11.52	4.28	4.48	1	1.56	1.7	7.46	13.3	10.5	2.88	95	32.5	39.56	87.32	9.7	17.52	91.9	105.56	4.02	42.48
Oct,02	17.92	9	3.7	3	22.3	26.5	20	11.2	9	4.3	6.5	6.3	11.64	21.7	15.7	0	41.9	7.3	26.5	9.16	1.5	53.5	6.9	20.8	1.3	17.19
Nov,02	32.7	24.96	8.7	53.32	6.7	21	29.16	10.8	2.96	1.5	1.9	2	16.31	19.7	29.3	1.9	36.9	2	17.72	55.9	41	3.9	5.7	0	2.3	18.03
Avg	65.72	23.63	10.32	17.56	20.91	13.80	12.65	5.37	3.61	1.68	2.14	2.72	15.01	14.69	18.09	2.10	100.85	23.80	60.07	81.96	36.02	25.84	43.34	38.90	2.85	37.38

Fig Poly-2: Monthly variations in average Polychaete density (no/m2) of Ulhas river estuary and Thane creek

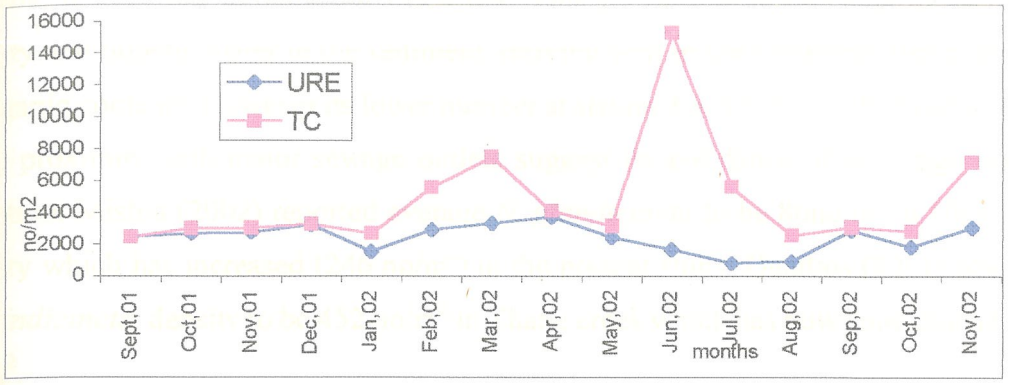
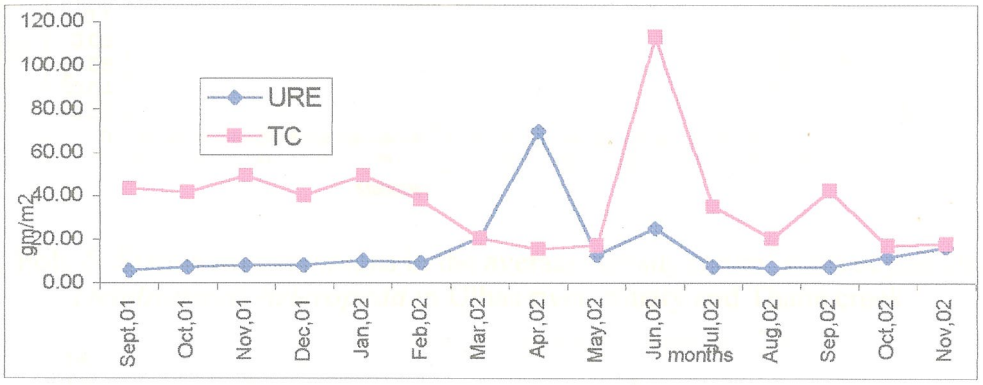


Fig Poly-3: Monthly variations in average Polychaete biomass (gm/m2) of Ulhas river estuary and Thane creek



Dendronereis heteropoda occurred in both the ecosystems with average densities almost similar (58 and 61 no/m^2). Its dominance was in the upper 2/3rd stretch of both the ecosystems. They showed very low or nil densities at stations with high sewage pollution such as 3 & 15 and the highest peaks were observed a few stations downstream or upstream. In Ulhas river estuary the seaward stations had nil density of *Dendronerids*, in Thane creek It had low occurrence towards the seaward end thus showing adverse effect of salinity. Mishra (2002) has not reported the polychaete in Ulhas river estuary. Quadros (2001) noted distribution and density of *Dendronereis heteropoda* similar to the present observation.

Nereis glandicincta This polychaete occurred in both the ecosystems under study but more predominantly in Thane creek (Table Poly-1) In Ulhas river estuary it mainly

occurred in the upper half of the estuary. In Thane creek though it declined at seaward stations, it occurred through out the creek. This polychaete is probably governed by salinity and organic mater in the sediment, thriving well in the sediments which are rich in organic contents. However its lower number at station 3 & 15 (Fig. Poly-6) which have close proximity with major sewage outlets suggest its avoidance of very high organic pollution. Mishra (2002) reported average *N. glandicincta* to be 80no/m^2 in Ulhas river estuary which has increased (246 no/m^2) in the present study. Quadros (2001) observed *N.glandicincta* density to be 452 no/m^2 in Thane creek which has now gone down to 382 no/m^2.

Fig. Poly-4: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Glycera alba* in Ulhas river estuary and Thane creek.

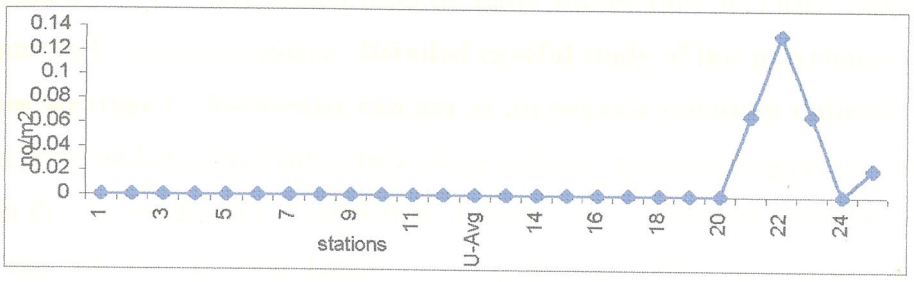


Fig. Poly-5: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Dendronereis heteropoda* in Ulhas river estuary and Thane creek.

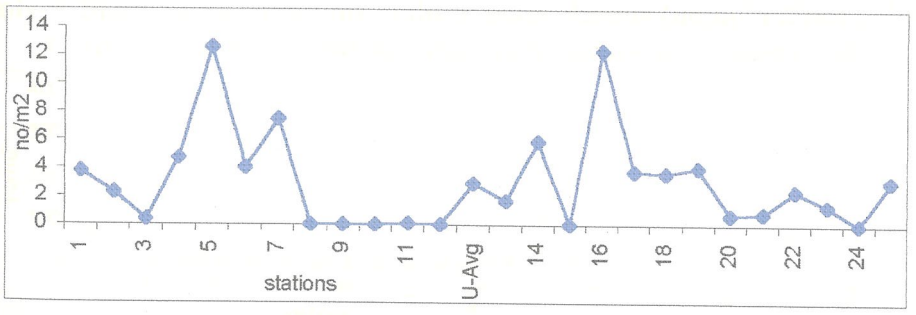
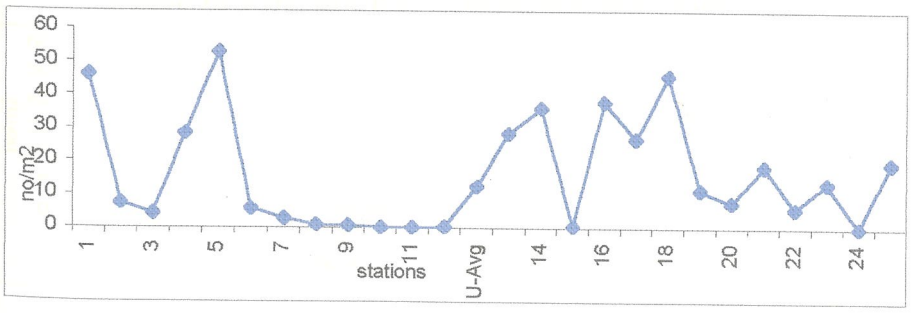


Fig. Poly-6: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Nereis glandicincta* in Ulhas river estuary and Thane creek.



Ceratonereis burmensis -

This polychaete occurred in low number in the upper half of the Ulhas river estuary but was predominant in Thane creek especially in the upper half probably indicating its preference to organically enriched sediments and brackish water conditions. At station 3 & 15 with very high organic load the polychaete showed low density. Its decline in downstream is a curious phenomena it could be due to increasing salinity or more disturbance caused by strong currents or due to chemical effluents received by these zones (in Ulhas river estuary St. 6 & in Thane creek Stn. 18 onwards received more effluents from industrial areas). Athalye (1988) and Mukherjee (1993) in their studies in the upstream stretch of Thane creek and Ulhas river estuary respectively, did not report this polychaete. It got established recently more successfully in Thane creek and has gained entry in Ulhas river estuary. **Detailed careful study of this polychaete is needed to confirm weather *C. burmensis* can act as an organic pollution indicator species,** because it got established in Thane creek along with the increasing organic pollution, thus displacing the earlier dominant polychaete *L.ounaryensis*. Quadros (2001) however has recorded much higher average density of the polychaete (7505 no/m2) in Thane creek with similar distribution pattern.

Fig. Poly-7: Stationwise variations in the average density (no/m^2 x 20)of polychaete *Ceratonereis burmensis* in Ulhas river estuary and Thane creek.

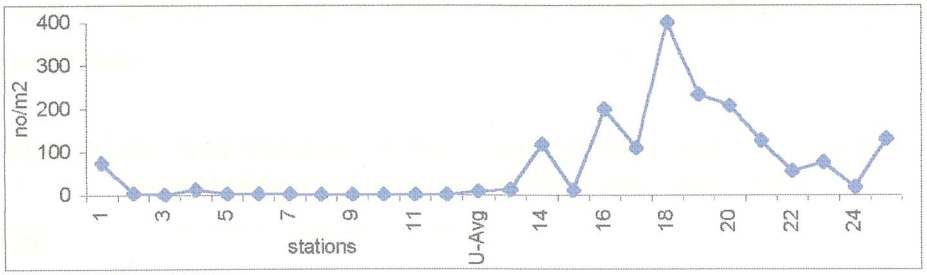
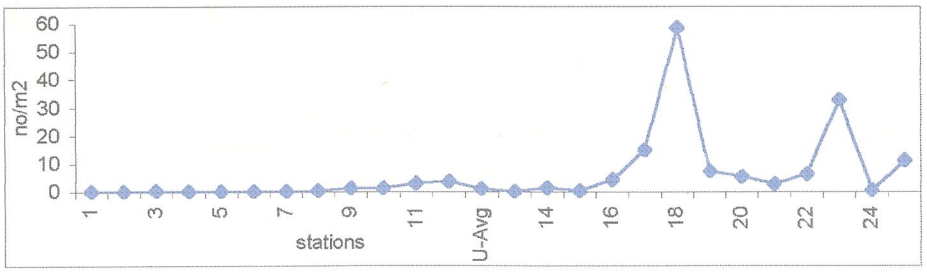


Fig. Poly-8: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Sigambra bassi* in Ulhas river estuary and Thane creek.



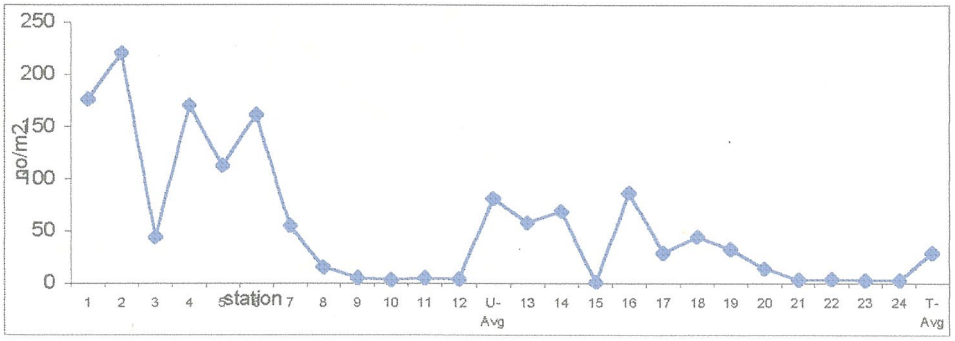
Sigambra bassi.

This polychaete occurred in low number in the lower stretch of Ulhas river estuary and more significantly in the middle and lower stretches of Thane creek. The polychaete probably prefers higher salinity. Quadros (2001) had recorded its average density 596 no/m2 in Thane creek as compared to which the present average density 222 no/m2 is lower. Mishra (2002) did not report this polychaete in Ulhas river estuary. Presently it is observed in low density (16no/m2) in the lower stretches of Ulhas river estuary.

Lycastis indica.

L.indica occurred more predominantly in Ulhas river estuary (Fig.Poly-9). The polychaete occurred significantly in the upstream stretches suggesting its preference to brackish water conditions. It can tolerate organic pollution, but not very high one. Hence occurred at low density at station 3 and 15. Athalye (1988) recorded *L.indica* average to be 2450 no/m2, whereas Quadros (2001) observed it to be 705 no/m2 in Thane creek. The present density is lower (571 no/m2) indicating decline of the polychaete. In Ulhas river estuary Mishra (2002) reported *L.indica* average density 133 no/m2 which has significantly increased to 1613 no/m2. **Thus *L.indica* which commonly is reported from organically polluted location is finding favorable environment in Ulhas river estuary and is getting eliminated from Thane creek probably due to excessive organic pollution.**

Fig. Poly-9: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Lycastis indica* in Ulhas river estuary and Thane creek.



***Lycastis ounaryensis*.**

This polychaete was once dominant in upper stretches of Thane creek. Athalye (1988) reported average density 26605 no/m^2, whereas in upstream stretch of Thane creek Quadros (2001) reported the density to be 4383 no/m2. The present density is too low suggesting its elimination from Thane creek.

This can be the effect of changed sediment texture. Earlier the sediment was silty clay i.e. had more clay and hence was harder. Now the sediment is clayey silt i.e. silt is more. This has made the sediment more soft and sinking. The change in sediment texture probably caused change in the polychaete fauna of Thane creek. In Ulhas river estuary Mishra (2002) did not report this polychaete which has now entered (density 6 no/m2) the estuary probably due to hostile conditions in Thane creek.

Fig. Poly-10: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Lycastis ounaryensis* in Ulhas river estuary and Thane creek.

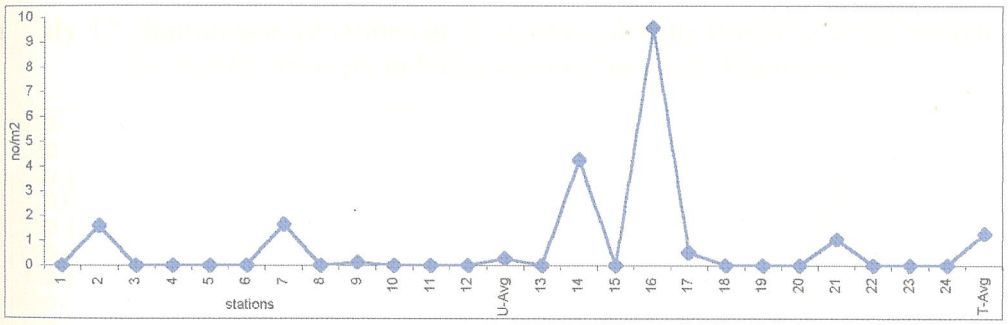
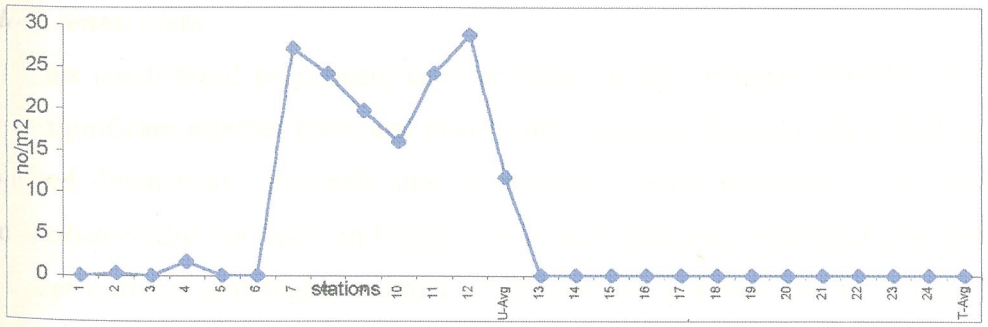


Fig. Poly-11: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Nephthys spp.* in Ulhas river estuary and Thane creek.



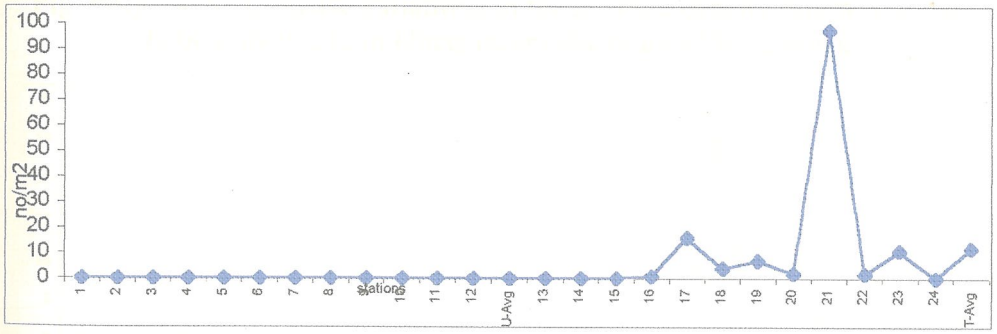
Nephyths spp.

This occurred in the lower stretches of Ulhas river estuary and was absent in Thane creek. The polychaete probably is not able to tolerate organic pollution and hence is absent from the upstream of Ulhas river estuary and entire Thane creek. Mishra (2002) and Quadros (2001) have not reported this polychaete in Ulhas river estuary and Thane creek respectively, which is seen in good number in Ulhas river estuary.

Boccardia tricuspa

This did not occur in Ulhas river estuary whereas in Thane creek it had moderate density and occurred throughout the stretch (maximum at Station 20) except in the three upstream stations. The polychaete probably favors high salinity and moderate organic pollution. As compared to the average density 46 no/m^2 reported by Quadros (2001) the present density 231 no/m^2 is significantly high.

Fig. Poly-12: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Boccardia tricuspa* in Ulhas river estuary and Thane creek.

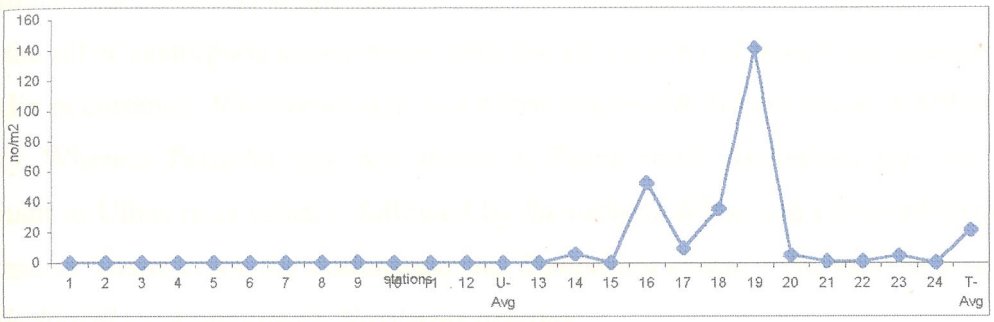


Polydora tentaculata

This small sized polychaete used to occur in the upstream stretches of Thane creek in significant number (personal observation Athalye) but now the polychaete has got pushed downstream, probably due to growing organic pollution in the upstream region. *Polydora* did not occur in Ulhas river estuary probably because it requires more calm water currents and higher salinity. *Polydora* was not reported from Ulhas river estuary by Mishra (2001) which has now sporadic occurrence in the downstream. In

Thane creek Quadros (2001) observed *Polydora spp.* in the lower stretches, but it had higher density 1246 no/m2 as compared to the present 423 no/m^2.

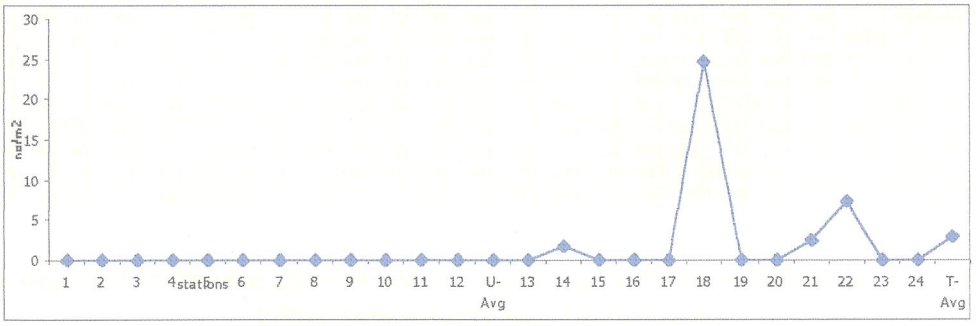
Fig. Poly-13: Stationwise variations in the average density (no/m^2 x 20) of polychaete *Polydora tentaculata* in Ulhas river estuary and Thane creek.



Tube polychaete (unidentified).

This showed sporadic occurrence in lower stretches of Thane creek. The density was low 60 no/m2 which corroborated with that (39 no/m2) reported by Quadros (2001).

Fig. Poly-14: Stationwise variations in the average density (no/m^2 x 20) of Tube polychaete in Ulhas river estuary and Thane creek.



Thus the types of polychaetes and their distribution in Thane creek and Ulhas river estuary are changing due to the changes in organic pollution, chemical pollution & sediment texture. Polychaetes like *L. ounaryensis, L.indica, Polydora tentaculata* etc are getting eliminated from Thane creek and replaced by *Ceratonereis burmensis*, whereas *L. indica* has increased in Ulhas river estuary and species like *Ceratonereis, Dendronereis, L. ounaryensis, Nephythys, Sigambra bassi* are getting introduced.

Mollusca

a) Gastropoda

The gastropodes included all together 13 types (Table) of which *Cerethideopsilla djadjaviensis* occurred both in Ulhas river estuary and Thane creek at all the stations. *Assaminea spp., Stenothyra spp.* (2 species), *Haminea crocata* and *Salinator burmana* were the other gastropods occurring in both the ecosystems of which the later two had sporadic occurrence. *Narsarrius spp.* and *Mitra amphorell* did not occur in Ulhas river estuary. Whereas *Turitella spp.* was absent in Thane creek. *Assaminea spp.* was most dominant in Ulhas river estuary followed by *Stenothyra deltae* and *Cerethidopsilla sp.* Whereas in Thane creek the dominance was *Stenothyra deltae* > *Stenothyra minima* > *Cerethidopsilla* > *Assaminea* > *Nassarius ornatus.*

Table Gast-1: Monthwise and stationwise variations in Gastropod density (no/m2) in Ulhas river estuary and Thane creek.

	Ulhas River Gastropods no/m2													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	20	460	0	1300	0	0	1540	40	20	100	560	337	720	880	0	1920	7260	5020	16040	7700	94060	8840	8160	560	12597
Oct,01	0	20	360	100	1300	240	200	1540	40	100	200	500	383	480	880	0	1560	7500	6000	15000	6500	140860	10500	10000	300	16632
Nov,01	0	20	240	200	880	480	0	1280	240	40	100	720	350	1280	880	200	2240	12660	10420	23000	13280	99920	13680	16480	700	16228
Dec,01	120	20	460	480	1560	1600	240	560	400	200	240	240	510	1600	1280	160	2240	12680	5020	13280	7280	86140	13280	12000	560	12960
Jan,02	0	60	0	100	160	0	280	60	0	100	80	160	83	1280	880	200	2240	12660	10420	23000	13280	99920	13680	16480	700	16228
Feb,02	80	0	0	60	0	0	1080	160	40	60	20	280	148	840	0	0	9540	43880	29660	57820	26180	720	63300	14080	40	20505
Mar,02	120	0	0	300	100	240	2480	100	40	200	300	200	340	1080	240	0	11300	37300	31200	35160	20100	500	45500	15300	40	16477
Apr,02	60	20	40	460	0	0	2520	80	160	320	20	740	368	240	0	20	1300	2320	540	700	140	147120	8800	56880	100	18180
May,02	760	160	40	500	0	0	2900	200	160	240	100	700	480	200	0	20	800	2640	400	240	100	96000	3000	33500	100	11417
Jun,02	620	20	0	260	60	0	1580	100	500	620	520	980	438	100	220	40	12960	51400	20280	2000	17280	65760	41060	27920	360	19948
Jul,02	360	80	0	500	100	0	1000	240	240	700	100	100	285	20	100	0	6500	13600	14900	440	2480	7120	2680	7700	120	4638
Aug,02	0	160	60	1540	100	0	280	60	0	100	80	160	212	0	160	0	1560	0	1780	15700	300	36520	35000	8700	120	8320
Sep,02	0	40	200	300	880	400	0	1280	240	40	100	720	350	1280	880	200	2240	12660	10420	23000	13280	99920	13680	16480	700	16228
Oct,02	400	160	40	500	0	0	2900	200	160	240	100	700	450	200	0	20	800	2640	400	240	100	8700	3000	19600	100	2983
Nov,02	120	0	0	300	100	240	2480	100	40	200	300	200	340	1080	240	0	11300	37500	33000	31560	17900	500	39720	15300	40	15678
Avg	176	52	127	373	436	213	1196	500	153	212	157	464	338	693	443	57	4567	17113	11964	17145	9727	65584	21048	18572	303	13935

Table Gast-2: Monthwise and stationwise variations in Gastropod biomass (gm/m2) in Ulhas river estuary and Thane creek.

