

# Macrobenthos in the nearshore coastal system of Bombay

(Key words : macrobenthos/biodiversity/pollution/anthropogenic wastes/ecological modification)

ANNIE MATHEW\* and K. GOVINDAN

*National Institute of Oceanography, Regional Centre, Versova, Bombay - 400 061, India.*

*\*C/o. Dr. Thomas Varghese, T.C. 27/2258, State Road, Trivandrum- 695 001, India.*

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## Abstract

Distribution, abundance and biodiversity of macrobenthic standing stock in the nearshore coastal system of Bombay were estimated (1985-86) in relation to the prevailing environmental stress due to disposal of anthropogenic wastes. Selected water quality parameters like S%o, DO, BOD, nutrients etc. were monitored. Macrobenthos and water quality of the Harbour - Thana creek System (HTS) and the Bassein creek - coastal system (BCS) were studied and compared. HTS sustained relatively higher macrofaunal abundance and biodiversity as compared to BCS. An increase in faunal group diversity as well as species diversity of polychaetes from the inner creek to the open coastal zone was noticed. Sediment texture and organic matter were correlated with macrofaunal standing stock. A pollution induced ecological modification of macrobenthos especially in the inner creek regions of Thana and Bassein was evident.

## Introduction

Rapid industrialisation associated with extensive population growth for the last few decades in Bombay was resulted in the release of large quantum (1500 mld)<sup>1</sup> of anthropogenic wastes into the nearby coastal marine ecosystem. The Harbour - Thana creek system (HTS) receives about 350 mld of domestic waste in addition to 180 mld of industrial waste<sup>2</sup>. Bassein creek - coastal system (BCS) receives a wide range of industrial and domestic wastes of about 36000 m<sup>3</sup> day<sup>-1</sup> as per information from the Maharashtra Industrial Development Corporation (MIDC), Bombay. Considerable amount of copper (11 t), lead (7 t), zinc (400 t), mercury (7 t) and chromium (0.5 t) are annually released into BCS through Kalu-Ulhas river system<sup>3</sup>. Many of these wastes entering the HTS and BCS were usually untreated or partly treated<sup>1,2</sup>. Such indiscriminate disposal of wastes will inevitably lead to a gradual but definite deterioration in the marine ecology of HTS and BCS. Pollution induced changes in the ecosystem like modification in the standing stock of phytoplankton<sup>4,5</sup>, zooplankton<sup>6,7</sup>, benthos<sup>8,9,10</sup>, and fishes<sup>11</sup>, alterations in biodiversity<sup>5,6,9,12</sup>, proliferation of pollution tolerant species<sup>5,7,9</sup> and less effective trophic conversion of the marine food chain<sup>13</sup> have been widely reported for the coastal waters of Bombay. Presently the north-eastern coastal ecosystem of Bombay is under noticeable pollution stress as per available informations<sup>5-13</sup> and the region, however, needs a more detailed investigations in order to