	Ulhas River Gastropods gm/m2													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	2.06	14.06	0	5.42	0	0	16.12	0.16	0.14	0.36	7.06	3.78	2.06	5.42	0	87.86	132.46	14.9	12.5	150.14	109.9	134.34	72.26	7.12	60.75
Oct,01	0	4.9	12	0.9	5.42	2.1	0	19.3	0.52	0.5	0.3	5.98	4.33	2.7	7.02	0	78.86	126.9	19.7	12.5	150.14	109.9	104.5	72.26	9.12	57.80
Nov,01	0	6.02	19.26	0.9	7.5	19.28	0	17.72	1.6	0.4	0.7	5.06	6.54	6.02	3.44	0	108.66	113.98	13.76	16.5	131.3	129.9	153.28	88.88	6.7	64.37
Dec,01	2.08	4.44	12.16	4.16	5.42	7.28	1.6	12.16	0.9	1.7	1	10.66	5.30	6.04	8.88	0	69.86	88.44	11.48	14.7	114.14	99.1	73.36	66.26	7.28	46.63
Jan,02	0	0.16	0	0.7	0.84	0	1.82	0.14	0	3.3	0.16	5	1.01	6.02	3.44	0	108.66	113.98	13.76	16.5	131.3	129.9	153.28	88.88	6.7	64.37
Feb,02	0.1	0	0	0.32	0	0	2.96	0.4	0.14	0.26	0.01	4.12	0.69	2.58	0	0	742.1	199.94	142.94	96.84	1050.2	33.26	289.1	572.26	1.56	260.90
Mar,02	1	0	0	1.5	0.9	1	19.6	0.8	0.16	1.2	0.5	0.5	2.26	4.5	2	0	31.24	67.72	39.72	68.9	18	2.3	57.7	21	1.6	26.22
Apr,02	0.02	0.4	0.12	61.4	0	0	31.6	18.54	43.7	2	1.5	0.82	13.34	2	0	0.1	130.42	239.82	96.6	37.98	0.3	235.12	46.42	369.36	1.7	96.65
May,02	19.9	1.3	0.02	2	0	0	6.5	1.6	1.6	2	1.9	3.3	3.34	4.9	0	0.4	6.5	11.3	4	3.7	1.6	119.24	37.3	41.7	0.18	19.24
Jun,02	1.12	0.04	0	0.8	0.14	0	8.6	0.7	2	3.84	0.92	5.66	1.99	1.5	2.36	0.1	124.08	315.1	126.68	213.04	717.36	288.2	128.4	166.1	2.4	173.78
Jul,02	7.7	1.8	0	3.9	1.9	0	9.7	1.8	2	5.3	0.7	0.7	2.96	0.16	0.16	0	34.9	54.9	56.9	9.7	12.64	53.7	21	77	1.2	26.86
Aug,02	0	0.4	0.1	2.26	0.26	0	1.82	0.1	0	19	0.16	1.9	2.17	0	1.5	0	20.7	0	19.7	75.36	1.9	35.72	20.56	20.12	0.1	16.31
Sep,02	0	6.02	19.26	0.9	7.5	19.28	0	17.72	1.6	0.4	0.7	5.06	6.54	6.02	3.44	0	104.44	103.98	13.76	16.5	107.3	123.56	109.56	67.64	6.7	55.24
Oct,02	17.9	1.3	0.02	2	0	0	4.7	1.6	1.6	2	1.9	3.3	3.03	4.9	0	0.4	6.5	11.3	4	3.7	1.6	79.24	37.3	41.7	0.18	15.90
Nov,02	1	0	0	1.5	0.9	1	19.6	0.8	0.16	1.2	0.5	0.5	2.26	4.5	2	0	31.24	37.5	27.76	39.36	18	2.3	39.2	21	1.6	18.71
Avg	3.39	1.92	5.13	5.55	2.41	3.33	7.23	7.30	3.74	2.88	0.75	3.97	3.97	3.59	2.64	0.07	112.40	107.82	40.38	42.52	173.73	103.42	93.69	119.09	3.61	66.91

Monthly and stationwise variations in Gastropod density and biomass are shown in Tables Gast-1 & Gast-2. They varied from 0 to 2900 no/m2 (avg. 338 no/m2) and 0 to 61.4 gm/m2 (avg. 3.97 gm/m2) respectively in Ulhas river estuary. Whereas in Thane creek the ranges were 0 to 147120 no/m2 (avg. 13935 no/m2) and 0 to 1050.5gm/m2 (avg. 66.91 gm/m2) respectively. Thus gastropods had much high density and biomass in Thane creek as compared to Ulhas river estuary. Mishra (2002) observed average density and biomass in Ulhas river estuary to be 3000 no/m2 and 200 gm/m2 respectively which are significantly higher than the present study. Quadros (2001) reported average gastropod density and biomass to be 6558 no/m2 and 66 gm/m2 which indicate increased average density in Thane creek but unchanged biomass. The rise in density is thus due to small sized gastropods. The present density is significantly higher as compared to 2396 no/m2 reported by Athalye (1988) **thus gastropod population has declined in Ulhas river estuary and increased in Thane creek**. The east bank of Thane creek and north bank of Ulhas river estuary had higher gastropod population.

Fig. Gast-1: Comparison of stationwise variation in average abundance and biomass of gastropods in Ulhas river estuary

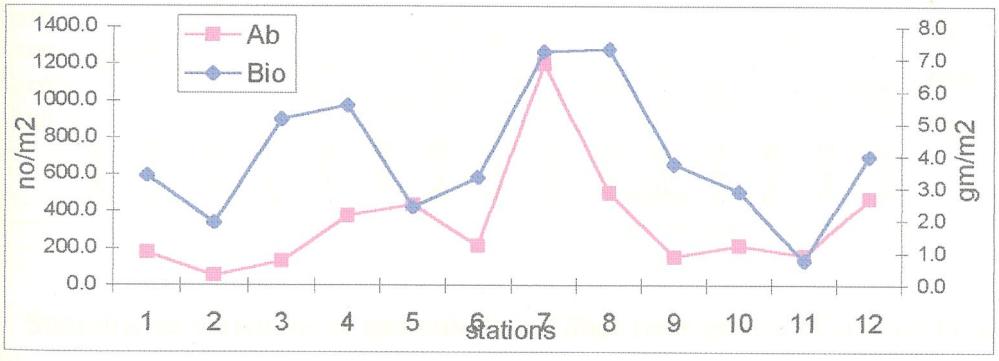


Fig. Gast-2: Comparison of stationwise variation in average abundance and biomass of gastropods in Thane creek

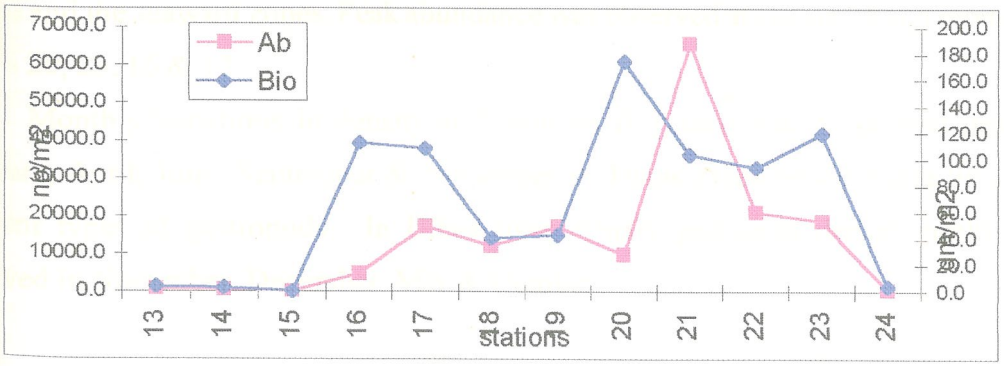


Fig. Gast-3: Monthly variations in the averages of gastropod density (no/m2) in Ulhas river estuary and Thane creek

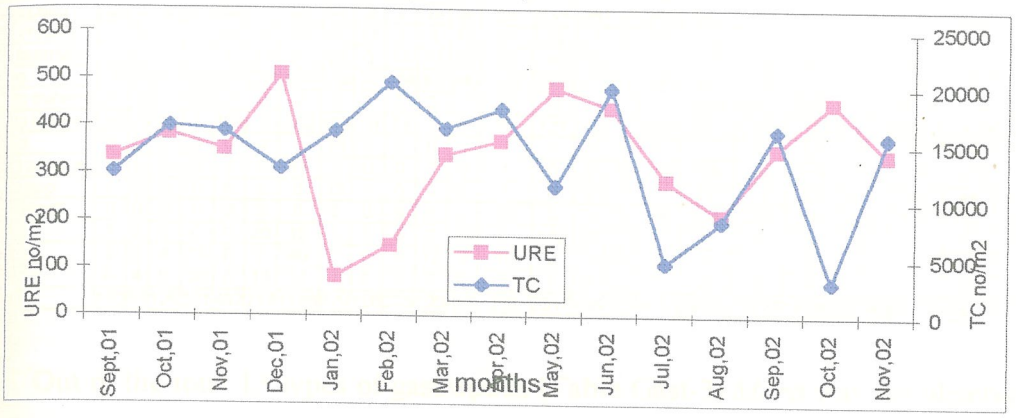
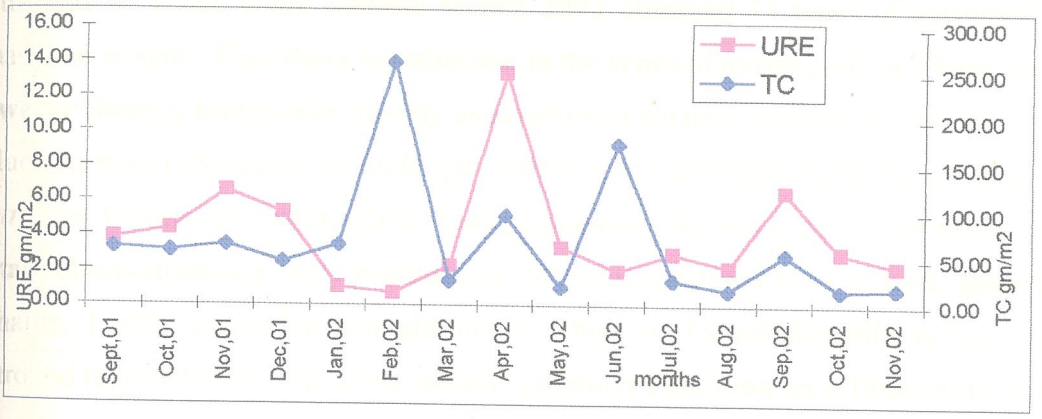


Fig. Gast-4: Monthly variations in the averages of gastropod biomass (gm/m2) in Ulhas river estuary and Thane creek



Stationwise variations in gastropods in Ulhas river estuary (Fig Gast-1) indicate bigger sized gastropods at station 6 & 9. In general middle zone had higher gastropod biomass and density. In Thane creek (Fig Gast-2) the gastropods mainly dominated in the middle and the seaward zones. Peak abundance was observed at station 21 and biomass at station 20, 23, 16 & 17.

Monthly variations in density and biomass (Fig Gast-3 & 4) showed peaks in February, April, June, September & November in Thane creek which could be due to different types of gastropods . In Ulhas river estuary gastropod density peaks were observed in November, December, May & October.

Fig. Gast-3: Stationwise variations in the total density (no/m2) of Gastropod species in Ulhas river estuary and Thane creek during the 15 month study period.

	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg
Cerethideopsilla	0	0	3	21	64	27	86	45	3	7	0	8	22	118	98	16	363	589	456	359	443	516	424	680	76	345
Haminea crocata	0	0	17	17	44	0	40	37	17	7	8	13	17	33	31	0	138	124	80	81	116	153	80	122	69	86
Salinater burmana	11	0	0	20	47	13	21	33	3	11	13	73	20	20	48	0	202	125	68	86	57	161	80	101	7	80
Assiminea	117	35	65	165	174	134	601	189	70	164	81	249	170	2886	93	81	456	69	266	0	0	0	0	0	0	321
Stenothyra minima	0	0	3	112	0	0	0	7	1	0	0	0	10	13	33	0	755	8439	5662	8727	2752	18101	7178	7062	27	4896
Stenothyra deltae	36	19	35	1	104	0	352	153	19	11	1	45	65	121	112	3	2341	9891	5105	7134	14039	32053	12574	8432	53	7655
Onchidium	0	0	0	0	0	0	0	16	5	0	0	4	2	7	0	0	13	1	0	13	0	11	0	13	0	5
Narsarrius ornatus	0	0	0	0	0	0	13	0	0	0	0	0	1	0	0	0	259	259	286	214	513	321	323	315	0	208
Narsarrius spp.	0	0	0	0	0	0	0	13	0	0	0	0	1	0	0	0	1	13	73	33	411	265	44	402	0	104
Mitra amphorell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	106	134	238	141	395	130	162	169	0	123
Melampus	1	0	0	0	0	20	15	3	1	5	3	11	5	112	20	7	37	7	0	0	0	0	0	0	0	15
Turitella	5	0	4	15	0	7	40	27	8	0	13	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Thiara	0	4	0	20	0	13	17	7	0	0	0	0	5	7	0	0	0	0	0	0	13	7	0	0	0	2
Total	170	57	126	371	432	214	1186	529	128	203	120	403	328	3317	435	106	4674	19652	12233	16790	18740	51717	20865	17297	231	13839

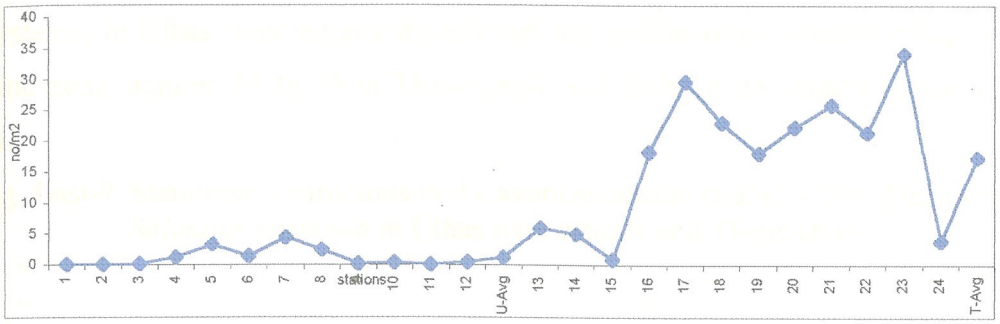
Out of the total 13 types of gastropods (Table Gast-3) *Mitra* was not observed in Ulhas river estruary whereas *Melampus spp*. was observed only on riverine end of Thane creek and lower stretch of Ulhas river estuary. Quadros (2001) reported 23 types of gastropods in Thane creek whereas Mishra 2002 observed 13 types of gastropods in Ulhas river estuary. Thus **there is reduction in the types of gastropods in Thane creek. However there is increase in density as mentioned earlier**. The species that are absent include *Auricula elongata, Auricula spp. Drupa spp. Fairbankia bombayana, Littorina ventricosa Melanoides tuberculata Dostia violaceae Neretina spp. Turbinicola nux.* Certain observations are really puzzling eg. *Dostia* is supposed to be a sturdy gastropod (Athalye, 1988), which has got eliminated where as *Cerethidiopsilla* is burrowing gastropod reported to be sensitive to organic pollution This however is flourishing well in Thane creek. The different gastropods showed the following stationwise trend.

Cerethideopsilla spp.

Average density of *Cerethideopsilla spp* . in Ulhas river estuary was 22 no/m^2. They occupied the middle region of the estuary. In Thane creek the average number was 345 no/m^2 and they occurred through out the creek. Their density was lower at stations 13, 14 & 15 which are more polluted organically. Athalye (1988) had observed their average density to be 220no/m2 in Upper stretch of Thane creek whereas Quadros (2001) recorded lower average density (166 no /m^2) for entire stretch of Thane creek. Mishra (2002) also observed lower density of the gastropod (3 no/m^2) in Ulhas river estuary. Thus the gastropod showed increased density in both the ecosystem. The gastropod is

known to be sensitive to organic pollution. Hence occurred low at organically polluted locations like station 3 and 15. But still its increase in Thane creek where pollution is increasing is mysterious.

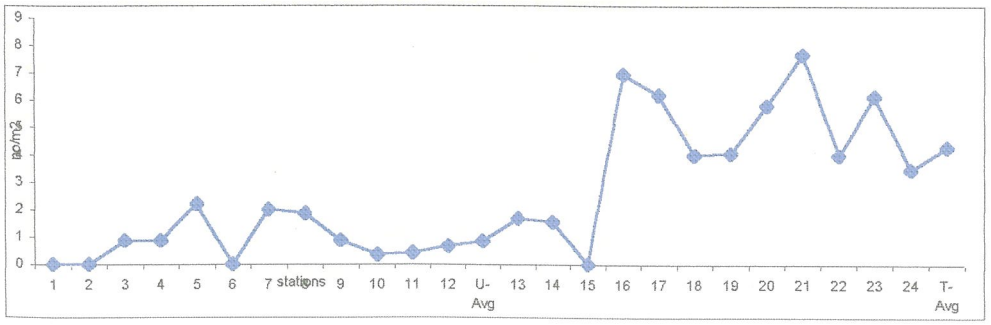
Fig. Gast-5: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Cerethideopsilla spp.* in Ulhas river estuary and Thane creek.



Haminea crocata

In Ulhas river estuary the average density was 17 no/m^2 where as in Thane creek it was 86 no/ m^2. In both the ecosystem this gastropod occurred through out the stretch. In Thane creek the gastropod had lower density at stations 13, 14 15 which have high organic pollution. Mishra 2002 recorded average density of gastropod 57 no/m^2 in Ulhas river estuary whereas Quadros (2001) observed in Thane creek the density to be 12 no/m^2. Thus the density has decreased in Ulhas river estuary and increased in Thane creek. In the earlier studies on Thane creek by Athalye (1988) this gastropod was not recorded.

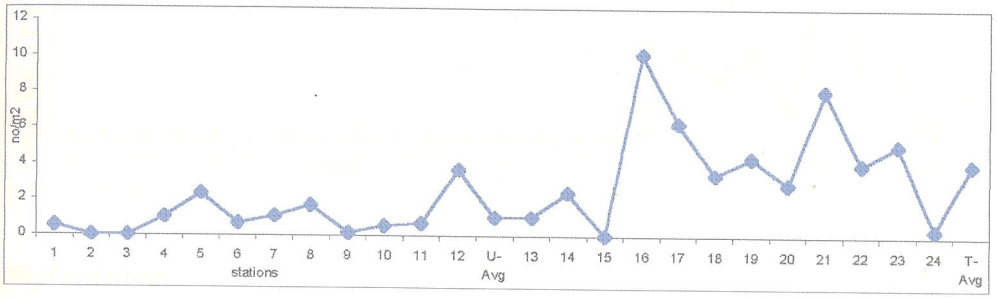
Fig. Gast-6: Stationwise variations in the average density (no/m^2 x 20)of gastropod *Haminea crocata* in Ulhas river estuary and Thane creek.



Salinater burmana

The gastropod had average density 20 no/m^2 in Ulhas river estuary and 80 no/m^2 in Thane creek. Compared to earlier data of Ulhas river estuary by Mishra (2002), 1130 no/m^2 and Thane creek by Quadros (2001), 20 no/m^2 there is decrease of the population in Ulhas river estuary and increase in Thane creek. The gastropod is probably favored by high organic pollution. Though the gastropod occurred throughout the stretch of the two ecosystems, In Ulhas river estuary it preferred the middle zone whereas it kept low in riverine zone stations 13 to 15 in Thane creek and high on the middle region of The creek.

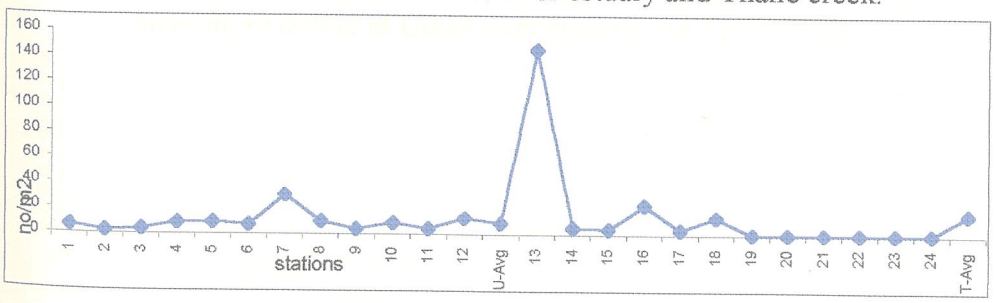
Fig. Gast-7: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Salinater burmana* in Ulhas river estuary and Thane creek.



Assaminea bervicula

This small gastropod occurred through out the Ulhas river estuary and the upstream half of Thane creek. The density however was lower 170 no/m^2 in Ulhas river estuary as compared to Thane creek 321 no/m^2 Mishra (2002) recorded higher density (1580 no/m^2) in Ulhas river estuary, whereas in Thane creek also the density has significantly reduced than 568 no/m^2 observed by Quadros (2001) the gastropod had peak density at station 13 of Thane creek and station 7 of Ulhas river estuary.

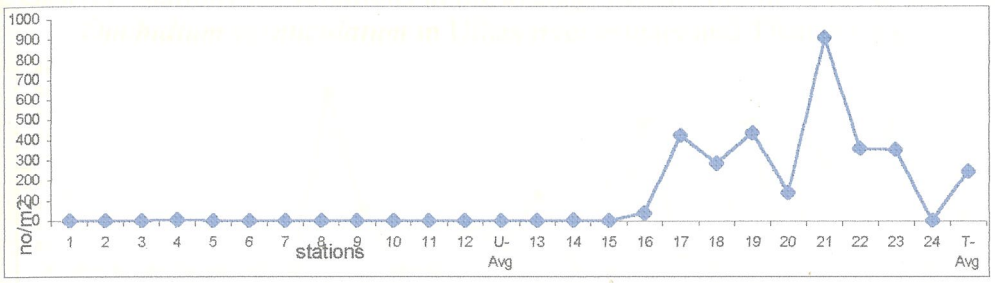
Fig. Gast-8: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Assaminea bervicula* in Ulhas river estuary and Thane creek.



Stenothyra minima

This gastropod had sporadic occurrence in Ulhas river estuary with average density 10 no/m^2 but in Thane creek its density was significant (average 4896 no/m^2) Its distribution was from station 16 onwards. Quadros (2001) recorded low density 1060no/m^2 in Thane creek whereas Mishra (2002) in her studies on Ulhas river estuary did not observe this gastropod. Thus the gastropod has significantly increased in Thane creek and just establishing in Ulhas river estuary.

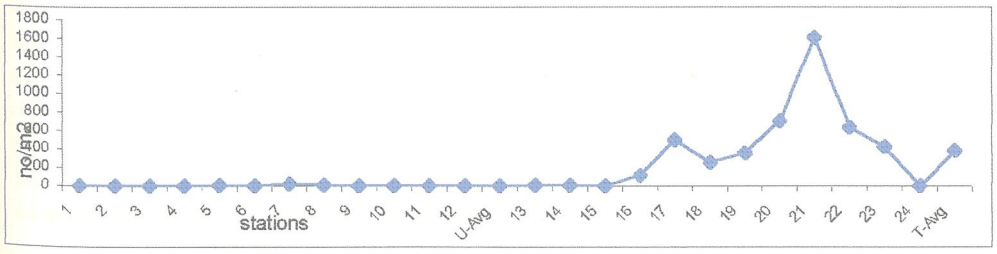
Fig. Gast-9: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Stenothyra minima* in Ulhas river estuary and Thane creek.



Stenothyra deltae

In Ulhas river estuary the gastropod had average density 65 no/m^2, whereas in Thane creek it was 7655 no/m^2. The distribution in Ulhas river estuary was not uniform (fig) With the highest density at station 7. In Thane creek the density was low at station 13, 14, & 15 on riverine end which increased downstream up to station 21 and then gradually declined. When compared to the average densities of earlier studies by Quadros (2001) 3256 no/m^2, on Thane creek the density of the gastropod in Thane creek has increased whereas it has got introduced in Ulhas river estuary because Mishra (2002) in her studies did not report the gastropod in Ulhas river estuary.

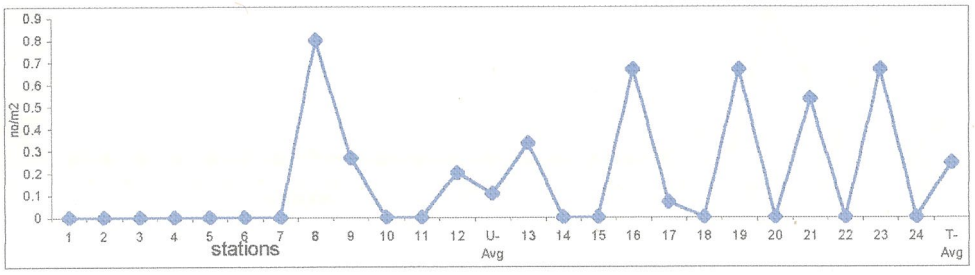
Fig. Gast-10: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Stenothyra deltae* in Ulhas river estuary and Thane creek.



Onchidium vernuculatum

This gastropod had sporadic occurrence with low average density 2 no/m^2 in Ulhas river estuary and 5 no/m^2 in Thane creek. The distribution was not uniform. It occurred in the downstream stretch of Ulhas river estuary and entire Thane creek probably due to its avoidance of fresh water conditions. Mishra (2002) reported distribution similar to the present one in Ulhas river estuary but she observed higher density 37 no/m^2, whereas Quadros (2001) reported similar density of *Onchidium* in Thane creek.

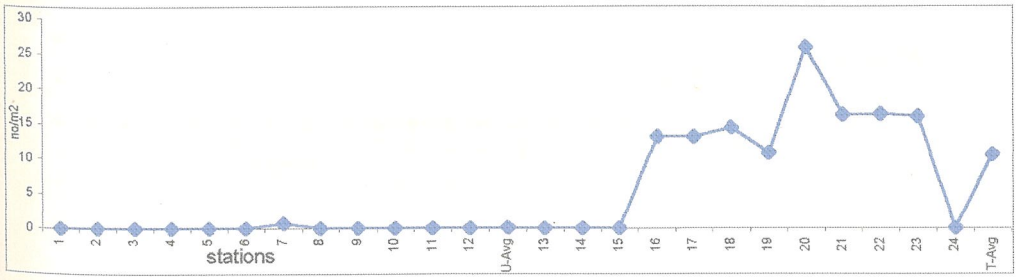
Fig. Gast-11: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Onchidium vernuculatum* in Ulhas river estuary and Thane creek.



Narsarrius ornatus

This gastropod had significant occurrence in Thane creek (avg. density 207 no/m^2) and was very rare in Ulhas river estuary (avg. density 1 no/m^2). In Thane creek it did not occur at the organically polluted stations 13 to 15 and also the last station 24. Its peak occurrence was at station 20. As compared to the density reported by Quadros (2001) 23 no/m^2 the population shows increase in Thane creek whereas the population has significantly decreased in Ulhas river estuary as compared to that observed by Mishra 120 no/m2.