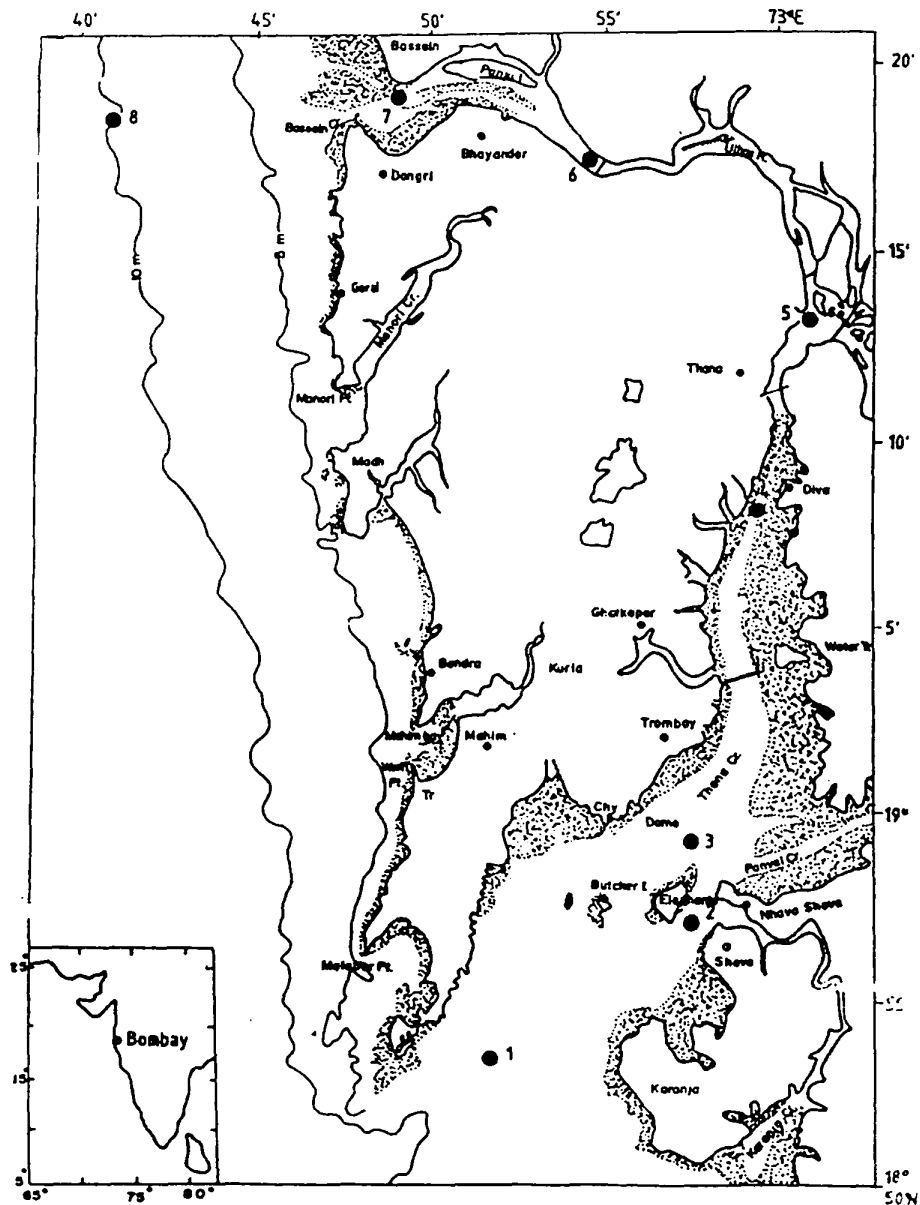


Fig. 1—Location of sampling stations.

prevent severe ecological damage. Benthic organisms have been long considered as the best indicators of environmental stress due to pollution<sup>8,10,13</sup> and, therefore, a comparative study on macrobenthos of HTS and BCS was undertaken.

### Material and Methods

Monthly collections were made from eight stations covering a distance of about 90 km (Fig.1) over a period of 15 months during 1985-86. Water samples were collected using Niskin Samplers and selected water quality parameters viz., temperature, salinity, pH, dissolved oxygen, biological oxygen demand, nitrate, nitrite and phosphate were analysed using standard procedure<sup>14</sup>. Sediment samples were collected using a van Veen grab of 0.04 m<sup>2</sup> area. Grab samples were quadruplicated at each station. About 100 g of sediment was collected at each sampling site stored in ice, later dried at 70° and analysed for organic matter<sup>15</sup> and sediment texture<sup>16</sup>. Samples for macrobenthos were sieved using a 500 µm mesh sieve and the contents retained on the sieve were preserved in 5% buffered formalin and analysed as per standard procedure<sup>16</sup>. The biomass was estimated on wet weight basis. Due to unfavorable weather conditions and other navigational problems, sampling could not be done from station 8 during July, 1986.