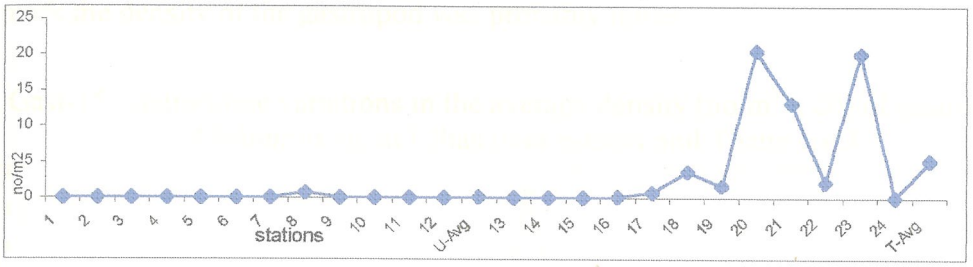
Fig. Gast-12: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Narsarrius ornatus* in Ulhas river estuary and Thane creek.



Narsarrius spp.

The species had a negligible presence in Ulhas river estuary (at station 8 only) whereas in Thane creek the average density was 103 no/m2 and it occurred significantly at the downstream seaward stations 20 to 23. As compared to earlier observations by Quadros (2001) (15 no/m2) the present density of Thane creek was higher whereas the density of Ulhas river estuary has got reduced as compared to that (83 no/m2) recorded by Mishra (2002).

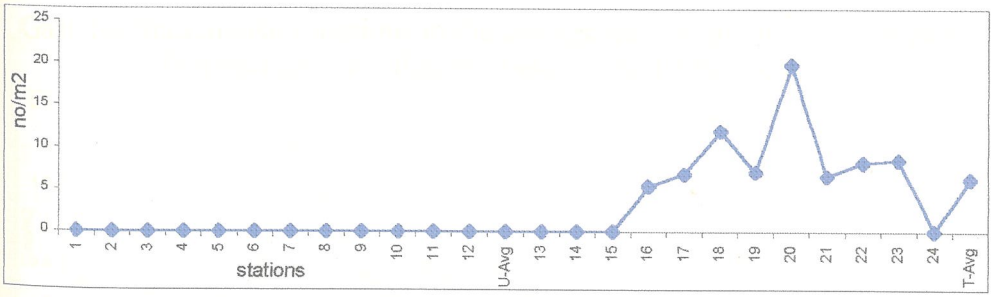
Fig. Gast-13: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Narsarrius spp* in Ulhas river estuary and Thane creek.



Mitra amphorell

The gastropod did not occur in Ulhas river estuary as also reported by Mishra (2002) Whereas in Thane creek it occurred at all stations except at organically polluted stations 13 to 15. The density increased from stations 16 to 20 and then declined. The average density in Thane creek was 123 no/m2. Quadros (2001) recorded in Thane creek the density of *Mitra spp*. 31 no/m2 which in last two years has increased.

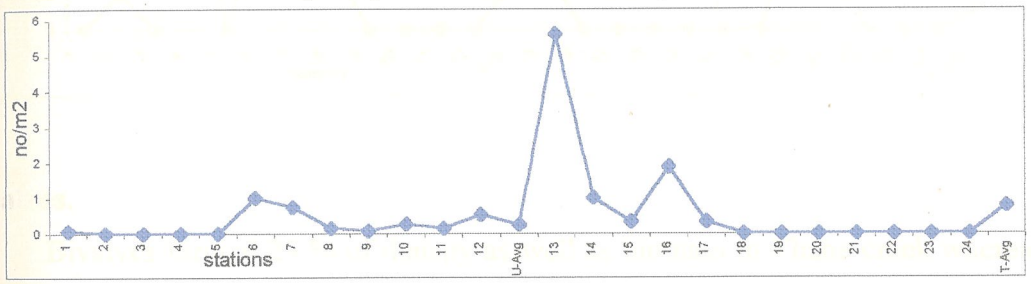
Fig. Gast-14: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Mitra amphorell* in Ulhas river estuary and Thane creek.



Melampus sp.

The average density of this gastropod was 5 no/m^2 in Ulhas river estuary and 15 no/m^2 in Thane creek. The occurrence was in the middle and seaward zone of Ulhas river estuary and only on riverine side of Thane creek. The gastropod occurred at all tidal levels but was more predominant at high level water mark (HLWM) and show ascending and descending on the tree trunk during High tide and Low tide respectively. Quadros (2001) observed in Thane creek the distribution of *Melampus spp.* similar to the present one and the density 7 no/m^2. Mishra (2002) reported higher density (43 no/m^2) at the base of mangroves (HWLM) of Ulhas river estuary. The present study being at mid level water mark the density of the gastropod was probably lower.

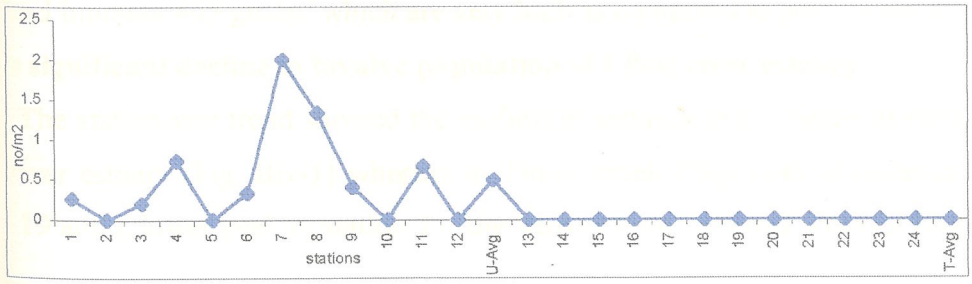
Fig. Gast-15: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Melampus sp.* in Ulhas river estuary and Thane creek.



Turitella spp.

This gastropod with relatively bigger size occurred only in Ulhas river estuary distributed throughout the estuary having peak density at mid zone stations 7 &8. The average density was 10 no/m^2. Quadros (2001) has reported sporadic occurrence of the gastropod (avg. density 4 no/m^2) in Thane creek.

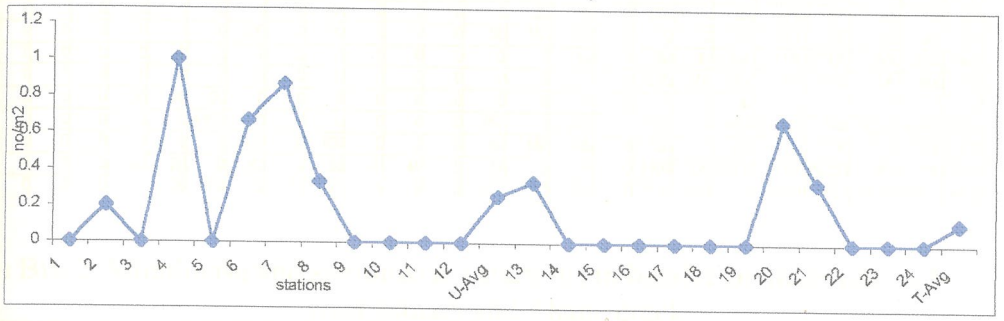
Fig. Gast-16: Stationwise variations in the average density (no/m^2 x 20) of gastropod *Turitella spp.* in Ulhas river estuary and Thane creek.



Thiara spp.

Thiara spp. showed sporadic occurrence in both the ecosystems but had higher density (avg. 5 no/m^2) in Ulhas river estuary as compared to Thane creek (avg. 2no/m^2). The study in 1999-2000 by Quadros had shown higher density of *Thiara spp.* (91no/m^2) in Thane creek with high population density in middle stations. The present survey shows reduced population.

Fig. Gast-17: Stationwise variations in the average density (no/m^2 x 20)of gastropod *Thiara spp.* in Ulhas river estuary and Thane creek.



Bivalves.

Bivalves formed 29 % of density as well as biomass in Thane creek whereas in Ulhas river they had 2 % share in total density and 1 % in biomass. Thus Ulhas river had lower bivalve population than Thane creek. The average population density was 101 no/m^2 (range 0 to 4480 no/m^2) in Ulhas river estuary and 13929 no/m^2 (range 0 to 250000no/m^2) in Thane creek. Whereas the average biomass was 0.22 gm/m^2 (range 0 to 19.3 gm/m^2 in Ulhas river estuary and 50 gm/m^2 (range 0 to 1110gm/m^2) in Thane creek. Quadros (2001) reported average density of bivalves 6862 no/m^2 and biomass 90 gm/m^2 in Thane creek. The present density is higher but the biomass lower, which could be due to increase in small bivalves. Mishra (2002) observed average density of bivalves 11238 no/m^2 and biomass 465 gm/m^2 which are very high as compared to present figures. **Thus there is significant decline in bivalve population of Ulhas river estuary**.

The stationwise trend showed the highest abundance and biomass at station 6 in Ulhas river estuary (Fig. Biv-1) whereas in Thane creek (Fig) peak abundance was at station 19 and a lower peak at station 21, the density then declined. Peak of biomass at

station 21 with reduced density suggest large size bivalve at that station. In fact the biomass abundance trend in fig. suggest larger size bivalves at stations 18, 20, 21 & 23.

Table Biv-1: Monthwise and stationwise variations in bivalve density (no/m2) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek										
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	240	0	2260	0	2580	244100	540	43720	50100	9600	240	29448
Oct,01	0	0	0	0	100	3280	0	200	0	0	0	0	298	0	200	0	4560	0	2400	250000	600	63120	55000	8500	200	32048
Nov,01	0	0	0	0	0	4480	0	0	0	0	0	0	373	0	240	0	2720	0	4380	217920	540	92240	31900	5280	240	29622
Dec,01	0	0	0	1280	240	2240	0	0	0	0	0	0	313	0	240	0	2260	1280	2580	210080	560	37240	70100	4800	240	27448
Jan,02	0	0	0	0	0	40	0	0	0	0	0	0	3	0	240	0	2880	0	4380	231920	540	102440	31900	5280	240	31652
Feb,02	0	0	0	40	20	0	0	0	20	20	40	40	15	0	0	0	960	120	19920	27120	27200	500	200	6840	40	6908
Mar,02	0	0	0	60	20	0	40	0	20	20	40	0	17	0	0	0	1100	120	15100	31240	25200	400	160	8440	100	6822
Apr,02	0	0	0	0	0	0	0	0	60	0	0	0	5	20	60	0	660	0	380	240	1100	260	7780	860	60	952
May,02	0	0	0	0	0	0	500	0	100	0	0	0	50	180	100	0	700	0	200	300	700	200	3300	500	0	515
Jun,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	160	40	33280	140	32320	880	5080	1440	0	6117
Jul,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	240	160	3300	240	1700	540	1600	700	20	708
Aug,02	0	0	0	20	20	20	0	0	0	0	0	0	5	0	0	0	0	0	40	0	0	0	0	0	0	3
Sep,02	0	0	0	0	0	4400	0	0	0	0	0	0	367	0	240	0	2720	0	4380	217920	540	92240	31900	5280	240	29622
Oct,02	0	0	0	0	0	0	500	0	100	0	0	0	50	180	100	0	700	0	200	300	700	200	3300	500	0	515
Nov,02	0	0	0	60	20	0	40	0	20	20	40	0	17	0	0	0	1100	120	15100	31100	22200	400	160	8440	100	6560
Avg	0	0	0	97	28	964	72	13	21	4	8	3	101	25	115	0	1535	123	7215	97508	7629	28959	19499	4431	115	13929

Table Biv-2: Monthwise and stationwise variations in bivalve biomass (gm/m2) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek										
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	2.22	0	8.1	0.2	9.44	74.5	1.44	108.94	77.02	33.96	1.78	26.47
Oct,01	0	0	0	0	0.5	19.3	0	0.7	0	0	0	0	1.71	0	2.1	0	9.3	0.2	9.44	74.5	1.44	102.5	77.02	33.96	1.78	26.02
Nov,01	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	2.22	0	13.5	0.2	14.84	59.98	1.44	99.92	66.9	48.96	1.12	25.76
Dec,01	0	0	0	1.6	2.04	4.22	0	0	0	0	0	0	0.66	0	4.44	0	11.28	2.44	14.48	71.5	2.2	90.94	64.68	53.32	1.6	26.41
Jan,02	0	0	0	0	0	0.36	0	0	0	0	0	0	0.03	0	2.22	0	13.5	0.2	14.84	59.98	1.44	99.92	66.9	48.96	1.12	25.76
Feb,02	0	0	0	0.8	0.02	0	0	0	0.06	0.1	0.02	0.9	0.16	0	0	0	0.76	0.2	445.24	1076.72	1110.4	872.3	30.7	719.6	2.5	354.87
Mar,02	0	0	0	0.18	0.06	0	0.12	0	0.06	0.06	0.1	0	0.05	0	0	0	21.2	5	173.34	73.5	39	14	5	33	1.9	30.50
Apr,02	0	0	0	0	0	0	0	0	0.5	0	0	0	0.04	5	0.06	0	0.86	0	21	19.16	29.9	547.9	55.04	11.16	2.4	57.71
May,02	0	0	0	0	0	0	1.9	0	1.1	0	0	0	0.25	11.7	6.5	0	19.3	0	2	2.2	2.5	1.8	9.7	12.5	0	5.68
Jun,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.1	0	2.66	1.8	154.12	4.6	705.6	141.2	230.04	51.36	0	107.62
Jul,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	4.9	1.9	73.6	19	27	15	33	6.96	0.4	15.15
Aug,02	0	0	0	0.4	0.96	0.06	0	0	0	0	0	0	0.12	0	0	0	0	0	40	0	0	0	0	0	0	3.33
Sep,02	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	2.22	0	13.5	0.2	14.84	59.98	1.44	99.92	66.9	48.96	1.12	25.76
Oct,02	0	0	0	0	0	0	1.9	0	1.1	0	0	0	0.25	11.7	6.5	0	19.3	0	2	2.2	2.5	1.8	9.7	12.5	0	5.68
Nov,02	0	0	0	0.18	0.06	0	0.12	0	0.06	0.06	0.1	0	0.05	0	0	0	21.2	5	93.34	32.88	39	14	5	33	1.9	20.44
Avg	0.00	0.00	0.00	0.21	0.24	1.60	0.27	0.05	0.19	0.01	0.01	0.06	0.22	1.89	1.91	0.00	10.62	1.16	72.17	108.71	131.02	147.34	53.17	76.55	1.17	50.48

Fig. Biv-1: Comparison of stationwise variations in average abundance and biomass of Bivalves in Ulhas river estuary

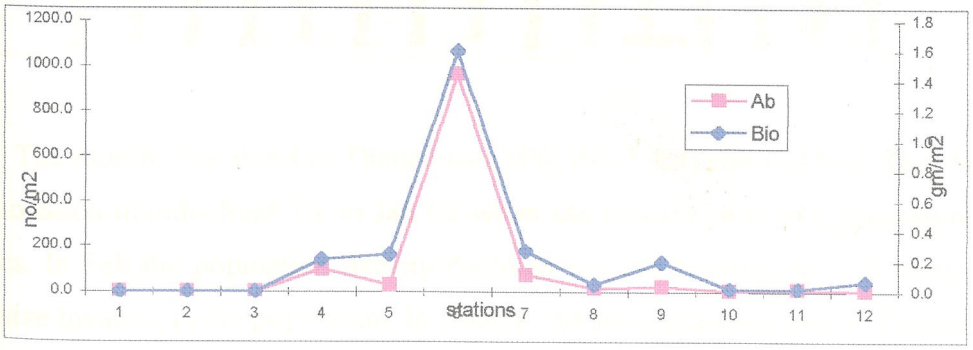


Fig. Biv-2: Comparison of stationwise variations in average abundance and biomass of Bivalves in Thane creek

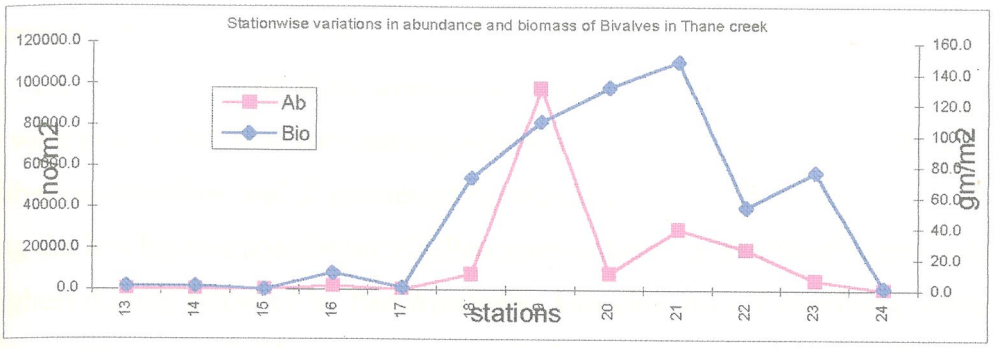


Fig. Biv-3: Monthly variations in the averages of bivalve density (no/m2) in Ulhas river estuary and Thane creek

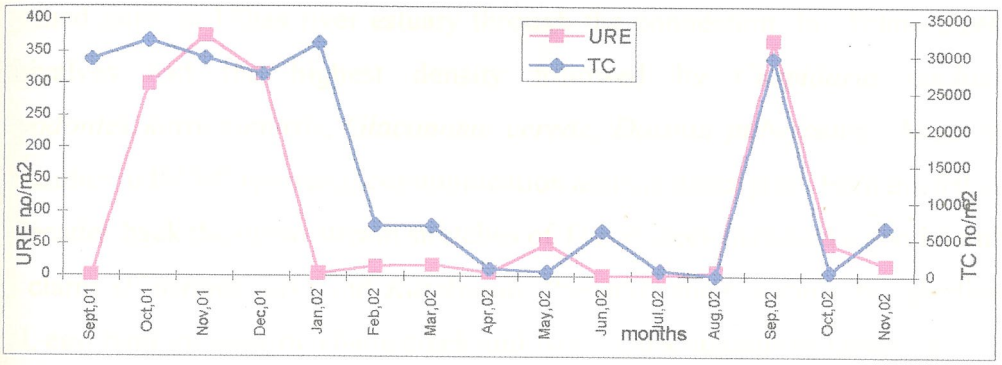
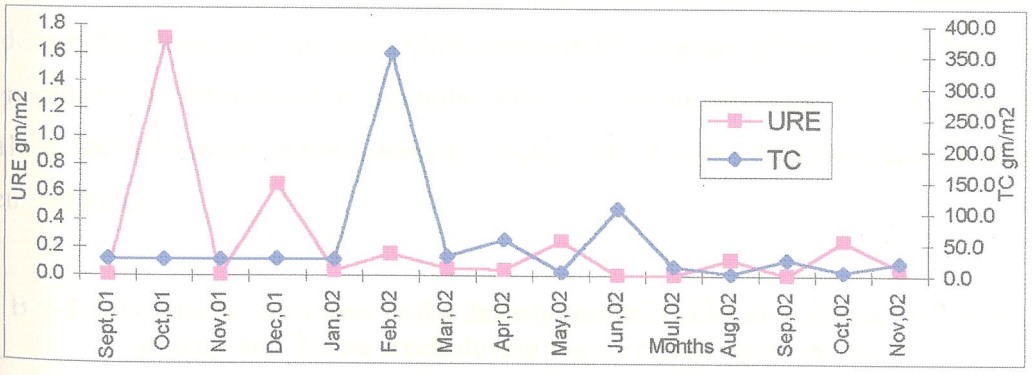


Fig. Biv-4: Monthly variations in the averages of bivalve biomass (gm/m2) in Ulhas river estuary and Thane creek



The month wise trend in Thane creek (Fig Biv-3 &4) showed high abundance in post monsoon months Sept. 01 to Jan 02 when the biomass was low suggesting small bivalves. In Feb the population density declined but the biomass showed peak due to larger size bivalves in the population. In general, the post monsoon season was favorable

for bivalve population. The monthwise population in Ulhas river estuary showed higher bivalve population and biomass in post monsoon of 2001 as compared to the post monsoon of 2002.

Total 9 types of bivalves were recorded from both the ecosystems of which 6 types were present in Ulhas river estuary whereas all 9 types were found in Thane creek. The bivalves *Cardium* and 2 species of *Katelysia* were absent in Ulhas river estuary. Among the low bivalve population of Ulhas river estuary, unidentified microbivalve had the highest density followed by *Brachyodontes karachinenses*, *Cuspidaria cochinensis* *Dosinia pubiscens*, and *Glaconome cereae*. In fact most of the bivalves of Ulhas river estuary occurred at station 6 which is close to the confluence with Thane creek probably they gained entry in Ulhas river estuary through the connection. In Thane creek also microbivalves had the highest density followed by *Cuspidaria cochinensis*, *Brachyodontes karachinensis*, *Glaconome cereae*, *Dosinia pubescence*. According to earlier studies at BARC (personal communication and the description from the fishermen, a few decades back the down stream stretches of Thane creek harbored a good number of Blood clams (*Cardium spp.*) and *Katelyasia*. Presently their number has declined, in general, east bank stations of Thane creek and North bank stations of Ulhas river estuary had higher bivalve density. Mishra (2002) reported only 2 species of Bivalves in Ulhas river estuary but with higher population density. Presently the types have increased but the density has decreased. Quadros (2001) reported 10 species of bivalves in Thane creek the number has come down marginally. The stationwise distribution of the dominant bivalves, Microbivalve, *Brachyodontes*, *Cuspidaria*, *Dosinia*, *Katelysia* and *Cardium* is discussed below.

Fig. Biv-3: Stationwise variations in the density (no/m2) of bivalve species in Ulhas river estuary and Thane creek during the 15 month study period.

	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg
Katelysia opima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	74	93	376	44	109	85	5	66
Katelysia marmorata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	8	4	0	2
Cuspidaria cochinensis	0	0	0	45	11	128	0	0	0	0	0	0	15	7	49	0	148	32	1168	1278	2133	114	926	524	47	535
Glaconome cereae	0	0	0	3	0	40	3	0	5	1	5	0	5	12	25	0	148	174	690	226	533	178	262	105	7	197
Dosinia pubescence	0	0	0	0	0	33	27	0	15	1	0	0	6	7	0	0	149	81	407	166	291	86	134	17	7	112
Microbivalve	0	0	0	0	0	466	0	13	0	0	0	0	40	0	20	0	964	20	4819	94300	3582	28273	17611	2915	40	12712
Brachydontes karachinensis	0	0	0	0	0	291	40	0	0	0	0	0	28	0	0	0	0	0	39	1084	391	102	684	218	0	210
Razor clam	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	192	0	0	0	0	16
Cardium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	41	112	40	82	37	5	28
Total	0	0	0	48	11	958	69	13	20	3	5	3	94	25	94	0	1415	307	7211	97188	7610	28845	19816	3906	110	13878

Microbivalve (unidentified)

In Ulhas river estuary though the average density was 40 no/m^2 the bivalve occurred significantly at station 6 and very few organisms were recorded at station 8. In Thane creek except for the first 3 stations no. 13, 14, 15 the bivalve occurred in significant number average density 12712 no/m^2 The peak density 94300 no/m^2 was recorded at station 19. The density then declined on either sides of the station, except for 2nd order peak at station 21 (Fig Biv-5 & Table Biv-3). Quadros (2001) reported average density 4849 no/m^2 and similar trend as the present one in Thane creek. Thus the density has increased in Thane creek. Mishra (2002) in her studies during 1999-2000 on Ulhas river estuary did not report the bivalve suggesting its recent entry in the estuary.

Fig. Biv-5: Stationwise variations in the average density (no/m^2 x 20) of microbivalve (unidentified) in Ulhas river estuary and Thane creek.

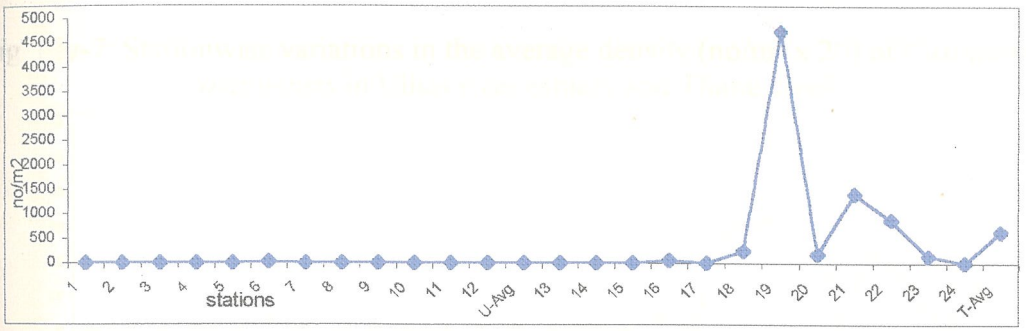
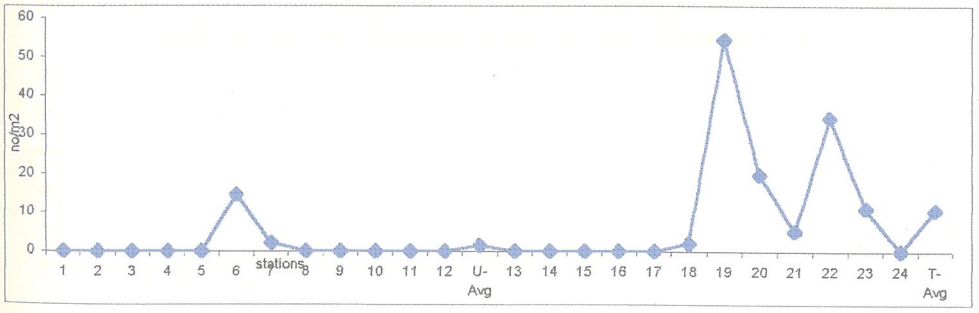


Fig. Biv-6: Stationwise variations in the average density (no/m^2 x 20) of *Brachyodontes karachinensis* in Ulhas river estuary and Thane creek.



Brachyodontes karachinensis.

This bivalve had average density 28 no/m^2 in Ulhas river estuary but occurred mainly at station 6 and slightly downstream. In Thane creek it did not occur on the riverine end i.e. From station 13 to 17. Downstream it had moderate population. The

average density in Thane creek was 210 no/m^2 which is less as compared to 287 no/m^2 reported by Quadros (2001). Mishra (2002) reported very high density of this bivalve (4975 no/m^2) in Ulhas river estuary which has significantly reduced now.

Cuspidaria cochinensis.

In Ulhas river estuary this bivalve occurred maximum at station 6 and then reduced at upstream stations 5 and 4. Its average density was 15 no/m^2. In Thane creek. The average density was quite high 535 no/m^2. It occurred throughout the creek except at station 15 which is heavily polluted by sewage. Its maximum density was in the middle zone at station 20. The density reduced on either sides of this station. The present density in Thane creek is slightly higher than 374 no/m^2 reported by Quadros (2001). In earlier studies by Mishra (2002) the bivalve was not reported from Ulhas river estuary.

Fig. Biv-7: Stationwise variations in the average density (no/m^2 x 20) of *Cuspidaria cochinensis* in Ulhas river estuary and Thane creek

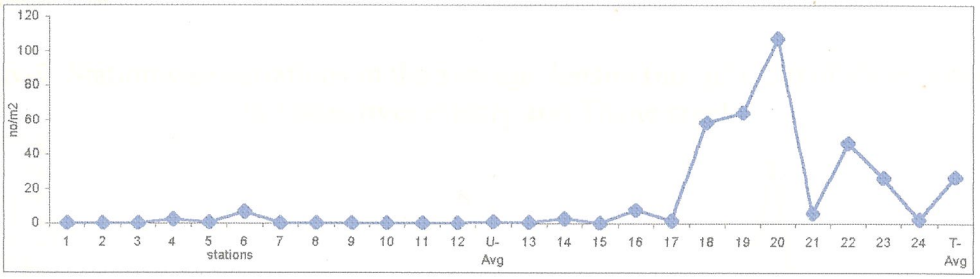
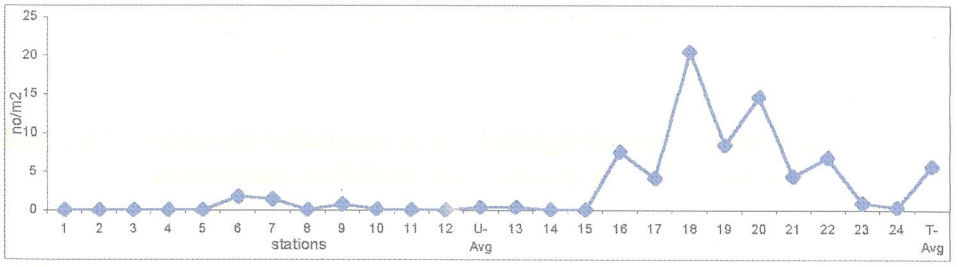


Fig. Biv-8: Stationwise variations in the average density (no/m^2 x 20) of *Dosinia pubescenes* in Ulhas river estuary and Thane creek



Dosinia pubescenes

The bivalve had low average density in Ulhas river estuary (6 no/m^2) whereas in Thane creek the average was 112 no/m^2. In both the ecosystems the population density was maximum in the middle zone with intermediate salinity. In general, the population

was low or absent at stations having high organic pollution due to proximity with sewage reach. Mishra (2002) did not report this bivalve in Ulhas river estuary while studying in 1999-2000. Quadros (2001) recorded almost similar density 95 no/m^2 in Thane creek.

Katelysia spp.

Two species of *Katelysia* namely *Katelysia opima* and *K. marmorata* ocurred only in Thane creek. The later occurred sporadically with average density 2 no/m^2 whereas *K. opima* had average density of 66 no/m^2. The bivalve is edible and is collected by locals. A few decades back the bivalve was available in the creek in significant number. But presently the population has declined. The highest density of *K. opima* was recorded at stn. 20 and the bivalve was restricted to the middle and seaward zone of the creek. Probably the clam needs high salinity conditions. Quadros (2001) observed average density of *Katelysia spp.* to be 99 no/m^2 which is slightly higher than the present one indicating declining trend of the bivalve. He observed distribution pattern similar to the present one.

Fig. Biv-9: Stationwise variations in the average density (no/m^2 x 20) of *Katelysia opima* in Ulhas river estuary and Thane creek

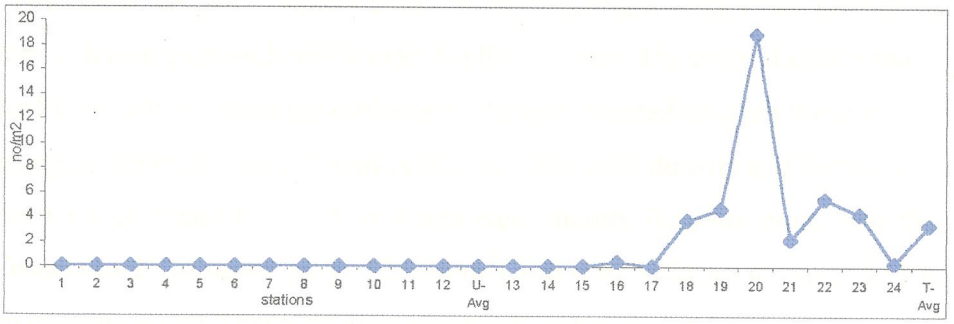
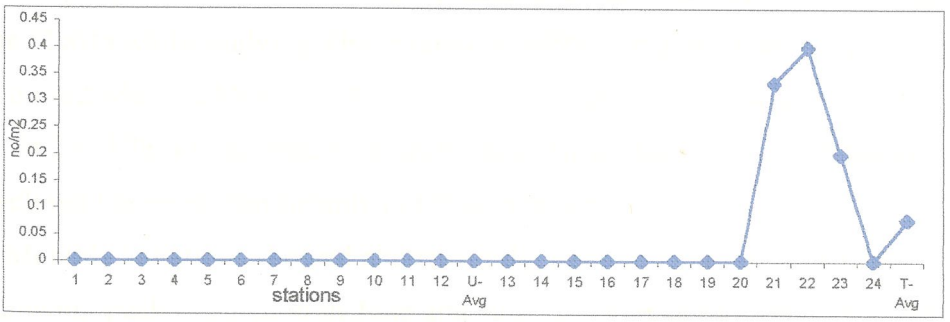


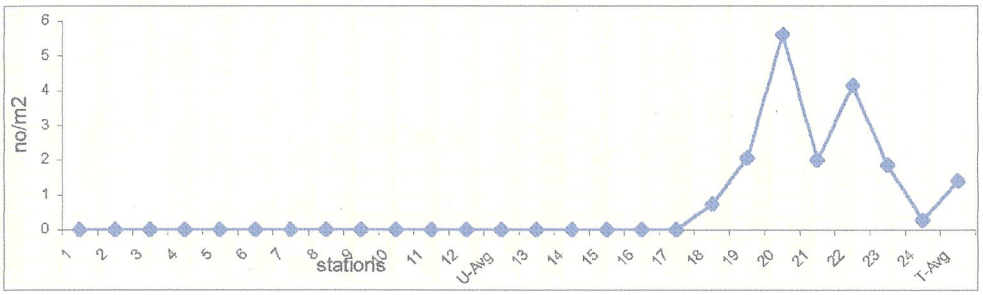
Fig. Biv-10: Stationwise variations in the average density (no/m^2 x 20) of *Katelysia marmorata* in Ulhas river estuary and Thane creek



Cardium asiaticum

This is also known as Blood clam and is collected by locals for food. It occurred only in Thane creek in the middle and seaward zones probably because it prefers high salinity and also calm waters. Hence, maxima was observed at station 20 average density of *Cardium* was 28 no/m^2 which is slightly higher than 15 no/m^2 reported by Quadros (2001). The rise however is not very significant.

Fig. Biv-11: Stationwise variations in the average density (no/m^2 x 20) of *Cardium asiaticum* in Ulhas river estuary and Thane creek



Crabs

The crabs were of 3 types namely *Ilyoplax gangetica* (a small crab of maximum size 2 mm.) Hermit crab and edible crab *Scylla scerrata*. However the later two occurred sporadically, mainly because the collection was not oriented to catch these crabs and they by chance got into the scoop for mud collection. The crab density and biomass are shown in Tables Cr-1 & 2 and Fig Cr-1 to 3 represent mainly *Ilyoplax gangetica* the density varied from 0 to 2720 no/m^2 (avg. 125 no/m^2) and 0 to 5120 no/m^2 (avg. 133 no/m^2) in Ulhas river estuary and Thane creek respectively, whereas the biomass varied between 0 to 25.4 gm/m^2 (avg 1.56 gm/m^2) and 0 to 59.5 gm/m^2 (avg 1.92 gm/m^2) in the two ecosystems respectively. Thus the difference between the two was not significant. Quadros (2001) while studying Thane creek in 1999- 2000 recorded *Ilyoplax* density to be 142 no/m2 whereas Mishra (2002) during the same period observed the crab density 1142 no/m2 in Ulhas river estuary. Thus the population densities in both the ecosystems have declined but more significantly in Ulhas river estuary.

Monthly variations showed almost similar trend in Ulhas river estuary and Thane creek showing peak population in June and July i.e. onset of Monsoon. The stationwise

picture (Fig Cr-1) showed high population density in the middle zone of Ulhas river estuary, declining on either sides whereas in Thane creek the population fluctuated alternately. Usually at stations with high organic pollution the population declined. (eg. Stations 15, 17, 19, 21 etc.)

Table Cr-1: Monthwise and stationwise variations in Crab density (no/m2) in Ulhas river estuary and Thane creek.

	Ulhas River		Crabs	no/m2										Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	20	0	0	0	320	40	20	400	20	0	0	0	68	100	60	0	340	0	60	0	220	20	0	20	0	68
Oct,01	40	0	0	0	240	40	20	300	20	0	0	0	55	120	200	0	240	0	60	0	100	20	0	20	0	63
Nov,01	20	0	0	0	320	40	20	200	20	0	0	0	52	100	60	0	340	0	60	0	220	20	0	20	0	68
Dec,01	0	0	0	240	240	200	20	200	20	0	0	0	77	200	60	0	480	0	60	0	240	20	0	20	0	90
Jan,02	0	0	40	0	0	40	0	0	0	0	0	0	7	100	60	0	340	0	60	0	220	20	0	40	0	70
Feb,02	0	0	0	0	120	100	20	0	0	0	0	0	20	0	0	0	320	0	0	20	0	0	0	0	0	28
Mar,02	160	60	0	0	240	100	20	0	0	0	0	0	48	800	0	0	500	0	0	240	0	0	0	0	0	128
Apr,02	0	0	0	0	0	300	160	0	0	0	0	0	38	300	0	0	20	280	160	40	100	0	0	0	0	75
May,02	500	0	0	0	0	200	40	0	0	0	0	0	62	360	0	0	160	200	120	120	60	0	0	0	0	85
Jun,02	960	100	780	1900	200	340	1300	2720	680	100	280	160	793	240	180	80	1560	0	800	80	5120	0	0	20	0	673
Jul,02	320	100	200	360	360	200	1700	1800	160	0	0	0	433	240	40	0	640	0	100	0	2300	0	0	0	0	277
Aug,02	20	0	120	160	360	120	0	0	0	0	0	0	65	160	60	0	400	0	60	0	300	80	0	20	0	90
Sep,02	20	0	0	0	240	120	20	200	20	0	0	0	52	100	60	0	340	0	60	0	220	20	0	20	0	68
Oct,02	360	0	0	0	0	200	40	0	0	0	0	0	50	360	0	0	160	200	120	120	60	0	0	0	0	85
Nov,02	160	60	0	0	240	100	20	0	0	0	0	0	48	800	0	0	500	0	0	240	0	0	0	0	0	128
Avg	172	21	76	177	192	143	227	388	63	7	19	11	125	265	52	5	423	45	115	57	611	13	0	12	0	133

Table Cr-2: Monthwise and stationwise variations in Crab biomass (gm/m2) in Ulhas river estuary and Thane creek.

	Ulhas River		Crabs gm/m2											Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-Avg
Sept,01	1.18	0	0	0	4.08	1.7	0.62	6.8	0.3	0	0	0	1.22	1.7	0.94	0	9.72	0	0.7	0	3.72	0.6	0	9.5	0	2.24
Oct,01	1.1	0	0	0	4.08	1.24	0.5	6.8	0.2	0	0	0	1.16	1.1	0.94	0	1.38	0	1	0	1.98	0.6	0	1.74	0	0.73
Nov,01	1.6	0	0	0	2.38	1.28	1.1	0.48	0.48	0	0	0	0.61	1.16	1.48	0	2.52	0	0.7	0	2.44	0.6	0	2.64	0	0.96
Dec,01	0	0	0	1.2	2.22	1.96	0.44	1.1	0.3	0	0	0	0.60	1	0.94	0	9.72	0	0.7	0	2.7	0.6	0	2.9	0	1.55
Jan,02	0	0	5.4	0	0	0.7	0	0	0	0	0	0	0.51	1.16	1.48	0	2.52	0	0.7	0	2.44	0.6	0	2.64	0	0.96
Feb,02	0	0	0	0	7	5.2	2.4	0	0	0	0	0	1.22	0	0	0	7.68	0	0	0.4	0	0	0	0	0	0.67
Mar,02	2.4	1.2	0	0	2.9	1.3	0.4	0	0	0	0	0	0.68	7.6	0	0	3.3	0	0	1.96	0	0	0	0	0	1.07
Apr,02	0	0	0	0	0	16	3	0	0	0	0	0	1.58	16	0	0	0.06	5.2	3.9	1	1.7	0	0	0	0	2.32
May,02	2	0	0	0	0	1	1	0	0	0	0	0	0.33	5.3	0	0	2.5	1.6	1.1	0.8	0.9	0	0	0	0	1.02
Jun,02	13.7	0.52	5.7	25.4	0.7	13	19	12.4	5.4	0.6	1	1.1	8.21	1.3	5	1.2	59.5	0	22	1.3	16	0	0	0.4	0	8.89
Jul,02	6.9	1.3	2.2	4.36	6.92	3.3	15.72	16.8	1.9	0	0	0	4.95	1.9	0.7	0	3.12	0	0.5	0	18.5	0	0	0	0	2.06
Aug,02	0.1	0	1	3.16	2.2	1.4	0	0	0	0	0	0	0.66	2.4	1.2	0	19	0	1.7	0	12.9	1.8	0	0.4	0	3.28
Sep,02	1.6	0	0	0	2.38	1.28	1.1	0.48	0.48	0	0	0	0.61	1.16	1.48	0	2.52	0	0.7	0	2.44	0.6	0	2.64	0	0.96
Oct,02	2	0	0	0	0	1	1	0	0	0	0	0	0.33	5.3	0	0	2.5	1.6	1.1	0.8	0.9	0	0	0	0	1.02
Nov,02	2.4	1.2	0	0	2.9	1.3	0.4	0	0	0	0	0	0.68	7.6	0	0	3.3	0	0	1.96	0	0	0	0	0	1.07
Avg	2.33	0.28	0.95	2.27	2.52	3.44	3.11	2.99	0.60	0.04	0.07	0.07	1.56	3.65	0.94	0.08	8.62	0.56	2.32	0.55	4.44	0.36	0.00	1.52	0.00	1.92

Fig. Cr-1: Stationwise variations in the average density (no/m^2 x 20) of *Ilyoplax gangetica* in Ulhas river estuary and Thane creek

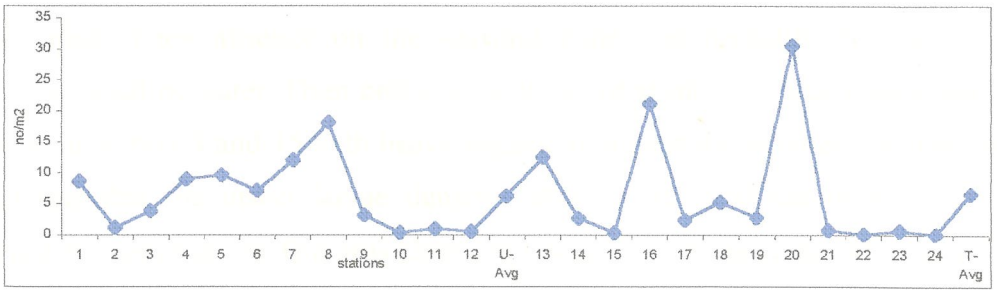


Fig. Cr-2: Stationwise variations in the average density (no/m^2 x 20) of *Scylla serrata* in Ulhas river estuary and Thane creek

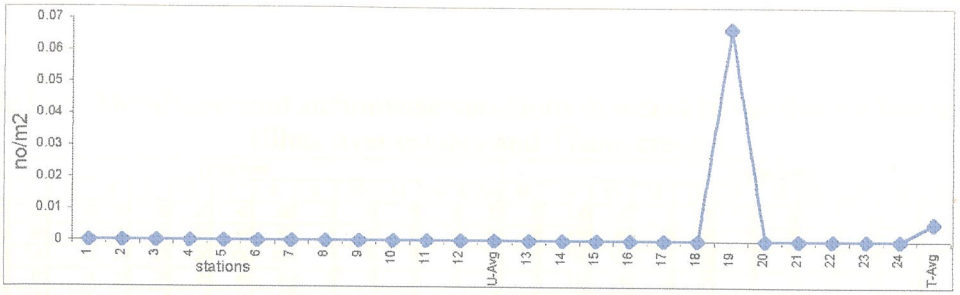
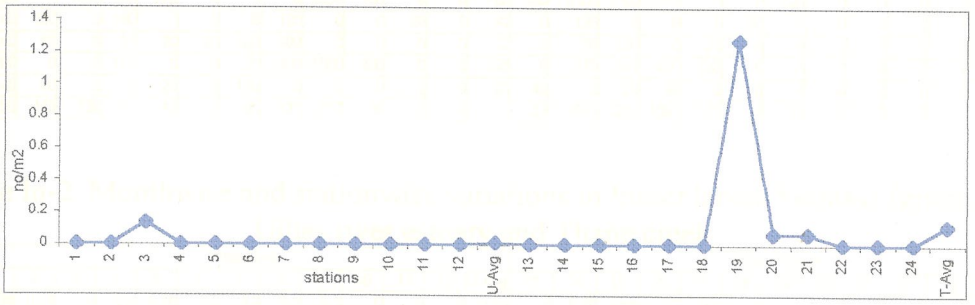


Fig. Cr-3: Stationwise variations in the average density (no/m^2 x 20) of *Hermit crabs* in Ulhas river estuary and Thane creek



Insect larvae (unidentified).

The insect larvae mainly included dipteran maggots (unidentified of two types) were probably the maggots feeding on organic matter. One type was so much resistant that it survived for a long time in 10 % formaldehyde. In Ulhas river estuary the density and biomass were in range 0 to 3360 no/m2 (avg. 147 no/m2) and 0 to 13 gm/m2 (avg. 0.4 gm/m2) respectively. In Thane creek they varied from 0 to 8300 no/m2 (avg 223 no/m2) and 0 to 28 gm/m2 (avg. 0.48 gm/m2)

Stationwise variations in abundance and biomass of insect larvae showed their occurrence through out the Ulhas (except station 12) and riverine and middle zone of Thane creek. Their absence on the seaward zone was probably due to their non preference of saline water. Their peaks were observed at stations with organic pollution. However at station 3 and 15 with heavy organic pollution the number was low. Mishra (2002) recorded the insect larvae density 1200 no/m2 in Ulhas river estuary. She observed 3 types of larvae. Quadros (2001) in his study on Thane creek observed 4 types

of Insect larvae and average density 492 no/m2 Thus there is reduction in population of insect larvae.

Table In-1: Monthwise and stationwise variations in Insect larvae density (no/m2) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	20	60	0	20	20	20	40	80	0	0	0	0	22	0	120	120	0	20	0	0	0	0	0	0	60	27
Oct,01	40	60	0	20	20	20	40	80	0	0	0	0	23	0	120	80	0	20	0	0	0	0	0	0	60	23
Nov,01	20	100	0	20	20	20	100	100	0	0	0	0	32	0	120	120	0	20	0	0	0	0	0	0	60	27
Dec,01	20	60	0	20	20	20	40	80	0	0	0	0	22	0	120	120	0	20	0	0	0	0	0	0	60	27
Jan,02	0	320	100	0	0	0	0	180	0	0	20	0	52	0	100	100	0	20	0	0	0	0	0	0	60	23
Feb,02	20	0	0	0	20	0	140	0	0	0	0	0	15	40	0	20	20	0	0	0	0	0	0	0	0	7
Mar,02	40	40	0	0	20	0	140	0	0	0	0	0	20	40	0	20	20	0	0	0	0	0	0	0	0	7
Apr,02	0	0	0	0	0	0	20	560	2100	0	0	0	223	0	820	40	960	1060	0	0	0	0	0	0	0	240
May,02	60	0	0	160	0	0	20	300	1500	300	0	0	195	0	820	100	400	700	0	0	0	0	0	0	0	168
Jun,02	0	1960	780	160	240	0	20	60	3360	80	0	0	555	0	7840	1060	6240	0	0	180	0	0	0	20	20	1280
Jul,02	1400	3300	1040	500	320	0	0	0	2300	160	0	0	752	360	5300	1300	8300	0	0	300	0	0	0	0	0	1297
Aug,02	40	180	0	140	0	0	0	120	0	0	20	0	42	0	120	0	0	0	60	0	0	0	0	0	0	15
Sep,02	40	80	0	20	20	20	100	100	0	0	0	0	32	0	120	120	0	20	0	0	0	0	0	0	60	27
Oct,02	60	0	0	160	0	0	20	300	1500	300	0	0	195	0	820	100	400	700	0	0	0	0	0	0	0	168
Nov,02	40	40	0	0	20	0	140	0	0	0	0	0	20	40	0	20	20	0	0	0	0	0	0	0	0	7
Avg	120	413	128	81	48	7	55	131	717	56	3	0	147	32	1095	221	1091	172	4	32	0	0	0	1	25	223

Table In-2: Monthwise and stationwise variations in Insect larvae biomass (gm/m2) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0.36	0.74	0	0.2	0.16	0.3	0.1	0.3	0.1	0	0	0	0.19	0	0.16	0.08	0	0.7	0	0	0	0	0	0	0.16	0.09
Oct,01	0.24	0.16	0	0.62	0.16	0.36	0.5	0.3	0.02	0	0	0	0.20	0	0.2	0.08	0	0.7	0	0	0	0	0	0	0.16	0.10
Nov,01	0.3	0.5	0	0.2	0.16	0.24	0.1	0.04	0.1	0	0	0	0.14	0	0.16	0.16	0	0.7	0	0	0	0	0	0	0.16	0.10
Dec,01	0.36	0.76	0	0.2	0.16	0.3	0.1	0.3	0.1	0	0	0	0.19	0	0.16	0.08	0	0.7	0	0	0	0	0	0	0.16	0.09
Jan,02	0	1.66	1	0	0	0	0	0.28	0	0	0.68	0	0.30	0	0.16	0.16	0	0.7	0	0	0	0	0	0	0.16	0.10
Feb,02	0.08	0	0	0	0.01	0	0.4	0	0	0	0	0	0.04	0.2	0	0.02	0.4	0	0	0	0	0	0	0	0	0.05
Mar,02	0.02	0.02	0	0	0.06	0	0.18	0	0	0	0	0	0.02	0.6	0	0.1	0.1	0	0	0	0	0	0	0	0	0.07
Apr,02	0	0	0	0	0	0	0.04	0.54	6.3	0	0	0	0.57	0	1.6	0.06	1.6	2.7	0	0	0	0	0	0	0	0.50
May,02	0.04	0	0	0.16	0	0	0.02	0.5	1.7	1.3	0	0	0.31	0	1	0.02	0.8	0.9	0	0	0	0	0	0	0	0.23
Jun,02	0	8.2	2.7	1.4	0.7	0	0.14	0.12	13	0.08	0	0	2.20	0	28	3	18.4	0	0	0.42	0	0	0	0.1	0.1	4.17
Jul,02	3	3.72	2.5	1.8	1.7	0	0	0	2.5	0.1	0	0	1.28	1.3	6.5	1.3	5.7	0	0	0.1	0	0	0	0	0	1.24
Aug,02	0.06	0.04	0	0.24	0	0	0	0.28	0	0	0.68	0	0.11	0	1	0	0	0	0.18	0	0	0	0	0	0	0.10
Sep,02	0.3	0.5	0	0.2	0.16	0.24	0.1	0.04	0.1	0	0	0	0.14	0	0.16	0.16	0	0.7	0	0	0	0	0	0	0.16	0.10
Oct,02	0.04	0	0	0.16	0	0	0.02	0.5	1.7	1.3	0	0	0.31	0	1	0.02	0.8	0.9	0	0	0	0	0	0	0	0.23
Nov,02	0.02	0.02	0	0	0.06	0	0.18	0	0	0	0	0	0.02	0.6	0	0.1	0.1	0	0	0	0	0	0	0	0	0.07
Avg	0.32	1.09	0.41	0.35	0.22	0.10	0.13	0.21	1.71	0.19	0.09	0.00	0.40	0.18	2.67	0.36	1.86	0.58	0.01	0.03	0.00	0.00	0.00	0.01	0.07	0.48

Fig. In-1: Stationwise variations in the average density (no/m^2 x 20) of *Insect larvae*-1 in Ulhas river estuary and Thane creek

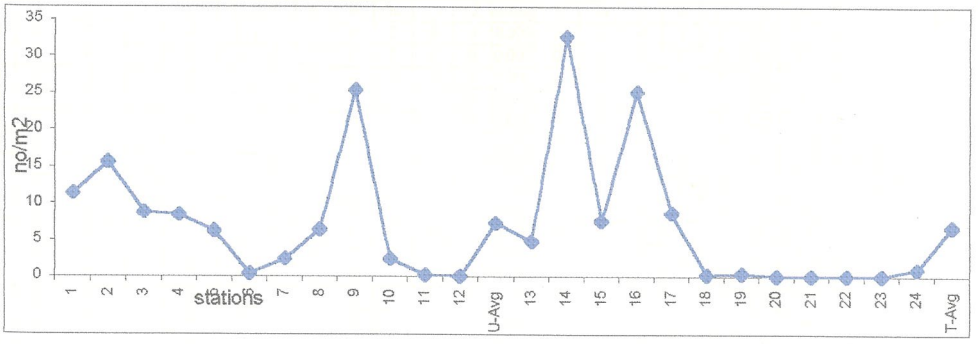
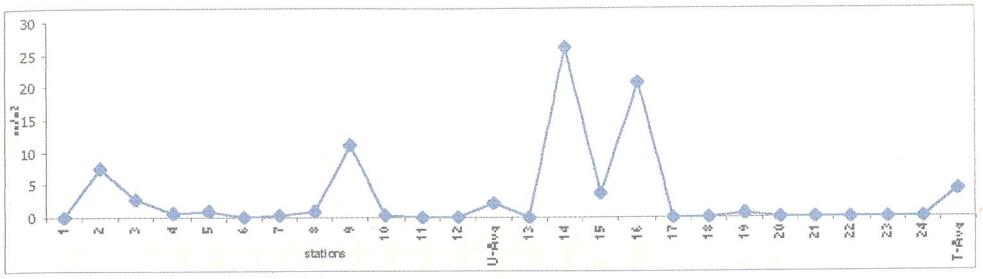


Fig. In-2: Stationwise variations in the average density (no/m^2 x 20) of *Insect larvae*-2 in Ulhas river estuary and Thane creek



Barnacles (Balanus & other crustaceans).