### Results and Discussion

#### *Environmental parameters :*

The water and sediment temperatures were found closely correspond to monthly air temperatures (Fig. 2 & 3). However, the inner creek regions (station 4 and 5) recorded relatively higher temperature as compared to the outer zones (Fig.4). This could be due to the impact of heated waste disposals reaching these stations apart from the shallowness and narrowness of the creek portion with less relative volume of watermass and high evaporation. pH fluctuated between 7.5 and 8.1 (av. 7.8) with an increase in pH from the creek to the open coast (Fig.4). Similarly salinity fluctuations were wider (0.3 to 36.7 ppt) at the inner creek (stations 4, 5 and 6) as compared to the outer (Fig. 2 & 3) zones (18.5 to 37.5 ppt) mainly due to freshwater influx, waste disposals and high evaporation. Considerable decrease in salinity during monsoon was noticed at all stations with the lowest value confined to the creek region (stations 4,5 and 6). In general a gradual increase in salinity from the creek towards the open sea was well marked (Fig.4). In monsoon, difference in salinity between surface and bottom waters was observed indicating a temporary stratification at selected regions of the creek system. Whereas in non-monsoonal a well mixed water body prevailed at HTS and BCS.

The impact of oxidisable matter entering a water body can be well indicated by the levels of DO and BOD of that water mass. The water was well saturated with respect to

Table 1- Distribution of polychaete species.

SPECIES	STATIONS							
	1	2	3	4	5	6	7	8
<i>Lumbriconereis latreilli</i> Audouin & Milne Edwards	+	+	+	-	-	+	+	+
<i>Cossura coasta</i> Kitamori	+	+	-	+	-	+	+	+
<i>Clymene grossa</i> Baird	-	+	+	-	-	-	-	+
<i>Prionospio pinnata</i> Ehlers	+	+	+	+	+	+	+	+
<i>Prionospio polybranchiata</i> Fauvel	+	+	+	+	+	-	+	+
<i>Ancistrosyllis constricta</i> Southern	+	+	+	+	+	+	+	+
<i>Paraheteromastus tenuis</i> Monro	-	+	+	-	+	+	+	+
<i>Nereis unifasciata</i> Willey	+	+	+	+	+	-	-	-
<i>Diopatra neapolitana</i> Delle Chiaje	+	+	+	-	+	+	+	-
<i>Glycera alba</i> Rathke	-	+	+	+	-	+	+	+
<i>Glycera longipinnis</i> Grube	+	+	+	-	-	+	+	+
<i>Pista indica</i> Fauvel	-	-	-	+	-	-	-	-
<i>Pullioella armata</i> Fauvel	+	-	-	-	-	-	-	+
<i>Nephtys oligobranchia</i> Southern	+	+	-	+	+	+	-	+
<i>Sabellaria cementarium</i> Moore	-	+	+	-	+	-	-	-
<i>Terebellides</i> sp.	+	+	+	-	-	-	+	+
<i>Owenia</i> sp.	+	+	+	+	-	+	+	+
<i>Maldane</i> sp.	+	+	+	-	-	-	+	+
<i>Perinereis cavifrons</i> Ehlers	+	+	+	+	+	+	-	-
Total number of species	14	17	15	10	9	11	12	14
							+	Present
							-	Absent

DO at HTS (av. 4.1 to 6.8 mg/l) especially during monsoon as compared to pre- and postmonsoon periods (Fig.5 & 6). The input of anthropogenic wastes into the creek system<sup>1,2</sup> resulted in relatively low DO and high BOD values especially at the inner creek regions (stations 4 & 5). However, complete depletion of DO was not encountered at any stations. In general, normal DO (>6 mg/l) and BOD (<2 mg/l) levels were noticed towards offshore

coastal stations (Fig.4) suggesting an appreciable improvement in environmental conditions of the coastal waters away from the creek system. The essential nutrients such as nitrate, nitrite and phosphate indicated relatively very high values associated with wide fluctuations especially in the inner creek regions (stations 4 to 6 ) as compared to the outer creek and open coastal systems (Fig.7 & 8). The concentrations of nitrite, nitrate and phosphate were abnormally high at stations 4, 5 and 6. The observed high levels of different nutrients would have resulted from release of sewage and nutrient rich industrial wastes especially into the inner creek system<sup>1</sup>. The high concentration of nitrite especially within the inner creek regions clearly indicative of relatively less oxidative potential of the water body and, therefore, the accumulation of nitrite in the inner creek system was suggestive of unhealthy conditions. The present results of various environmental parameters well support earlier findings for the study area<sup>2,17-21</sup>.