Barnacles normally occur on rocky substratum. In the present collection they occurred attached to small stone or gastropod shell. As they cannot survive high proportion of fresh water they did not occur in Ulhas river estuary whereas in Thane creek their density was from 0 to 200 no/m2 (Avg. 7 no/m2) and biomass 0 to 0.04 gm/m2.

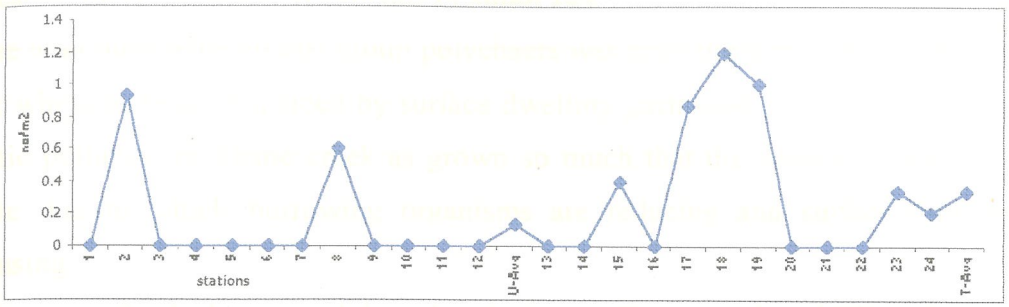
Table Bar-1: Monthwise and stationwise variations in Barnacle density (no/m2) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	3
Oct,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	3
Nov,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	3
Dec,01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	3
Jan,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	3
Feb,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0	0	0	0	13
May,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	8
Jun,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	60	0	22
Jul,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	8
Aug,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	100	0	0	0	0	0	0	60	23
Sep,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	3
Oct,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	8
Nov,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	7	27	27	0	0	0	11	4	7

Table Bar-2: Monthwise and stationwise variations in Barnacle biomass (gm/m2) in Ulhas river estuary and Thane creek.

	Ulhas River													Thane Creek											
	1	2	3	4	5	6	7	8	9	10	11	12	U-Avg	13	14	15	16	17	18	19	20	21	22	23	24	T-avg
Sept,01	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0.02	0	0	0	0	0	0	0.002
Oct,01	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0.02	0	0	0	0	0	0	0.002
Nov,01	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0.02	0	0	0	0	0	0	0.002
Dec,01	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0.02	0	0	0	0	0	0	0.002
Jan,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0.02	0	0	0	0	0	0	0.002
Feb,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0.000
Mar,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0.000
Apr,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0.04	0	0	0	0	0	0	0.003
May,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	0.04	0	0	0	0	0	0.003
Jun,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	0.04	0	0	0	0.02	0	0.005
Jul,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	0	0	0	0	0.04	0	0.003
Aug,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0.02	0	0.02	0	0	0	0	0	0	0.01	0.004
Sep,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0.02	0	0	0	0	0	0	0.002
Oct,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	0.04	0	0	0	0	0	0.003
Nov,02	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0.000
Avg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.011	0.008	0.000	0.000	0.000	0.004	0.001	0.002

Fig. Bar-1: Stationwise variations in the average density (no/m^2 x 20) of *Barnacle* in Ulhas river estuary and Thane creek



In Thane creek peaks of Barnacles were observed at stations 13, 15, 17, 18, 19, & 23. Balanid density was more on east coast of Thane creek Other crustaceans mainly included the organisms like gamarus. They occurred in negligible quantity in Ulhas river estuary and in Thane creek the average density was 130 no/m2 and biomass 0.21 gm/m2. The occurrence was significantly high on east coast than the west coast, Quadros (2001) reported lower balanus density 8 no/m2 in Thane creek during the study done in 1999-2000.

Summary

The macrobenthos included 6 major animal groups, namely coelenterata (sea anemones) nematodes, platyhelminthes, annelida (oligochaeta and polychaeta), mollusca (gastropoda and bivalves and arthropoda (crabs, balanus, other crustaceans and insects). The macrobenthic population density and biomass were 8 to 10 times higher in Thane creek as compared to Ulhas river estuary. This has resulted mainly due to heavy organic pollution in Thane creek caused by large amount of domestic sewage released, which gets relatively less diluted as compared to Ulhas river estuary owing to lesser water mass.

Considering density in Ulhas river estuary polychaeta formed the most dominant group followed by oligochaetes, nematodes, molluscs. In Thane creek nematoda was most dominant followed by gastropoda, bivalves and polychaetes. Considering biomass the trend was different. For Ulhas river estuary the order of dominance was polychaeta > Gastropoda > Crabs > others. In Thane creek it was Gastropod > bivalve > Polychaete > seaanemones. When the data was compared with the past data following significant differences were recorded.

1. The density in both the ecosystems showed increase but the biomass showed decrease suggesting **increase in the organisms of small size**.

2. The mud burrowing animal group polychaeta was once the dominant group in Thane creek which is being displaced by surface dwelling gastropods. This indicates that the organic pollution in Thane creek as grown so much that the sediments are becoming anoxic due to which burrowing organisms are reducing and surface dwellers are increasing.

3. The types of polychaetes and their distribution in Thane creek and Ulhas river estuary are changing due to increased organic pollution, chemical pollution and changed sediment texture. Polychaetes like *L. ounaryensis, L. indica, Polydora tentaculata* are getting eliminated from Thane creek whereas highly pollution tolerant *C. burmensis, Dendronereis spp., L. ouanaryensis, Nephythys spp., Sigambra bassi* are getting introduced in the estuary. These changes indicate that organic pollution in Ulhas river estuary is increasing and in Thane creek has crossed its limits.

4. The gastropod population has declined in Ulhas river estuary and increased in Thane creek. However the gastropod type *Auricula elongata, Auricula spp., Drupa spp., Fairbankia bombayana, Littorina ventricosa, Melanoides tuberculata, Dostia violaceae* (a organic pollution tolerant species), *Neretina spp., Turbinicola nux* which were recorded in the past were not reported in the present study. *Cerethideopsilla spp.* seems to develop resistance to organic pollution.

5. Bivalve population has declined in Ulhas river estuary and in Thane creek small sized bivalve types have increased. There is significant reduction in the density of edible bivalves *Cardium spp. (blood clam) and Katelysia spp.*

6. Crab Illyoplax sp. (a mud burrowing small size crab) has declined in both Thane creek and Ulhas river estuary but more significantly in Ulhas river estuary.

7. Both the ecosystems showed dominance of pollution tolerant animal groups but at certain stations which had proximity with major sewage reaches (viz. Station 3 and 15) their number dwindled indicating deterioration beyond their tolerance.

The macrobenthos in general indicate growing pollution in Ulhas river estuary and pollution level crossing the tolerance limits in Thane creek.

Chapter VII

Fishery

India has 8129 km long coastline, 5 million sq km of continental shelf area and 2.02 million sq km of Exclusive economic zone (EEZ) which supports varied biodiversity (Somavanshi and Bhargava, 2002). There is about 3.9 million ha. of estuarine and 3.5 million ha of brackishwater area in the country. Approximately 1.2 million ha of coastal area has been identified suitable for brackish water aquaculture. These areas support a good amount of fishery of different types and the present estimate of marine fishes in India is 2.8 million tonnes. However in last two decades the Indian Fishery scenario has rapidly changed and has shown signs of depletion.

In view of the global conventions on biodiversity and code of conduct for responsible fisheries (CCRF) the Indian fisheries will have to adopt certain measures for management and conservation of biodiversity in coastal waters for use of these resources by future generations. Maharashtra contributes significantly to marine fishery production of India. In Maharashtra, Mumbai and Thane contribute significantly. However the Mumbai- Thane area has a large industrial belt and burgeoning human population which can cause significant harm to aquatic life and critical ecosystems through discharge of effluents and sewage (Somavanshi and Bhargava, 2002). Creeks and estuaries are very important environments from fishery point of view because they act as feeding and breeding grounds for many marine (as well fresh water) fishery organisms. Hence, these environments should be constantly assessed, monitored, and measures to avoid the ill effects of pollution should be defined and implemented.

Thane creek and Ulhas river estuary were once very rich ecosystems giving excellent fishery yield, but since the development of the Asia's largest industrial belt and cosequent urbanisation; the fishery of this region is declining. Gokhale and Athalye (1995) while studying the upstream stretch of Thane creek during 1991-1993 observed almost 67% decline in fishery near Thane city as compared to that in 1984-85. Presently fishing activity near Thane city has completely stopped due to extremely poor yield. This observation made it necessary to study the fishery of Thane creek and Ulhas river estuary to know the exact present status.

Materials and Methods.

Zonewise samples were collected from November 2001 to October 2002. Care was taken to ensure collection from all possible types of gears used by local fishermen such as barrier net (Vana), Hand net (Yeri), bag net (Bokshi & Dol), drift net (disco jali) and hand picking in prominent fishing areas. Fishes were carried in ice box to the laboratory for further study.

Fish types were identified using the identification keys in "Fishes of India" (Day, 1889). The fishing intensity in most of the parts of these ecosystems fluctuated seasonally and even daily on acount of unattractive yield. Due to this reason it was difficult to estimate quantative fishery. Hence emphasis was given on qualitative aspects. Apart from recording the types of fishes; at every station the data on different types of fishing nets, different methods of fishing, polluting sources, sand dredging were recorded through observations and interview with the fishermen. The data has been presented zonewise.

Types of fish, prawns, crabs & Mollusc obtained during the study

Table F-1 shows zonewise distribution of fin fish fauna of Ulhas river estuary and Thane creek. Total 61 types belonging to 23 families were recorded of which 47 types were recorded in Ulhas river estuary and 55 types in Thane creek. The difference in number could be mainly due to more brackish water conditions in Ulhas river estuary as compared to dominance of sea water in Thane creek.

The shell fishery distribution has been shown in Table F-2. Total 17 types were recorded which included molluscs and crustaceans. In shell fishery more types (fifteen) were recorded in Ulhas river estuary mainly due to more diversity of arthropodan animals. In Thane creek 12 type of fishery organisms were recorded of which molluscan types were more than Ulhas river estuary. Edible clams, Cardium spp. and Katelysia spp. were not observed in Ulhas river estuary probably due to lower average salinity (as the fresh water flow is more) and faster currents of water. As seen from Table F-1 & F-2 the fishery declines towards zone 1 i.e. riverine end of the creek as well as estuary. This can be called a natural phenomenon as the salinity reduces towards the riverine end. But if we compare Thane creek with Ulhas river estuary it is observed that relatively high proportion of total fishery types reach up to zone 1 in Ulhas river estuary, whereas in

Thane creek most of the fish types are captured at the mouth of the creek and less than 10 % can reach the upstream stretch Zone 1. To trace the reason for this disturbance causing activities were recorded in each zone. They are summarised in Table F-3.The major anthropogenic disturbances include sand excavation, sand landing, sewage and industrial effluent outlets, solid waste dumping and reclamation. As seen from the Table the sand excavation and sand landing activities were not observed in Thane creek. In Ulhas river estuary the middle zone had this activity the maximum. If other activities are seen the disturbances were uniformly spread in Ulhas river estuary, whereas in Thane creek the anthropogenic disturbance causing factors were more in the riverine zone which reduced towards the sea. Due to these disturbances and polluting factors probably the fishery was affected. In Thane creek heavy pollution probably repelled the fishes from entering the upstream region of the creek. Only 6 i.e. 9 % of the total fishery type were recorded in zone 1 whereas in zone two 17 types i.e. 25 % of the total were recorded. In Ulhas river estuary as the water mass is more the pollutants got diluted so also the organic pollution was much lower than Thane creek. This allowed more fishery types to reach zone 1. (13 types, i.e. 22%) and zone 2 (43 types i.e. 74 %) The zone wise availability of fishes has affected the fishing activities in Ulhas river estuary and Thane creek. Table F-4 has summerised the fishing activities in different zones. The zones with more stress and less fishery types (Zone 1, Zone 2) show low fishing activity because of nonavailability of fishery yield. Thus it can be concluded that the quantitative fishery has got significantly affected by the pollution status of different zones of Thane creek and Ulhas river estuary.

Comparison with the past data and other observations.

1) Gokhale and Athalye (1994) estimated quantitative fishery in 5 km upstream stretch of Thane creek near Thane city and compared it with the earlier data of 1984 -85. They reported 67 % decline in fishery of this region caused due to pollution. Presently there is "zero" fishing practice in this region as no fish catch is available. This shows, to what extent the pollution has increased.

2) Fishery organisms like fishes *Trypauchen vagina*, mudskippers and molluscs *Paphia spp., Meretrix spp., Cardium spp.* and prawns were abundant in Thane creek about 20 years back. They were seen up to zone 1. Presently they are eliminated from zone 1 and

zone 2. The mudskipper and prawn are not obtained almost throughout the Thane creek. This has happened mainly due to a) severe and growing pollution (organic and chemical) in the creek and especially in zone 1 & 2 (in zone 3 the pollutants get diluted, reducing their impact). b) The sediment composition of Thane creek has changed significantly in past decade. Previously the sediment was silty-clay with more clay and less silt. This made the substratum hard and less sinking which was favourable for prawns, mudskippers, etc. Presently the siltation in the creek has got enhanced due to heavy sewage load, solid waste dumping and construction activities. This has made the sediment clayey-silt, i.e. more silt, less clay. Such sediments are very much sinking type and unfavourable for prawns, mudskippers and bivalves. Hence probably the above organisms have got eliminated from the creek.

3) Zone 1 in Ulhas river estuary showed growing organic pollution and siltation hence from this zone also mudskippers are getting displaced.

4) Zone 1 & 2 of Thane creek showed heavy pollution by plastic bags which clogged the nets, making the fishing operations almost impossible.

5) The only favourable observation to note is significantly good variety of fishery at the mouth of the creek. The fishery however is not able to move in the upstream zones. This suggests that if the pollution in the creek is checked in time, the fishery in the upstream zones can be revived.

Conclusion

Thus the fishery studies in Thane creek and Ulhas river estuary have shown the extent of deterioration due to pollution in different areas of the two ecosystems but at the same time they indicate the possibility of reviving the systems if mitigation measures are timely implemented.

Table F-1 *Zonewise occurrence of the Fin fish fauna in the Ulhas river estuary and Thane creek*

	FIN-FISH FAUNA		ULHAS RIVER ESTUARY			THANE CREEK		
No	SPECIES	FAMILY	Z-I	Z-II	Z-III	Z-I	Z-II	Z-III
1	Boleopthalmus dussumieri	Gobiidae	+	+	+++++	-	-	+
2	Boleopthalmus boddaerti		-	+	+++	-	-	+
3	Gobioides tennuis		-	+	+	-	-	-
4	Gobius giuris		-	+++	+	-	-	++
5	Gobius ocelatus		-	-	++	-	-	+
6	Tripauchen vagina		-	++	+++	-	-	-
7	Eleotris amboinensis	Trachinidae	-	-	-	-	-	+
8	Sillago sihama	Clupeidae	-	+	++	-	-	+++
9	Kawala coval		-	+	+++	-	-	+++
10	Trichiurus savala		-	++	+++	-	-	+++
11	Clupea sp.		-	++	++++	-	-	++
12	Pellona feligera		-	++	+++	-	+	++
13	Pellona elogata		-	++	++	-	-	++
14	Coilia Dussumieri		-	+	+++	-	-	+++
15	Chaetosus chacunda		-	-	+++	-	++	++
16	Chaetosus nasus		-	+	++	+	+	+++
17	Engraulis sp.		-	++	+++	-	-	+
18	Megalops cyprinoids	Chromidae	++	+	+	-	-	++
19	Etroplus maculates	Sparidae	-	+	++	-	-	-
20	Chrysophrys datnia	Cyprinodontidae	-	++	++	-	-	++
21	Haplochilus lineatus		-	++	++	-	-	-
22	Mugil spigleri	Mugilidae	+	-	+++	+	-	++
23	Muugil Dussumieri		-	++	-	+	-	++
24	Batrachus grunniens	Batrachidae	-	+++	+	-	-	+
25	Lates calcarifer	Percidae	+	+	+	-	+	++
26	Therapon theraps		-	+	+++	-	+	+++
27	Therapon jarbua		+	-	+++	-	+	+++
28	Teuthis cramin		-	++	-	-	-	+
29	Oreochromis mossambicus	Cichlidae	++	+++	++	-	+	+
30	Mystus gulio	Siluridae	++	+	++	++	+++	++
31	Mystus sp.		+	+	++	-	-	-
32	Arius thalassinus		+	-	+++	-	-	++
33	Plotossus arab		-	-	-	-	-	-
34	Osteogeniosus militaris		-	+	-	-	-	+
35	Barbus pinnauratus	Cyprinidae	-	++	-	-	-	++
36	Scaena Dussumieri	Scieaidae	-	-	++++	+	+	+++
37	Scaena glaucus		+	+	-	-	+	+++
38	Otolithoides brunneus		-	-	++	-	+	++
39	Umbrina russellii		-	+	-	-	-	++
40	Tetrodon Fulvitilis	Gymnodontes	-	+	++	-	-	+
41	Tetrodon oblongus		-	-	++	-	-	+
42	Tetrodon stellatus		-	-	-	-	-	+
43	Tetrodon lunaris		-	-	-	-	-	+
44	Polynemus tetradactylus	Polynemidae	-	-	+	-	-	+++
45	Cynoglossus elongates	Pleuronectidae	-	-	++	-	-	++
46	Cynoglossus lingua		-	+	+	-	-	++
47	Congromuraena anago	Muraenidae	--	-	++	-	-	+
48	Harpodon nehereus	Scopelidae	-	-	++	-	-	+
49	Sctophagus argus	Squamipinnes	-	-	+++	-	-	+
50	Triachanthus brevirostris	Sclerodermi	-	-	+	-	-	+
51	Triachanthus strigilifer	Carangiidae	-	-	-	-	-	+
52	Caranx sp.		-	-	-	-	-	+++
53	Equula rueonius		-	++	++	-	-	+
54	Equula splendens		-	-	-	-	-	++
55	Equula insidiatrx		-	-	-	-	-	+
56	Equula Dussumieri	Scombridae	-	-	-	-	-	+
57	Rastrelliger kanagurta		-	-	-	-	-	++
58	Cybium guttatum		-	-	-	-	-	+
59	Echeneis neuerates	Stromatidae	-	-	-	-	-	+
60	Stromateus argenteus		-	-	-	-	-	+
61	Stromateus sinensis		-	-	-	-	-	+
	Total no of spp.		*10*	*33*	*41*	*5*	*11*	*55*

Table F-2 : Zone wise occurrence of shell fish in Ulhas river estuary and Thane creek.

	Shell Fish Fauna		Ulhas river estuary			Thane creek		
No	SPECIES	FAMILY	Z-I	Z-II	Z-III	Z-I	Z-II	Z-III
1	Parapenaeopsis sculptilis	Penaeidae	-	+++	++	-	+	++
2	Peneaus sp.		-	+++	+++	-	+	+
3	Metapenaeus monoceros		-	+	++	-	-	++
4	Metapeneaus sp		-	-	++	-	-	-
5	Penaeus indicus		-	-	++	-	-	+
6	Trachypenaeus sp.		-	-	+	-	-	-
7	Macrobrachium rosenbergii.	Palaemonidae	-	++	+	-	-	-
8	Acetus sp.	Sergestidae	-	+	+	-	+	++
9	Alpheus sp.	-	-	-	+	-	-	+
10	Cardium sp.	-	-	+	+	-	+	++
11	Paphia sp.	-	+	+	++	-	++	++
12	Katelysia	-	-	++	+	-	-	-
13	Portunus sanguinolentus	-	-	-	++	-	-	+
14	Charybdis sp.	-	-	-	++	-	-	-
15	Scylla serrata.	-	++	++++	++	+	+++	++
16	Octopus sp	-	-	-	-	-	-	+
17	Loligo sp..	-	-	-	-	-	-	+
	Total No of spp.		2	9	15	1	6	12

Table F-3 : Types of disturbances observed in Ulhas river estuary and Thane creek.

No	A Sand dredging activity	Ulhas River estuary			Thane creek		
		Z-I	Z-II	Z-III	Z-I	Z-II	Z-III
1.	No. of boats engaged in sand excavation	11	83	8	-	-	-
2.	Sand landing stations	2	7	2	-	-	-
Total A		13	90	10	-	-	-
No.	B Other anthropogenic activities						
1.	Major sewage & industrial effluent outlets	4	3	5	12	9	2
2.	Distruction of mangrove sites through solid waste dumping and reclamations.	9	9	7	6	6	5
Total B		13	12	12	18	15	7

Table F-4 : Types of Fishing activities in Ulhas river estuary and Thane creek.

No	FISHING TYPE	ULHAS RIVER ESTUARY			THANE CREEK.		
		Z-I	Z-II	Z-III	Z-I	Z-II	Z-III
1.	Mudskipper fishing	2	1	24	-	-	-
2.	Bag net (Dol/Bokshi)	-	20	71	-	-	11
3.	Barrier net (Vana)	2	15	12	1	4	35
4.	Driftnet (Disco jail)	-	2	-	1	45	250
5.	Dragnet (Yeri)	1	-	-	-	-	10 (150)*
Total		5	38	107	2	49	306

* The gear was used extensively for prawn fishing from March to May and August to October, when water temperature was high.

Chapter VIII
Heavy Metals

Introduction

Heavy metals form an important abiotic component of marine ecosystem when it is recipient of domestic and industrial effluents and solid wastes because these effluents contain different heavy metals. Particularly lead, zinc, and cadmium are present in significant quantity in the sewage sludge and effluents (Valicla *et al.*, 1976). Even in digested sludge the metals are plentiful in bound form and they get released to a considerable extent when they are dumped in marine water due to altered physico-chemical environment (Laxen, 1983). Thus the metals which are immobile in one environment (sludge) can get released in the other (sea water).

In shallow waters of coastal zones and especially in estuaries where the salinities are changing, the behaviour of metals is very complex, governed by many environmental factors as well as metabolism of water and sediment (Harbison, 1986). The metals associate with sediment particles either by adsorption or by complexation, forming part of the particle structure which gradually sink with sediment (Laxen, 1983). Thus the shallow water systems not only provide a physical trap for fine particles and their transported load of trace metals but also a chemical trap for precipitation of metals from solution.

The trace metals present in waters and sediments are not conservative but go through biogeochemical cycles and tend to accumulate in organisms at various trophic levels creating potential hazards for the biota and human beings. Various organisms are known to accumulate metals to levels higher than their environments, resulting in biomagnification (Murphy and Spiegel, 1983). It is necessary to regularly check the metal levels in the abiotic and biotic components and implement suitable measures to maintain them low.

Thane creek, as mentioned eariler receives metals through heavy load of untreated domestic sewage and industrial effluents. According to Sahoo and Mukherjee (1983), the Ulhas river estuary also receives high ampunt of metals (10,000 kg Copper and 4000,000 kg Zinc per annum) through the sewage and effluents discharged from many industrial sectors in Ambernath, Kalyan, Dombivili and Thane region. In the present study the

metals namely Copper, Cadmium, Lead, and Zinc in different components of Thane creek and Ulhas river estuary were studied.

Materials and Methods

The samples were taken in measured quantity (100 ml water / 1 gm sediment / 1 gm or maximum quantity of tissue) and digested using suitable quantity of concentrated acids viz. HNO_3 or HCl and $HClO_4$. The clear digest was diluted to 50 ml volume using double distilled water. The metal estimation was done at IIT, Powai using Inductively Coupled Plasma Atomic Emission Spectroscopy.

Results and Discussion

According to the metal analysis report from IIT - Powai, concentration of cadmium and lead were below detectable level of 0.1 ppm, hence concentration of copper and zinc are shown in Table Me-1 to 8. In earlier studies (Athalye, 1988 and Athalye & Gokhale, 1995) significant amount of lead was detected in the samples the present results indicate reduction in lead contents whereas there was negligible to low cadmium in the samples of Thane creek hence occurrence of undetectable levels of cadmium in the present samples is not suprising.

Metals in water samples (Table Me-1).

Copper - Seasonal averages of copper contents ranged from 0.43 ppm to 1.25 ppm with overall average (0.767 ppm) in Ulhas river estuary and from 0 to 1.96 ppm (avg. 1.12 ppm.) in Thane creek. Thus the copper level was slightly higher in Thane creek. The seasonal variations showed high copper during monsooon and relatively lower concentration in other seasons, however in Thane creek average copper contents were high in premonsoon (summer). Mahajan *et al.* (1987) during their study in 1985 recorded average 0.011 ppm copper in Thane creek and Ulhas river estuary thus there is **69 times increase in copper contents of water of Ulhas river estuary and 101 times increase in Thane creek.**

Zinc - The zinc contents in the water were in general high in Thane creek (overall average 0.404 ppm) than in Ulhas river estuary (overall average 0.17 ppm). As compared

to the average zinc values reported in water samples of 1985 (Mahajan *et al.*, 1987, Ulhas river estuary - 0.112 ppm and Thane creek 0.093 ppm) **there is 4 times increase in Thane creek and 1.5 times increase in Ulhas river estuary**. Thus though the zinc levels have increased in past 18 years, the rise is not as high as copper. The season wise variation in average zinc levels was from 0.01 to 0.3 ppm in Ulhas river estuary and 0 to 0.72 ppm in Thane creek.

Metals in Sediment (Table Me-2)

Copper - Average copper in the sediments of Ulhas river estuary was 232.87 ppm (µg/g) whereas in Thane creek it was 204 ppm. Mahajan *et al.* (1987) reported 110 µg/g and 91 µg/g average copper in the sediments of Thane creek and Ulhas river estuary respectively. **As compared to the values there is 2.5 times increase in Ulhas river estuary and 1.8 times increase in Thane creek.** In Ulhas river estuary the sediment copper was high in monsoon and declined by premonsoon. In Thane creek the variation in the sediment metal was not high, the highest average was recorded in winter (Late post monsoon) and the minimum average in monsoon.

Zinc - Sediment zinc also showed higher average in Ulhas river estuary (248 ppm) as compared to Thane creek (228 ppm). The seasonal trend showed high zinc in monsoon which declined by premonsooon or summer. This trend was observed both in Thane creek and Ulhas river estuary. **The zinc levels have almost doubled in both the ecosystems** as compared to those reported by Mahajan *et al.* (1987).

Thus, as compared to the increase in the metal contents of water, the increase in the sediments is relatively less.

Metals in Mangroves.

Metal levels in leaves, stem and pneumatophores (roots) of three species of mangroves namely *Avicennia marina, Sonneratia apetala* and *Rhizophora mucronata* were studied . In general average copper content ranged from 14.31 ppm (µg/g) to 28.79 ppm. As compared to sediment metal levels the mangroves did not show significant bioaccumulation. Zinc levels in *A. marina* and *S. apetala* were more than double as

compared to the copper but in *R. mucronata* they were comparable with copper. Average zinc contents ranged from 22.45 to 161.45 ppm. *Sonneratia apetala* in general had higher metals as compared to the other mangroves. Some of the averages from Thane creek were higher than Ulhas river estuary but the difference cannot be said to be very significant.

Metals in Plankton (Table Me-4)

The phytoplankton showed more bioaccumulation of metals as compared to zooplankton. It is probable that they do not have ability to regulate the metals.

Metals in Macrobenthic organisms

Mollusca (Table Me-5 & 6) - In the molluscan organisms metal contents were studied in shell as well as body tissue to find out whether they accumulate metals in the shell. However the metal levels in the shells were not very high. Bioaccumulation was noticed to some extent in *Cuspidaria spp., Haminea spp.* but not very significantly. Average metals in gastropod shells were copper 147 ppm in Ulhas river estuary and 74 ppm in Thane creek. Zinc 312 ppm in Ulhas river estuary and 215 ppm in Thane creek. Whereas in biomass the averages were copper 286 ppm in Ulhas river estuary and 150 ppm in Thane creek. Zinc 531 ppm in Ulhas river estuary and 210 ppm in Thane creek. This showed higher metal levels in the gastropods of Ulhas river estuary as compared to Thane creek. Mahajan *et al.* (1987) reported levels of Copper and Zinc to be 0.026 to 0.034 ppm and 0.425 to 0.454 ppm respectively in Thane creek and Ulhas river estuary. As compared to these values of year 1985, the present metal contents are extremely high which indicate growing metal pollution in the creek and the estuary. High levels of copper and zinc were observed especially in *Melampus spp., Assaminea spp.* and *Stenothyra spp.*

In the bivalves Copper ranged from 15 ppm to 125 ppm and zinc from 15 to 2618 ppm. The averages were relatively lower than the gastropods and acccumulation was not significant in the shell except *Cuspidaria spp.* As compared to the levels reported by Mahajan *et al.* (1987) - copper 0.048 to 0.067 ppm and zinc 0.526 to 0.620 ppm, the present values are significantly high.

Polychaetes (Table Me-7) - Polychaetes in general had very high metal contents. Average copper ranged from 394 to 2433 ppm and average zinc from 362 to 2037 ppm. Among the three species studied for metals, *Lycastis indica* had very high copper (6177 ppm in Thane creek) and showed significant bioaccumulation (concentration factor with sediment = 30). The polychaetes in general had high concentration factors indicating significant bioaccumulation. The fluctuating levels of metals suggest that the polychaetes probably eliminated the accumulated metals after they reached a threshold value.

The present metal levels are extremely high as compared to those reported by Mahajan *et al* (1987). They recorded average metals in the polychaetes to be in Thane creek Copper 0.053 ppm and Zinc 0.296 ppm. and in Ulhas river estuary Copper 0.062 ppm and Zinc 0.358 ppm. However it is not clear from the publication as to which polychaetes were predominant during those days. As mentioned earlier the polychaete fauna from the two ecosystems has changed in past 10 to 15 years due to growing pollution. It is probable that presently the metal tolerant polychaetes might have settled in these ecosystems.

Other macrobenthos (Table Me-7) - The other macrobenthos included the crab *Illyoplax gangetica*, nematodes, oligochaetes, sea-anemones, insect larvae. All of them accumulated significant amount of metals. The metal levels were especially very high in nematodes and oligochaetes. Thus small organisms seem to accumulate more amount of metal. Data by Mahajan *et al.* (1987) has given average metals in crabs as Copper 0.029 ppm in Thane creek and 0.028 ppm in Ulhas river estuary; Zinc 0.324 ppm in Thane creek and 0.414 ppm in Ulhas river estuary. As compared to these values in 1985, the present values (160 to 4562 ppm Copper, 348 to 4750 ppm Zinc) are too high.

Fishery Metals (Table Me-8) - The metals in the muscles of dominant fish types namely *Tilipia spp., Mugil spp., Mystus spp., Boleopthalmus spp., Lates spp.,* and crab *Scylla serrata* were studied the average copper was 15 ppm in Ulhas river estuary and 35 ppm in Thane creek. Whereas average zinc was 78 ppm in Thane creek and 83 ppm in Ulhas river estuary. Among the fishes *Tilipia spp.* contained the highest amount of metal. Crab *Scylla serrata* showed higher contents than the fishes Nair *et al.* (1997) reported 1.5 ppm Copper and 27 ppm Zinc in *Mugils* of Cochin coast, the present values are slightly higher

than these. However they are significantly high as compared to fish average values 0.013 ppm copper 0.3336 zinc recorded by Mahajan *et al.* (1987) during the study of these ecosystems in 1985.

Summary The comparison of metal averages recorded in 1985 (Mahajan *et al.*, 1987) with the present data clearly indicate how metal contents are growing significantly in all the abiotic and biotic components of Ulhas river estuary and Thane creek. The small organisms like nematodes, oligochaetes could be probably useful as indicators of metal pollution as they show more bioaccumulation.

Table Me-1 : Heavy metals (ppm) in the waters of Ulhas river estuary and Thane creek.

		Copper		Zinc	
	Seasons	Ulhas River Estuary	Thane Creek	Ulhas River Estuary	Thane Creek
Zone 1	Monsoon	1.231	2.736	0.025	0.545
Zone 2		1.55	0.4676	0	0.003
Zone 3		0.976	0.408	0	0
Avg		1.25	1.20	0.01	0.18
Zone 1	Winter	0.2502	0	0	0
Zone 2		1.095	0	0.2185	0
Zone 3		0.387	0	0	0
Avg		0.58	0.00	0.07	0.00
Zone 1	Summer	0.155	0.3	0.18	0.375
Zone 2		0.62	0.39	0.375	0.285
Zone 3		0.515	3.25	0.34	1.485
Avg		0.43	1.31	0.30	0.72
Zone 1	Premonsoon	1.11	2.91	0.345	0.77
Zone 2		0.19	1.79	0.13	0.975
Zone 3		1.12	1.19	0.43	0.41
Avg		0.81	1.96	0.30	0.72
Overall avg.		0.767	1.12	0.17	0.404

Table Me-2 : Heavy metals (ppm.) in the Sediments of Ulhas river estuary and Thane creek.

		Copper		Zinc	
	Seasons	Ulhas River Estuary	Thane Creek	Ulhas River Estuary	Thane Creek
Zone 1	Monsooon	361.98	201.98	367.95	296.95
Zone 2		224.98	169.98	349.95	226.95
Zone 3		228.98	221.98	229.95	254.95
Avg		271.98	197.98	315.95	259.62
Zone 1	Winter	296.98	202.98	242.95	237.95
Zone 2		215.98	207.98	215.95	229.95
Zone 3		212.98	221.98	193.95	238.95
Avg		241.98	210.98	217.62	235.62
Zone 1	Summer	179.98	286.98	226.95	194.95
Zone 2		194.98	165.98	217.95	184.95
Zone 3		178.98	158.98	184.95	181.95
Avg		184.65	203.98	209.95	187.28
Overall avg.		232.87	204.31	247.84	227.51

Table Me-3 : Heavy metals (ppm.) in the Mangroves of Ulhas river estuary and Thane creek.

Mangroves	Copper		Zinc	
	Ulhas River Estuary	Thane Creek	Ulhas River Estuary	Thane Creek
A.marina leaves	19.98	22.98	75.95	68.95
A.marina stem	22.98	9.98	47.95	47.95
A.marina pneumatophores	29.98	9.98	54.95	39.95
Avg	24.31	14.31	59.62	52.28
S.apetala leaves	15.98	36.98	63.95	146.95
S.apetala Stem	29.98	20.605	75.95	175.95
Avg	22.98	28.7925	69.95	161.45
Rhizophora leaves	22.98		27.95	
Rhizophora stem	13.98		16.95	
Avg	18.48		22.45	

Table Me-4 : Heavy metals (ppm.) in the Plankton of Ulhas river estuary and Thane creek

Plankton	Copper		Zinc	
	Ulhas River Estuary	Thane Creek	Ulhas River Estuary	Thane Creek
Zooplankton	68.162	105.98	118.132	205.95
PhytoPlanktonk	766.647	699.98	866.617	1162.45

Table Me-5 : Heavy metals (ppm.) in the Macrobenthos -Gastropods of Ulhas river estuary and Thane creek

	Gastropods	Copper		Zinc	
		Ulhas River Estuary	Thane Creek	Ulhas River Estuary	Thane Creek
Shell metals	**Cerethidea**	16.264	6.537	85.669	12.909
	Melampus	111.096	--	188.844	--
	Stenothyra	157.128	140.894	328.526	193.137
	Salinater	61.523	26.301	534.57	61.008
	Assaminea	257.485	63.621	194.205	70.41
	Haminea	--	67.018		535.12
	Avg	146.81	74.46	311.54	214.92
Biomass metals	Onchidium	191.647	262.48	119.394	65.228
	Cerethideopsilla	159.98	125.98	184.95	64.45
	Salinater	149.98	146.855	283.283	103.075
	Melampus	699.98	--	1899.95	--
	Assaminea	316.647	171.409	199.95	328.521
	Stenothyra	199.98	149.98	499.95	599.95
	Haminea	--	47.123	--	97.093
	Avg	286.37	150.64	531.25	209.72
Shell to biomass ratio	Cerethideopsilla	0.102	0.052	0.463	0.2
	Salinater	0.41	0.179	1.887	0.592
	Melampus	0.159		0.099	
	Assaminea	0.813	0.371	0.971	0.214
	Stenothyra	0.786	0.939	0.657	0.322
	Haminea		1.422		5.511
	Average	0.542	0.72775	0.9035	1.65975

Table Me-6 : Heavy metals (ppm.) in the Macrobenthos -Bivalves of Ulhas river estuary and Thane creek

	Bivalves	Copper		Zinc	
		Ulhas River Estuary	Thane Creek	Ulhas River Estuary	Thane Creek
Shell metals	Katelysia		15.98		18.95
	Cardium		8.98		14.95
	Glauconome	3.874	12.763	140.511	31.066
	Cuspidaria	76.456	21.903	2617.602	60.229
	Average	40.17	14.91	1379.06	31.30
Biomass metals	Katelysia		21.409		107.093
	Cardium		103.48		91.95
	Glaconome	99.98	74.98	299.95	166.617
	Cuspidaria	149.98	124.98	499.95	199.95
	Average	124.98	81.21	399.95	141.40
Shell to biomass ratio	Katelysia		0.746		0.177
	Cardium		0.087		0.163
	Glaconome	0.039	0.17	0.468	0.186
	Cuspidaria	0.51	0.175	5.236	0.301
	Average	0.275	0.295	2.852	0.207

Table Me-7 : Heavy metals (ppm.) in the Polychaete and other macrobenthos of Ulhas river estuary and Thane creek

	Copper		Zinc	
	Ulhas River Estuary	Thane Creek	Ulhas River Estuary	Thane Creek
Polychaetes				
N.gangetica	351.647	277.253	206.617	304.495
Ceratonereis	466.647	845.980	2716.617	463.950
L.indica	364.980	6176.647	3187.450	316.617
Avg Polychaete	394.424	2433.293	2036.894	361.687
Other Macrobenthos				
Nematodes	1449.980	999.980	2549.950	4749.950
Oligochaetes	1233.313	4562.480	1066.617	1749.950
I.gangetica	769.717	159.657	1130.213	348.337
Larvae	883.313	579.980	799.950	4159.950
Seaanemone		104.819		591.885

Table Me-8: Heavy metals (ppm) in the Fishery types of Ulhas river estuary and Thane creek

	Copper		Zinc	
	Ulhas River Estuary	Thane Creek	Ulhas River Estuary	Thane Creek
Tilipia Ulhas	28.48	4.98	74.95	56.95
Mugil	21.98	9.98	32.95	38.95
Mystus	12.48	4.48	39.95	43.95
Boleopthalmus	6.23		28.075	
Lates calcarifer		4.48		27.45
Scylla serrata	6.98	150.48	239.95	220.95
Average	15.23	34.88	83.175	77.65

Chapter IX

Awareness Lectures

Importance of Public Awareness.

Mangrove ecosystems are of great ecological and economic importance in protecting the shore lines and boosting the fishery production. The mangroves dominate one quarter of the world's tropical coastline. But the ecosystems are fast disappearing at a time when there are clear indications of potential changes in climate, sea level rise, etc. (Kathiresan, 1995). The reasons for the fast disappearing of mangroves are many. The primary one being total disregard to the environment and the general notion that the mangrove are marshy mosquito laden wasteland which deserves reclamation. Infact the importance of mangroves surfaced only around the 1600's, highlighting most of its uses including the medicinal properties. But unwise political decisions and land allocations did little to conserve mangroves world wide. Nevertheless the government of India is definitely ahead of many other countries as it had introduced a scheme for conservation and management of mangroves way back in 1970's, though negligibly successful. The government alone isn't to be blamed, as the common man is hardly aware of the wealth the mangroves provide. Just as the educated people know honey bee for honey and not for pollination causing increased crop yield, mangroves are mainly exploited for fuel. The common man is oblivious to the fact that 2/3 rd of all the fish caught throughout the world are hatched in the tidal areas and mangrove marshes. A canoe-ride through the breath taking beauty of mangroves rich in bird and insect fauna is a great attraction for tourist. This aspect of tourism is very well tapped in countries like U.S.A. and Singapore that have less mangrove cover than India. In India there is distinct lack of awareness not only among the public but also at administrative level and the judiciary. Except for a few forest officers like Dr. Arvind Raddi who did significant work for conservation of mangroves, most forest authorities show disconcern over the issues of mangroves which is the main cause of decline of mangroves. Hence to generate a consciousness and conserve the lifeline i.e. mangroves, the concept of public awareness gains importance.

Awareness Activities:

Keeping in mind the importance of public awareness and concern for mangroves, various activities were conducted in the form of lecture series, slide shows, field trips and poster exhibits. Lectures were conducted for School and College students, Teachers and Common man in Saraswati School Thane, Royal College - Mira road, Sophia College - Peddar road, NGO - HOPE -Thane, NGO - World Wide Fund for Nature- India, MSO. In addition a National Seminar was also conducted in November 2002 (Plate 17).

National Seminar and its response.

A National Seminar on Creeks, Estuaries and Mangroves - Pollution and Conservation was organised by the zoology department from 28th to 30th November 2002 as an extension to the Project work. The seminar was aimed towards interacting with researchers in the field of mangroves from India. The effort to organise the seminar was promptly supported by Mumbai Metropolitan Region - Environment Improvement Society and the college management Vidya Prasarak Mandal. The seminar had participants from seven coastal states of India including Maharashtra. A total of 130 participants and 50 invited guests, which included dignitaries from various fields including the scientific community attended. The seminar was inaugurated by Dr. A.G. Untawale (retd. NIO scientist) who also released the proceedings of the seminar. The program included 18 invited talks (15 published in the proceedings) including ones by Mr. Debi Goenka and Dr. Sarnathan and 65 research papers. All the delegates were given sufficient time to present their paper and interact. In addition to Oral presentations, 60 posters covering various aspects of mangroves, creeks, estuaries were displayed. The villagers who have been helping in the research work were felicitated during the valedictory session. The seminar got a good press and media coverage and was well accepted by all present. The seminar helped exchange the ideas of conservation and also increase the awareness of mangroves among the common man.

While conducting these awareness programmes it was realised that much more needs to be done to spread the awareness in each and every village along these ecosystems.

Chapter X

Conclusion and Remedial Measures

Conclusion

The present ecological study of Ulhas river estuary and Thane creek was done from September 2001 to November 2002. During the course of study various parameters were observed and assessed, following which the subsequent conclusions are made.

Mangroves : The mangrove cover in both the ecosystems is rapidly declining due to various reasons such as cutting for fuel, agriculture, aquaculture ponds, reclamation for road, constructions, sand landing centres, etc. **In the past one decade extensive cover is lost due to various anthropogenic activities. Conservation of mangroves need to be done on priority basis.**

Water : Both the ecosystems have very high suspended solids, in Ulhas river estuary mainly due to sand dredging and in Thane creek due to sewage pollution.

Ulhas river estuary shows low dissolved oxygen in upstream stretches whereas dissolved oxygen in Thane creek is low throughout its length indicating polluted state. This is also reflected in high B.O.D.

Both the ecosystems have high nutrients due to pollution. Silicates are exceptionally high and the reason needs to be investigated. Thane creek has higher PO_4-P due to sewage pollution and Ulhas river estuary has high NO_3-N due to agricultural runoff and some polluting source.

Changing salinity trend (lowering of salinity) in Thane creek as compared to past suggest (i) increased sewage load and (ii) obstruction in tidal flow.

The water parameter studies show high pollution throughout the Thane creek and in the upper stretch (station 1 to 4) of Ulhas river estuary.

Phytoplankton : Significant reduction in phytoplankton as compared to past studies in both Ulhas river estuary and Thane creek are suggestive of **chemical pollution causing death of the phytoplankton.**

Zooplankton : Comparison of zoplankton trend with past data revealed that pollution in Ulhas river estuary though high probably has not crossed tolerance limits but reduction in density to 1/27 in Thane creek **indicates some untraced chemical pollution alongwith excessive organic enrichment.**

Sediment : The sediment texture which was silty-clay (more clay) in this region is changing to clayey-silt (more silt). **This (siltation) has happened in upper stretches of Ulhas river estuary and along the entire Thane creek**; the reasons being growing sewage load, solid waste dumping and reclamation. This has made the sediments soft and sinking, unsuitable for fish and prawn breeding. **Prawns and mudskipper are completely eliminated from Thane creek.** It has affected the benthic faunal composition. In Ulhas river estuary the siltation is spreading downstream also.

Macrobenthos : As compared to past the macrobenthic density has increased and biomass has decreased indicating dominance of small sized organisms. The changing picture of the faunal types has shown elimination of certain types from Thane creek and their introduction in relatively less organically polluted Ulhas river estuary. **This in general suggest that in Thane creek the pollution is crossing tolerance limits and in Ulhas river estuary it is growing.**

Fishery : The data indicates significant deterioration of fishery in Zone 1 and Zone 2 (stations 13 to 20) of Thane creek. **Due to pollution the fishery types do not enter in the upstream stretches of the creek.** However good diversity near the mouth of Thane creek suggest that if pollution is controlled it may be possible to revive the fishery of the creek. **In Ulhas river estuary also fishery is adversely affected in upstream stretches (zone 1) in the down stream stretches better fish variety is seen.**

Heavy metals : As compared to the metal levels in different abiotic and biotic components recorded during year 1985 by Mahajan *et al* (1987), the present metal

contents are significantly high which **indicates growing metal pollution in both Ulhas river estuary and Thane creek.**

In general the deterioration in Ulhas river estuary is moderate but growing and in Thane creek it is extreme. It is necessary to prevent further deterioration in both the ecosystems and try to revive the Thane creek.

Remedial Measures

The studies have shown the rapidly deteriorating condition of Thane creek and Ulhas river estuary. Especially the estimation of heavy metals in different components show how the levels of toxicants are growing in the two ecosystems. When the world is searching for newer food resources to meet the demands of growing population, we cannot afford to allow these two important ecosystems to die. It is therefore necessary to plan and immediately implement the remedial measures. For success, consistent and whole hearted efforts are needed. The suggested remedial measures fall under two categories A) The measures that can be implemented at individual level. B) The measures to be implemented at community level.

A) The remedial measures that can be implemented at individual level.

It is necessary that every citizen understands the seriousness of the pollution problem and contributes sincerely

1) Minimizing the solid wastes at source : At family level the degradable and non-degradable matter in the solid wastes can be seperated. The degradable matter can be converted to biofertilizer by using bio-decomposition techniques. This will reduce the total solid waste load by at least 40 to 50 %. The decomposed matter can be used as fertilizer for indoor plants and garden plants within the building premises.

2) As an individual, one can contribute by educating others regarding the importance and neeed for conservation of all our natural resources including creeks, estuaries and mangroves. This will help in spreading the message to masses.

B) The remedial measures that can be implemented at community level.

These can be implemented by a building, society or a bigger housing complex. If necessary the municipal corporations should make suitable rules so that it becomes a binding to practice the suggested measures.

1. Reuse water: The water used for bathing and washing clothes can be collected in separate tank and repumped in separate overhead tanks so as to use it for flushing the toilets or watering the gardens. This will conserve water and also reduce the quantity of sewage effluents.

2. Septic tank method for treatment of excreta: In earlier days when the population of Mumbai-Thane region was less, the septic tank method was discontinued because it was thought that the sewage will get sufficiently diluted when directly released in the creek and ocean. However due to significant population growth in this region, the sewage load has increased; which is building up the pollution level. It is therefore recommended that the septic tank method be restarted. In this the excreta is collected in the underground, leak proof tank, allowed to decompose to produce nutrient rich fertile water. This can be properly treated and used as a good quality fertilizer. This will minimize the sewage load and also our dependence on artificial chemical fertilizers.

3. Sorting and recycling of the non-degradable solid wastes: The municipal corporation should make it obligatory to the citizens to sort the non-degradable solid wastes like tin, plastic, etc. and encourage recycling / processing units within the corporation limits. This will further reduce the quantum of solid waste and solve the problem of availability of disposal area. Normally due to high pressure of solid waste disposal problem, the banks of creek, estuaries and mangrove mudflats are used as dumping grounds. This causes obstruction in the water flow in the creeks, hampers sewage flushing ability and hence increases pollution. The reclaimed mangrove areas invite growth of slums or even residential constructions (Plate 19 & 20). Which further adds to the polluting factors. Therefore solid wastes dumping should never be allowed along the banks of creeks and estuaries. The present remedial measure will help in achieving this.

4. Proper check of industrial effluents by reliable agency and treatment of industrial effluent and sewage before release in the creek / estuary.

Presently it appears that (a) the checking of industrial effluent is not done properly and frequently (b) so also effective treatment is not done and (c) because of high concentration of industries and population in this region, the load of industrial effluent and sewage has increased beyond the capacity of the ecosystems. Hence proper treatment of individual effluent and sewage before their release becomes most essential.

5. Dredging to clear accumulated debris: Presently due to heavy sewage load, solid waste dumping and reclamation, the water flow in the creek is getting obstructed. This has resulted in poor flushing leading to deposition of silt and debris. This has infact occurred through out the stretch of Thane creek but more significantly in the upstream 6 - 7 km area and near the bridges. In Ulhas river estuary also siltation is observed in the upstream stretches. It is necessary to remove the silt and the debris by dredging especially in the upstream regions of the two ecosystems and near bridges. Dredging will have to be done carefully as it may result fish kill by clogging of gills and disturb the other fauna also. However its long term effects will be beneficial. The dredging should be carried out well before monsoon. The dredged silt can be deposited on the banks of the creek / estuary and mangrove plantation should be done on it.

Dredging such a large area will prove very costly. However, the government authorities should do the initial dredging, and the locals can be assigned do the maintenance. To obtain the objective the following projects may be taken up.

i) With the help of NGO's the local fishermen and native villagers can be motivated to take up this activity in their own area so that the debris is removed bit by bit and mangrove plantation is mobilized.

ii) Whenever activities such as construction of bridges, jetty etc., are taken up care should be taken that during construction period tidal flow is not obstructed and after the construction is over the debris and silt accumulated in the vicinity of the construction should be cleared by the construction company so that proper tidal flow is restored.

7. Encourage mangrove plantation, mangrove based activities and creek / estuary based activities : Presently cutting of mangroves for fuel and other purposes is a major damaging factor. By educating the natives, the mangrove plantation should be encouraged. The people should be taught to harvest mangroves in a cyclical manner

(rotation). This will conserve the mangroves and at the same time fulfil their needs. To encourage mangrove plantation awards can be instituted for both the locals as well as the industries. Infact it should be made obligatory to industries along Thane creek and Ulhas river estuary that they spend some definite amount on maintainence of mangroves. Such thing has been done by the Gujarat State government which has improved the conditions of mangroves in Saurashtra region.

It is necessary to educate the masses regarding benefits of the mangrove forests. Following occupations can be encouraged in mangrove forests and also in the creek / estuary.

Mangrove based activities.

i) Apiculture - Mangroves and their associates flower in different seasons and hence they can support 'Bee keeping' (Apiculture) as a supplementary occupation. The mangrove honey has a very good international market and if it is well tapped it can provide a source of income to the locals.

ii) Experiments have proved that certain species of mangroves have refreshing property like tea. If further studies are conducted and if they give good results, people will be motivated to plant mangroves, however care should be taken to avoid monoculture.

iii) The coastal plant *Prosopis juliflora* grows rapidly and can be planted in the back mangrove region. This plant can provide certain protection to the mangroves and even be used as an alternate source of fuel.

iv) If proper education is done and guidance is provided many useful products can be obtained from the mangroves. As it is mangroves are known to have many medicinal properties, though the detail studies are lacking. Further, scientist have found moisquitocidal properties in some species of mangroves. Moreover Mangroves also help in desalination of land.

If it becomes possible to protect and grow mangrove forests all the above activities would become possible. However due to the neglect and lack of initiative by our people especially forest department, mangroves are suffering damage.

Creek and estuary based activities.

1) Mussel Culture : Mussel can grow very well in the creek and estuary and in the past have been recorded in both the Thane creek and Ulhas river estuary. However with

increased anthropogenic activities and pollution they have become almost non-existent. Mussel can be grown in captivity in cages using floats and require some monitoring. Similar culture is done on the east coast of India as well as in Countries like Malaysia, Indonesia, Philippines, etc.

ii) Growing protein rich algae : In the creek waters protein rich algae such as *Ulva spp.*, *Enteromorpha spp.*, *Sargassum spp.* and other sea weeds can be grown. These weeds apart from their food value (protein rich) also form a good fuel source either in dry form or as biogas.

iii) Crab pens : In Malaysia, crab growing is a common practice in the mangrove swamps along creeks and estuaries. For this purpose a small area of mangrove is fenced with poles preferably of mangrove origin or bamboo and are stocked with crabs. The crabs are fed with trash fish, when the crabs have grown to marketable size they are separated and sold, there by keeping a constant stock of the crabs and ensuring a minimum income.

iv) Fish cultivation in floating cages : This has been practiced on a trial basis in Indonesia where in fine mesh nylon net cages with floats on the top are kept in the creek / estuary,. In thesee cages suitable sturdy fish is cultivated by introducing seed. Fishes like *Tilipia spp.*, *Mugil spp.*, *Mystus spp.*, etc., can be grown in this manner.

v) Brush pile fishery : This is the traditional method practiced in Srilanka, wherein the basic property of mangroves providing food and shelter is put to optimum use. In this method an enclosure is made with poles and branches of mangroves preferably *Avicennia spp.* are left in the water. After a few weeks when the fish have gathered the region surrounding the mangrove branches is encircled with a nylon net keeping the fishes entrapped. Later the branches are removed and the fish are allowed to grow and then harvested.

There are some additional prospects if we manage and maintain these two ecosystems.

vi) Additional prospects

1. It will be possible to promote ecotourism in these ecosystems because they are already attracting birds like Flamingoes, Pintail ducks, Avocets, Osprey, Kingfishers, Gulls, Terns, Coots, etc. and will attract more if properly managed.

2. In Thane-Mumbai- Kalyan - Dombivili complex these ecosystems can be useful for ferry transport, which will reduce the load on roads and trains.

With the initiative of NGO's, Environment Improvement societies, Social workers and with the support and encouragement of government such activities should be undertaken alongside of creeks and estuaries. Which will protect the environment and provide lively-hood to the natives. For the deterioration of our precious ecosystems we cannot simply blame population explosion and industralization because this has mainly happened due to our lethargy, neglect and irresponsible attitude. If we change ourselves and implement the available techniques positively we can still maintain the balance in the nature.

About Thane Municipal Corporation Proposal.

There are plans declared by Thane Municipal Corporation to treat the organic sludge in the creek by exogenous bacteria. However,

i) such treatment will not prove useful in a flowing water ecosystem. Further if sewage and solid waste pollution is not prevented or minimised the treatment will have to be repeated again and again which will prove to be very costly.

ii) Ecologically it is not advisable to add exogenous bacteria (with origin outside the ecosystem) in an ecosystem, as they can disturb the natural balance. Instead it is recommended that the bacteria for the treatment be isolated from the same environment, cultured in laboratory and used for treatment.

However, instead of such treatment, the earlier mentioned remedial measures will prove less expensive and long lasting.

What if Nothing is done ???????

The simplest answer to this question is -

" As regards Ulhas river estuary the deterioration is presently in the upstream region which may spread downstream. However as the water mass is more and sand dredging activity is going on the estuary will be able to withstand the sewage pollution for some more years, but its chemical pollution needs to be seriously viewed.

Thane creek in few years will become a foul smelling creek like Mahim creek with absolutely no fishery in it."

There are many more things that can happen if remedial measures are not implemented immediately.

1. The reclamation of mangrove swamps is causing their destruction on one hand. Whereas on the other hand it initially provides residential space for the poor (Plate 19 & 20) and development of slums. Whereas later on residential complexes develop in these places. This has happened at many places along the two ecosystems. This will lead to the following problem.

- The geomorphic head is near the Thane city and the region is highly earthquake prone, with the joining of the two banks due to increased construction and solid waste dumping activity the possibilities of earthquake will further increase.
- It will lead to monsoon floods in the low level residential areas of the cities causing heavy losses.
- It has been observed that the reclamation and solid waste dumping gives easy access for the vehicles to reach the creek / estuary water. Due to this the tankers carrying acid wastes from industries have been found to conveniently empty the toxic wastes in the creek / estuary.

2. These ecosystems are feeding and breeding grounds of many fishery organisms. If they get destroyed, it will affect the fishery in the ocean and the rivers. The process has already started, if we are disciplined and determined it is not impossible to stop further deterioration.

3. If the chemical pollution (including that of metals) grows in the ecosystems, there are chances that it will percolate in the deeper region of the earth and pollute the ground waters such pollution of drinking water can create serious health hazards.

4. The mangrove swamps are lungs of the cities, they are also sites for a variety of birds, Their destruction will cause reduction in the diversity of life and also affect adversely the climatic conditions of the city. This will definitely increase the health problem in the population.

Therefore it becomes the prime duty of municipal corporations, organizations working for environment improvement and all individuals to do their level best to protect the precious ecosystems like Thane creek and Ulhas river estuary.

Chapter XI

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PLATE 1: MAP

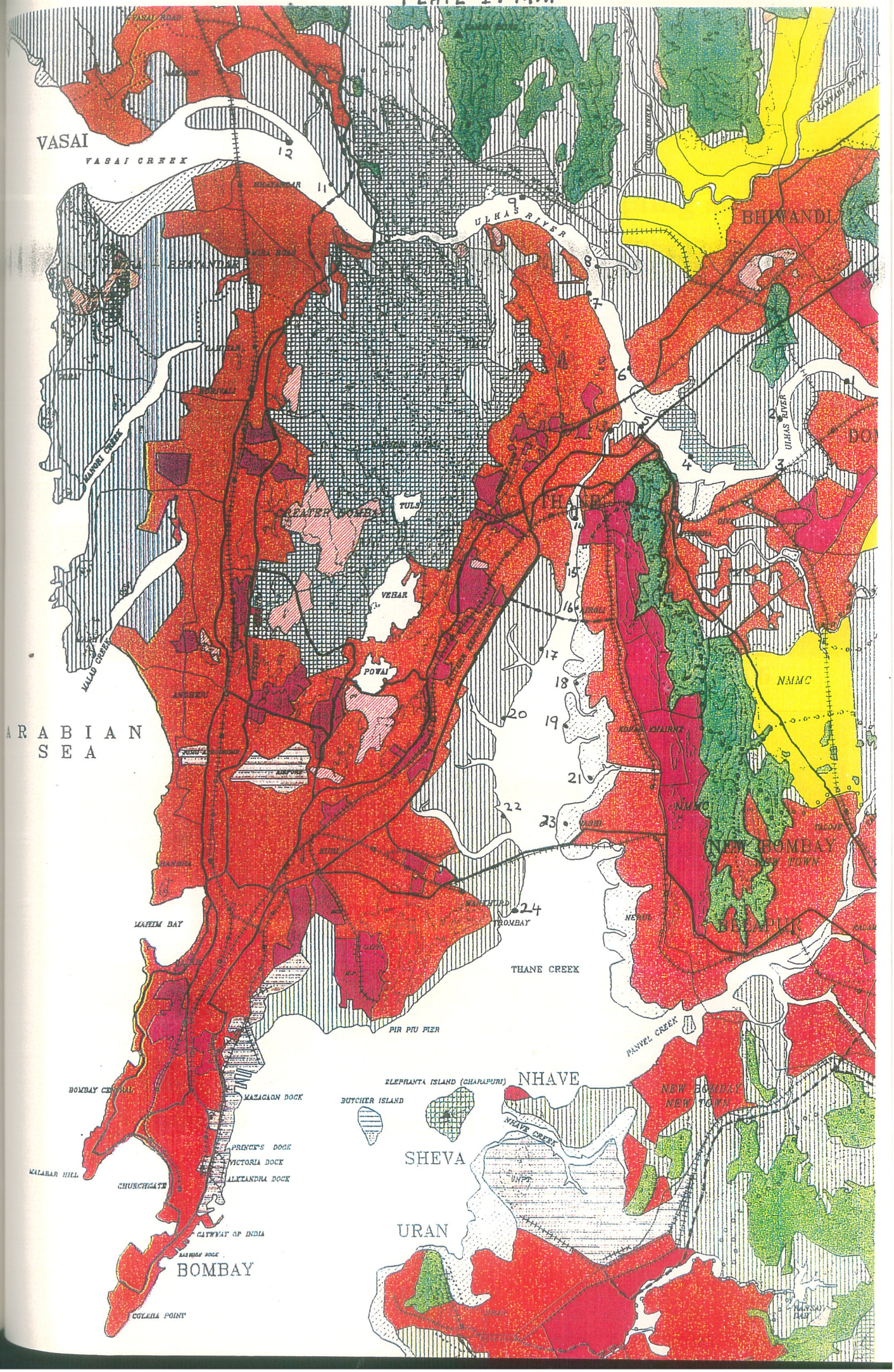

VASAI
VASAI CREEK
VASAI ROAD
BHIWANDI
ULHAS RIVER
ULHAS RIVER
GREATER BOMBAY
TULSI
THANE
VEHAR
POWAI
MALAD CREEK
ARABIAN SEA
NMMC
NMMC
NEW BOMBAY
NEW TOWN
MAHIM BAY
THANE CREEK
PIR PIU PIER
PANVEL CREEK
ELEPHANTA ISLAND (CHARAPURI)
NHAVE
BUTCHER ISLAND
NEW BOMBAY
NEW TOWN
SHEVA
URAN
BOMBAY CENTRAL
MAZAGAON DOCK
PRINCE'S DOCK
VICTORIA DOCK
ALEXANDRA DOCK
MALABAR HILL
CHURCHGATE
GATEWAY OF INDIA
BOMBAY
COLABA POINT

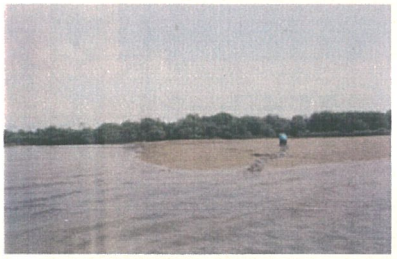
Plate 2 : Ulhas River Estuary Sampling stations



Station1



Station2



Station 3



Station 4



Station 5



Station 6



Station 7



Station 8



Station 9



Station 10



Station 11



Station 12

Plate 3 : Thane Creek Sampling stations



Station 13



Station 14



Station 15



Station 16



Station 17



Station 18



Station 19



Station 20



Station 21



Station 22



Station 23



Station 24








Plate 4: In the field







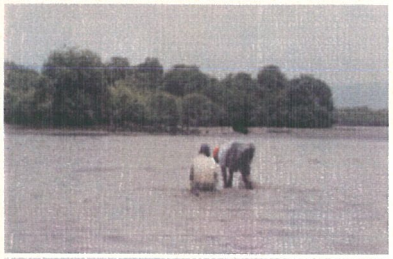













Plate 5: In the Laboratory





















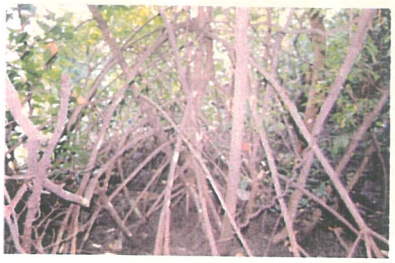
Plate 6: Adaptations in Mangroves



Waxy coating



Thick cuticle & salt glands



Columnar roots



Stilt roots



Vivipary



Net work of roots



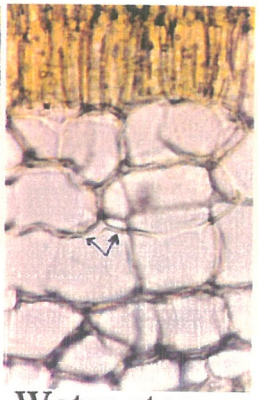
Knee roots



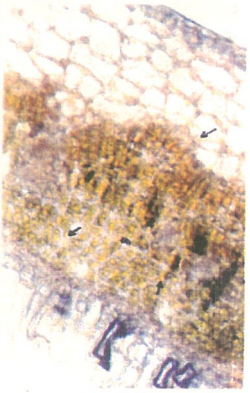
Pneumatophores



Salt glands



Water storage tissue



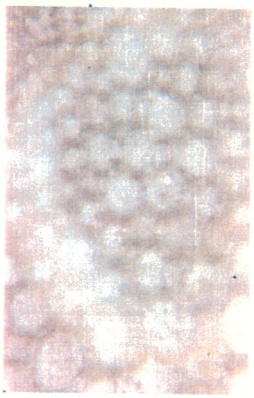
Tannin



Air spaces



Complete Mangrove ecosystem



Prismatic crystals

Plate 7: True Mangroves



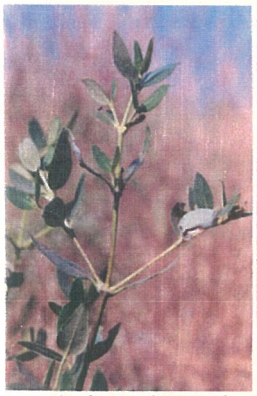
Bruguiera caryophylloides



Ceriops tagal



Ceriops decandra



Avicennia marina



A.marina acutissima



A. officinallis



Excoecaria agallocha



Sonneratia apetala



Rhizophora mucronata



Rhizophora apiculata

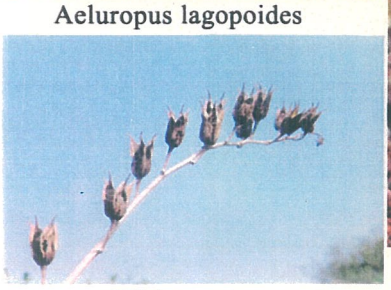


Aegiceras corniculatum

Non-Mangrove Halophytes



Aeluropus lagopoides



Hibiscus spp.



Hygrophila spinosa



Cyperus spp.



Suaeda maritime



Sesuvium portulacastrum

Plate 8: Mangrove Associates



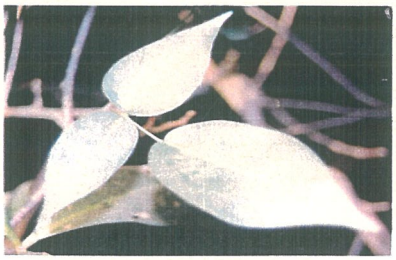
Dereis spp



Salvadora persica



Thespesia populneia



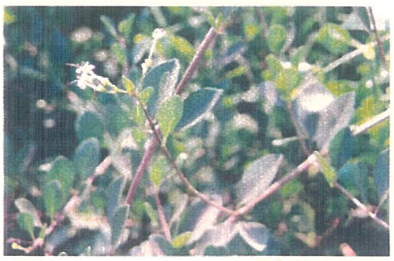
Dereis trifoliata



Acanthus ilcifolius



Ipomoea spp.



Clerodendron inerme



Calatropis gigantea



Cressa critica

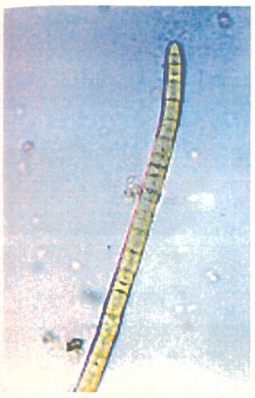


Larvae of Hyblaea peura

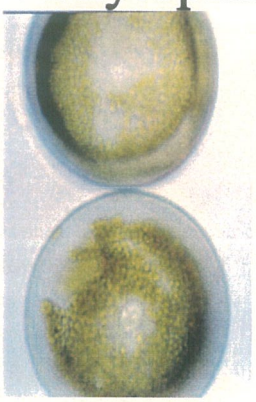


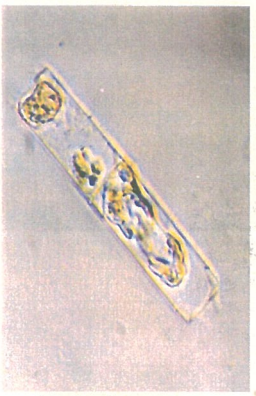
Hyblaea peura

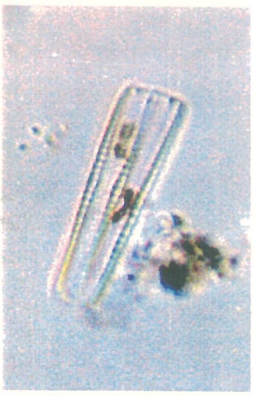
Plate 9: Phytoplankton

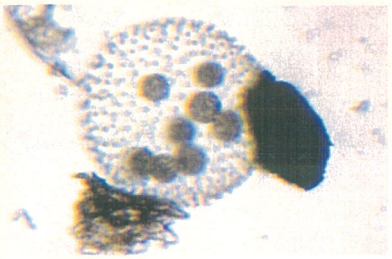

Oscillatoria spp.

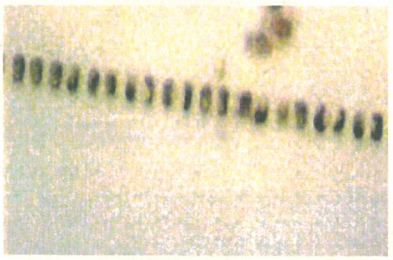

Pleurosigma spp.

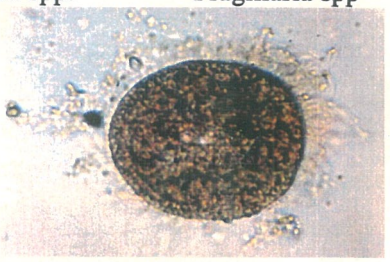

Cosinodiscus spp

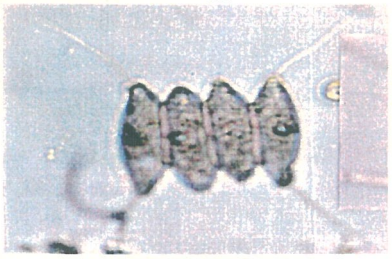

Melosira spp.

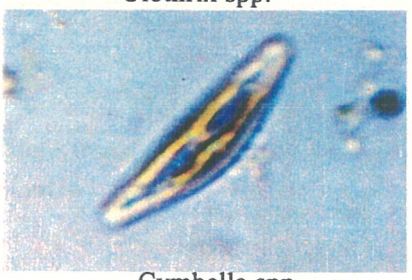

Fragillaria spp

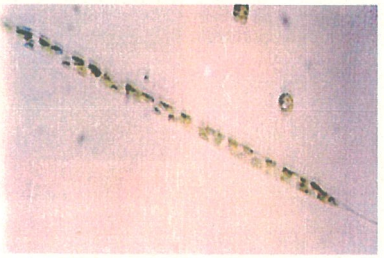

Volvox spp.

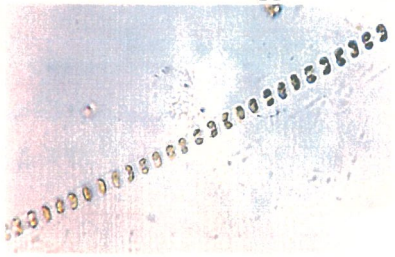

Ulothrix spp.

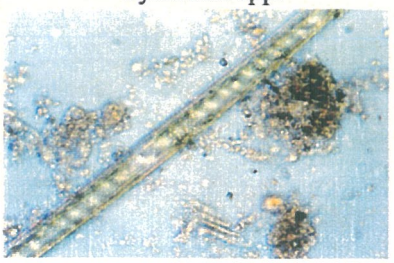

Golenkinia spp.

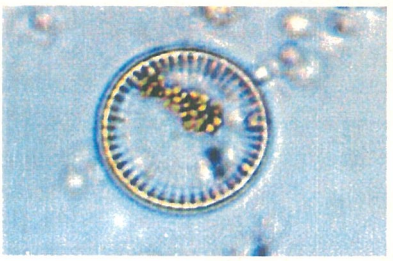

Scendesmus spp.

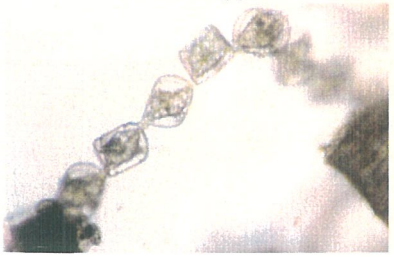

Cymbella spp.

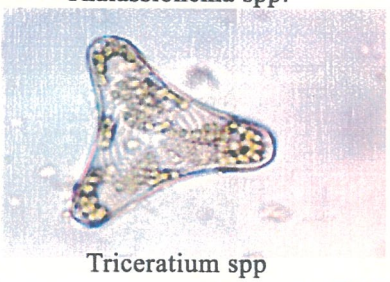

Rhizosolenia spp.

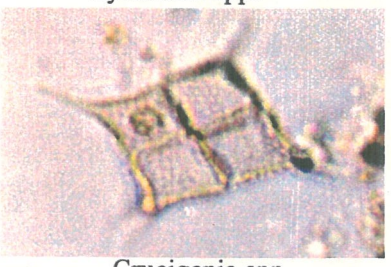

Ulothrix spp.

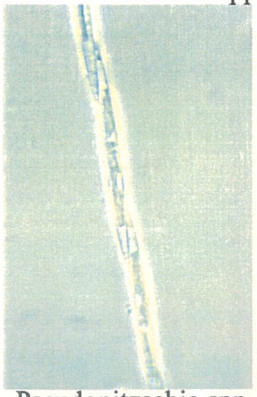

Thalassionema spp.


Cyclotella spp.


Thalassiosira spp.

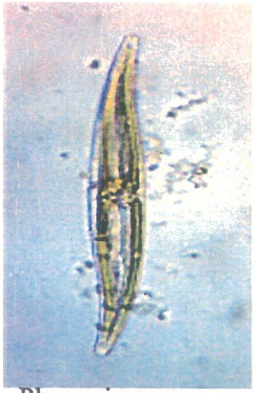

Triceratium spp


Crucigenia spp.


Pseudonitzschia spp.


Naviculla spp.


Nitzschia spp.


Pleurosigma spp.

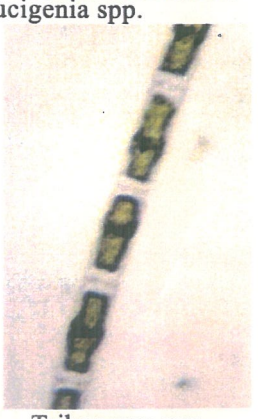
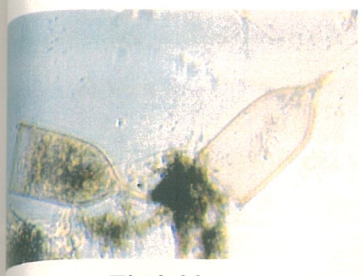
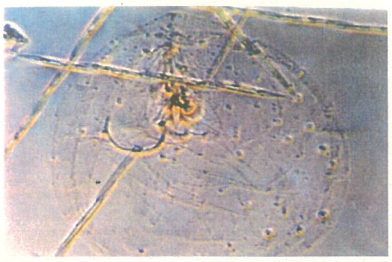

Tribonema spp.

Plate 10 : Zooplankton



Tintinids



Noctiluca

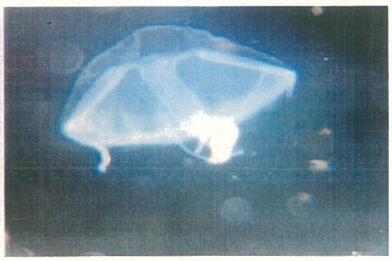


Foraminifera

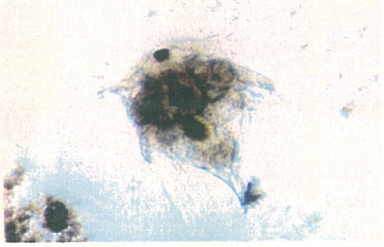




Siphonopore



Medusae



Nauplius



Beroe



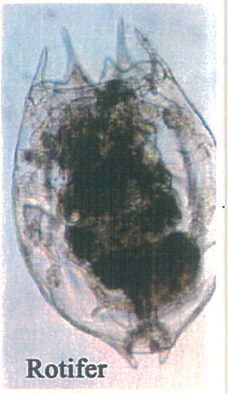
Gastropod veliger



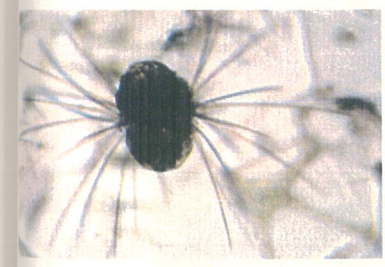
Bivalve larvae



Acetes spp.



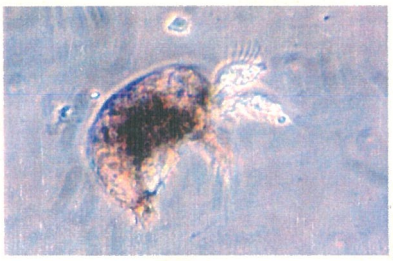
Rotifer



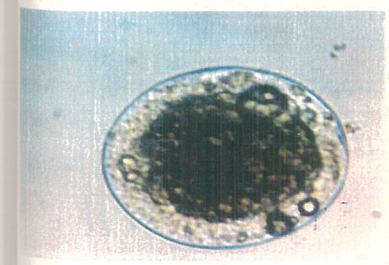
Setiger



Nematode



Cypris



Fish egg



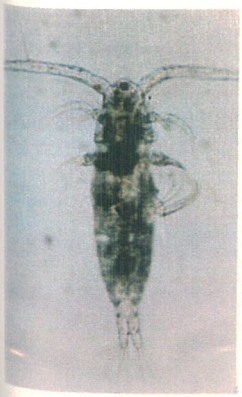
Fish larvae



Crustacean eggs



Zoea



Calanoid copepod



Cyclopoid copepod



Harpacticoid copepod

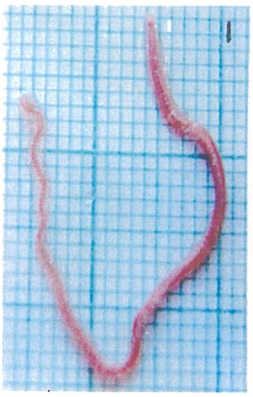


Cladocera



Protozoea

Plate 11: Polychaetes



Lycastis ounaryensis



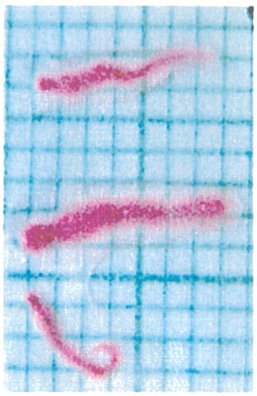
Nereis (ceratonereis) burmensis



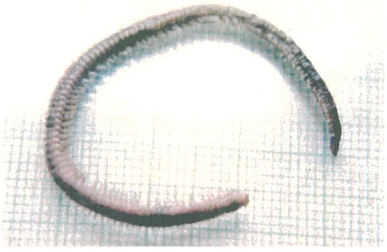
Polychaete bed



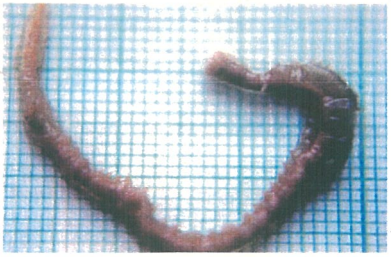
Dendronereis heteropoda



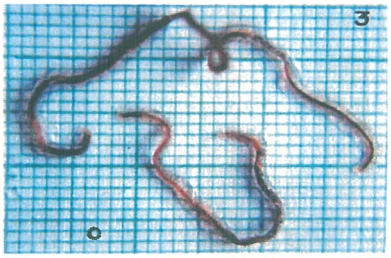
Sigambra bassi



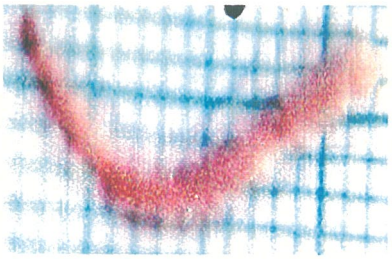
Nereis glandicincta



Glycera alba



Lycastis indica



Boccardia tricuspa



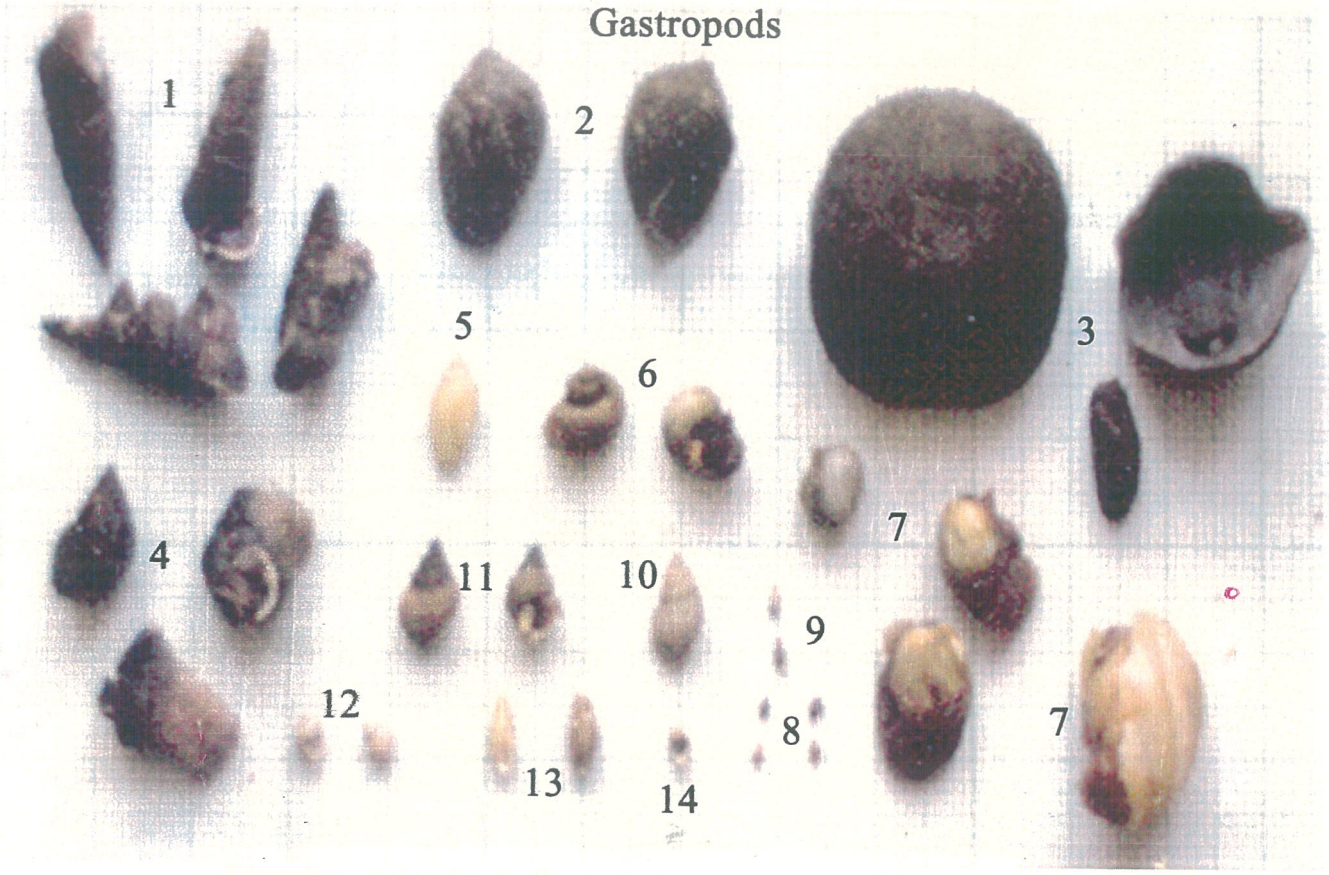
Arachnida



Insect larvae

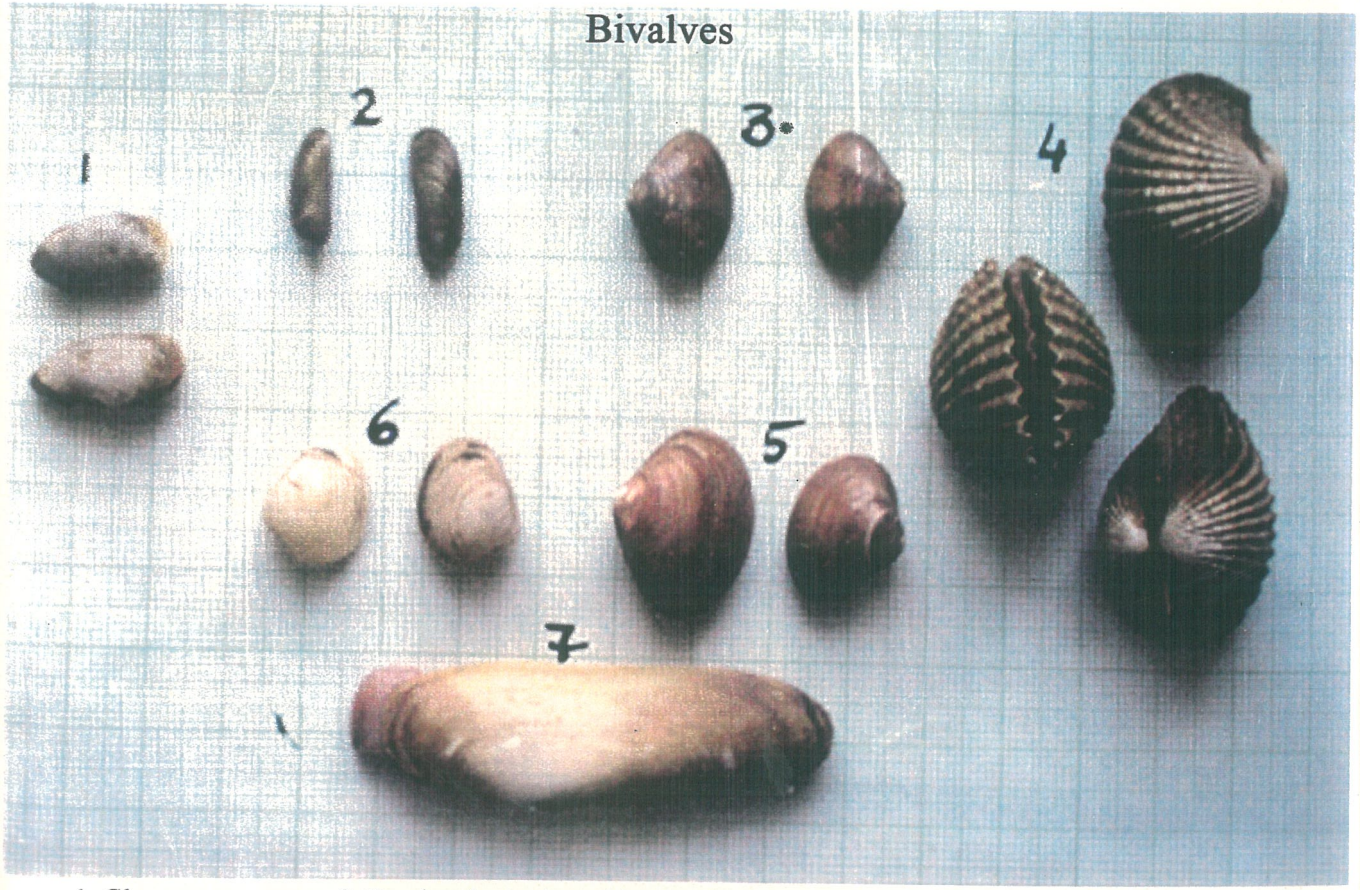
Plate 12: Mollusc

Gastropods



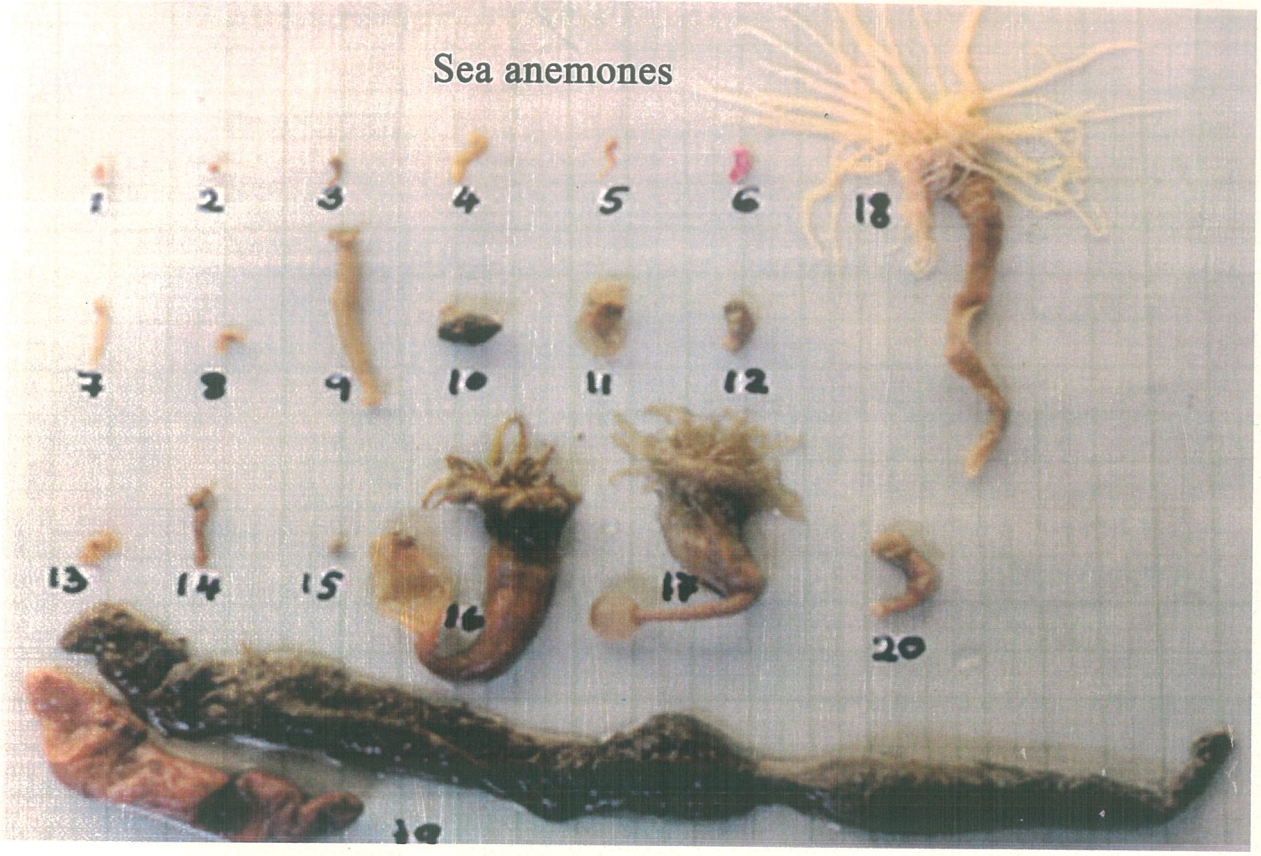
1. Cerethidea cingulata ; 2. Melampus ceylonicus ; 3. Onchidium verruculatum ; 4. Nassarius spp. ;
5. Auricula elongata ; 6. Salinater burmana ; 7. Haminea crocata ; 8. Stenothyra spp. 9. Thiara spp. ;
10. Drupa spp. ; 11. Nassarius ornatus ; 12. Assiminea bervicula ; 13. Auricula spp. ; 14. Littorina spp.

Bivalves

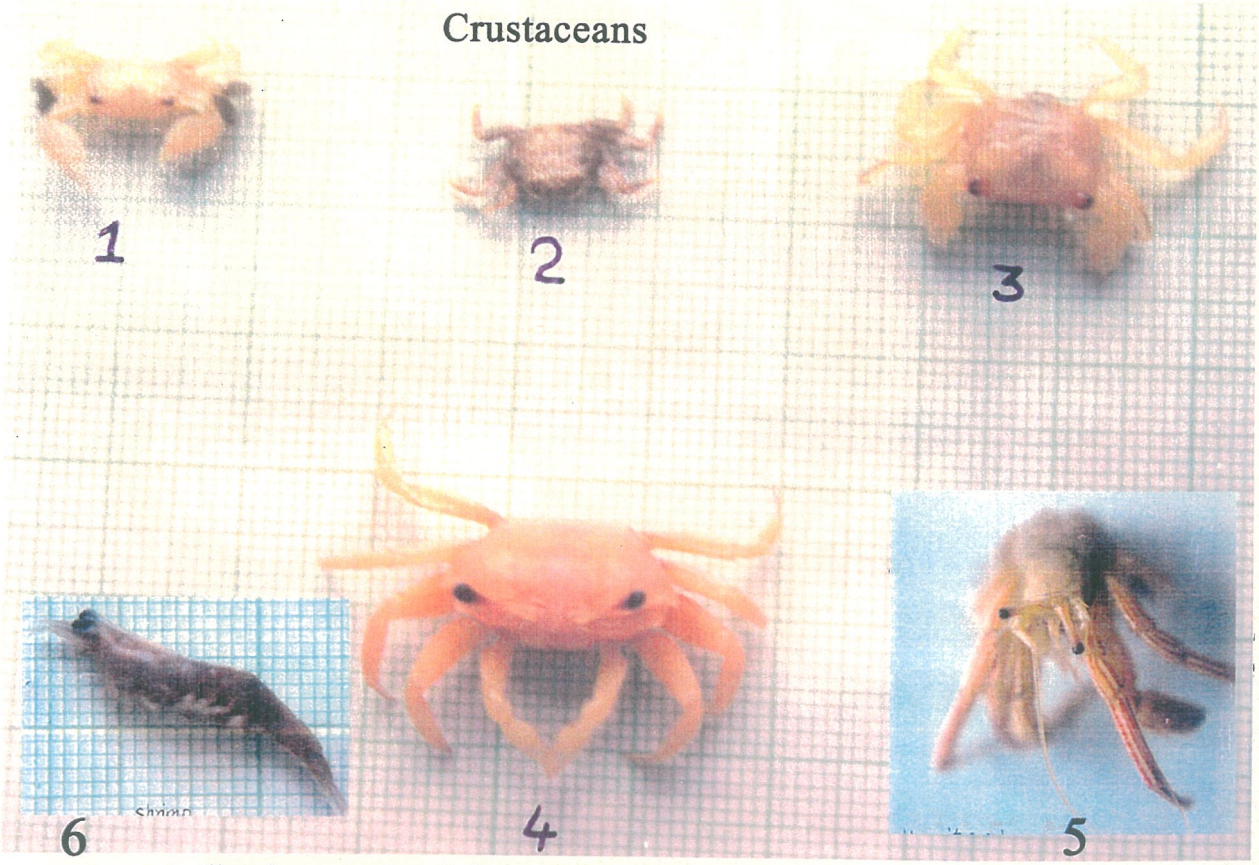


1. Glauconome cerea ; 2. Brachyodontes karachiensis ; 3. Katelysia marmorata ; 4. Cardium asiaticum
5. Katelysia opima ; 6. Dosinia pubescens ; 7. Razor clam.

Plate 13: Seaanemones & Crustaceans



Edwardsia athalyei (no.4); Pelocoetes spp. (nos. 5 & 7); Pelocoetes exul (no. 9);
Phytocoetes gangeticus (nos. 1 & 6); Stephensonactis ornate (nos. 11 & 14); Cerianthids (nos. 19 & 20)
Unidentifies (nos 2, 3, 8, 10, 12, 13, 15, 16, 17 & 18).



1. Illyoplax gangetica ; 2. Sesarma spp. ; 3. Varuna litterata ; 4. Uca spp.
5. Hermit crab; 6. Shrimp

Plate 14: Fishing activity.









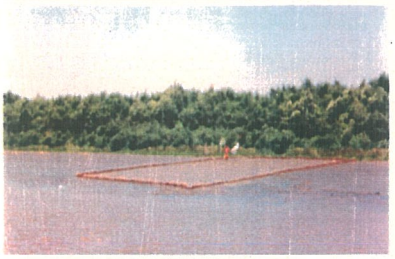
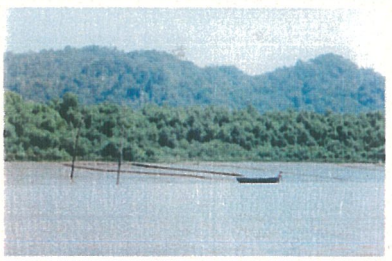








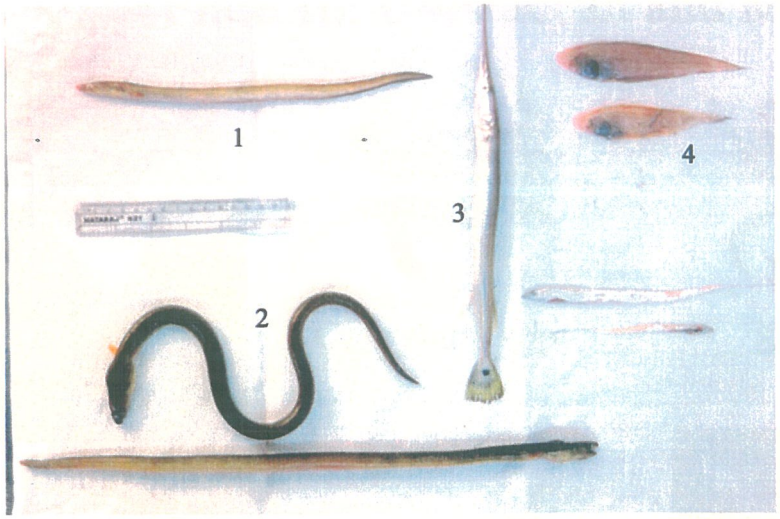








Plate 15: Fishes

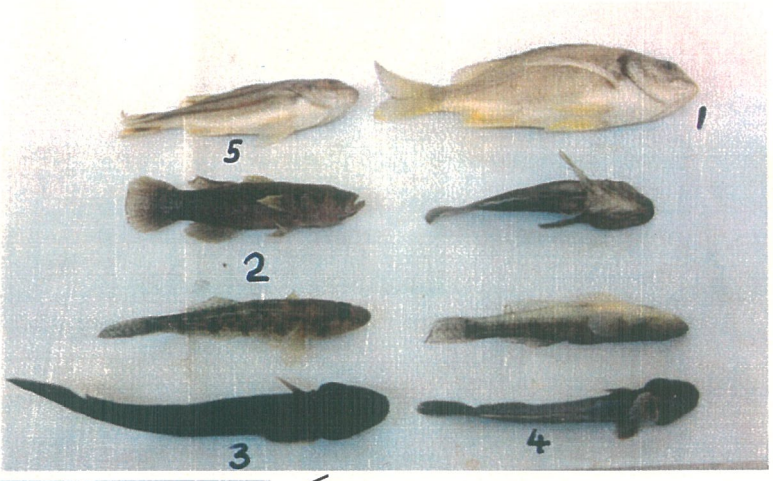


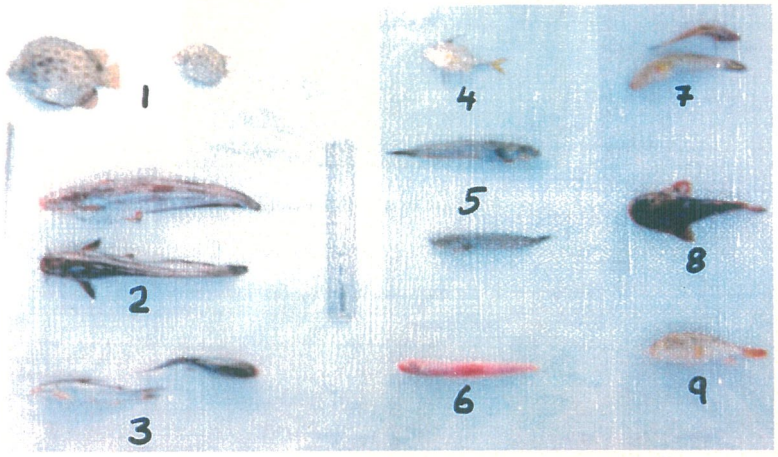
<----

1. Congromuraena anago
2. Aguilla spp.
3. Belone strongilurus
4. Cynoglossus spp.

----->

1. Chrysophrys datnia
2. Gobius spp.
3. Boleopthalmus boddaerti
4. Boleopthalmus dussumieri
5. Therapon theraps





<-----

1. Scatophagus argus
2. Plotosus arab
3. Mystus gulio
4. Triacnthus brevirostris
5. Eleotris spp.
6. Trypauchen vagina
7. Chrysophrys spp.
8. Batrachus grunniens
9. Tetrodon oblongus

---->

1. Pampus sinensis
2. Pampus argenteus
3. Sciaena dussumieri
4. Lates calcarifer
5. Umbrina spp.
6. Sciaena spp.
7. Otolithus brunneus

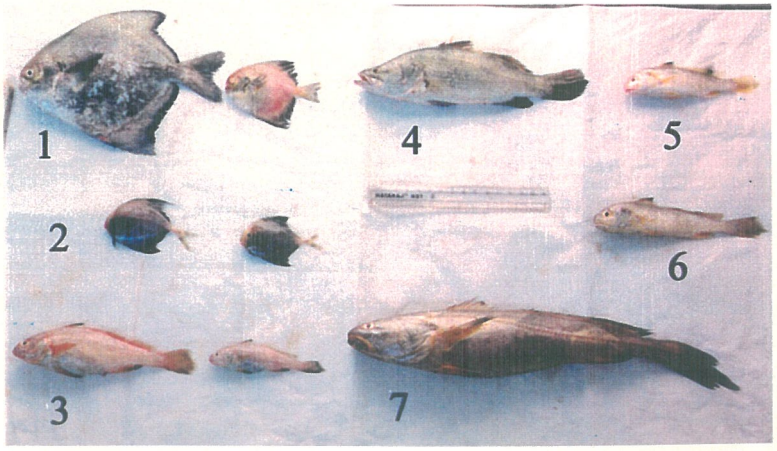
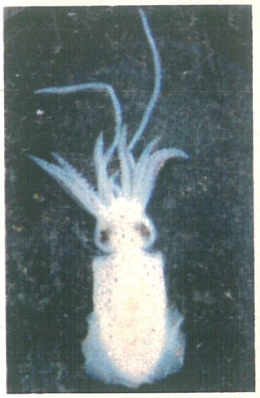


Plate 16: Crustacean and Mollusc fishery



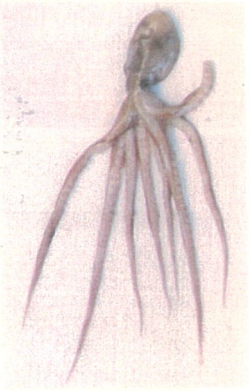
Loligo spp.



Charybdis spp.



Scylla Serrata



Octopus spp.



Macrobrachium rosenbergii



Squilla spp.



Acetus spp.



Peneaus spp.



Parapenaeopsis sculptilis



Metapeneaus spp.



Katelysia spp.

Cardium spp.









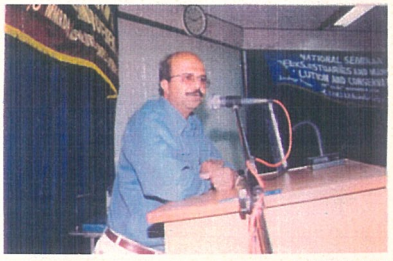



Plate 17
Educational activities









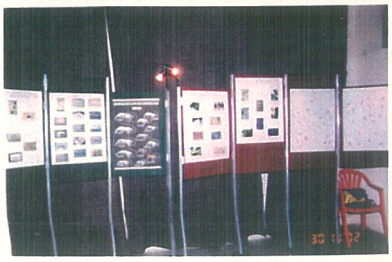



Plate 18 : Birds



Grey heron & Median egret



Sea gulls



Aggregation of birds



Avocet and Pintails



Blackwinged stilts, Terns & sandpipers



Coots & showeler



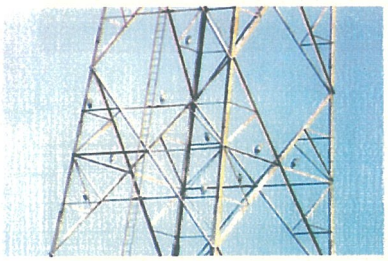
Flamingoes



Flamingoes



Flamingoes



Grey heron



Pintails



Sandpiper



Sandpiper



Terns & gulls



Median egret



Lapwing & Plover



Godwit



Night heron