Table 2- Distribution of molluscan species.

SPECIES	STATIONS							
	1	2	3	4	5	6	7	8
<i>Tellina</i> sp.	+	+	+	+	+	+	+	+
<i>Nucula layardi</i> Adams	-	+	+	+	-	-	-	+
<i>Meretrix meretrix</i> Linnaeus	-	-	+	+	+	-	-	-
<i>Paphia textile</i> Gmelin	-	-	-	+	-	-	-	-
<i>Pholas orientalis</i> Gmelin	-	-	-	+	-	-	-	-
<i>Arca granosa</i> Lamarck	-	-	-	+	-	-	-	-
<i>Pandora flexuosa</i> Sowerby	-	-	-	+	+	-	-	-
<i>Mactra</i> sp.	-	+	-	+	+	+	-	-
<i>Stenothyra deltae</i> Benson	-	+	+	+	+	+	-	+
<i>Nassarius stolatus</i> Gmelin	-	-	-	+	-	-	-	-
<i>Nassarius faveolatus</i> Reeve	-	-	-	+	-	-	-	-
<i>Cerideopsisilla cingulata</i> Gmelin	-	-	-	+	-	-	-	-
<i>Larina burmana</i> Blanford	-	-	-	+	-	-	-	-
Total number of species	1	4	4	13	5	3	1	3
						+	Present	
						-	Absent	

A mixture of sand, silt and clay in various proportions was encountered in the study area (Fig. 9). The results indicated a clayey-silt bottom at stations 1,2,3,4 and 8 while the stations 5 to 7 revealed significant percentage of sand dominant bottom conditions (Fig. 9). Marginal changes in mean particle size of sediments were observed during monsoon indicating the possible seasonal fluctuations of the substratum between pre- and postmonsoon periods (Fig. 3-5). The percentage of organic matter in sediments varied from 0.04 to 4.07 with a mean value of 2.4 (Fig. 9) in the study area. In confirmation with earlier finding<sup>9,10</sup> very high percentage of organic matter was notice at station 4 as compared to the rest of the stations. This perhaps could be related to the sewage disposals close to station 4 as well as contribution of high organic load from the adjacent mangrove ecosystem . A very low organic matter noticed at stations 6 and 7 could be correlated with predominantly sandy bottom conditions associated with strong channel currents. An inverse relationship between sediment organic matter and particle size was evident (Fig.9)

#### Macrobenthos :

##### Harbour-Thana System (HTS) :

HTS sustained the mean macrofaunal densities of 396 ( $\sigma$  638), 722 ( $\sigma$  587), 744 ( $\sigma$  946) and 1701/m<sup>2</sup> ( $\sigma$  1497/m<sup>2</sup>) mean biomass of 4.8 ( $\sigma$  16), 2 ( $\sigma$  2.5), 6.6 ( $\sigma$  14.4) and 40.7g/m<sup>2</sup> ( $\sigma$  61.1 g/m<sup>2</sup>) at stations 1,2,3, and 4; respectively . Evidently station 4 recorded the highest macrofaunal standing stock both in terms of population and biomass. Seasonally population maxima were observed during post-monsoon . Polychaetes were the most common and abundant group with an occurrence of 93 to 100%. They also contributed a faunal standing stock of 18 to 43% in terms of population (Fig.10) and 7 to 32% in terms of biomass (Fig.11.) Polychaetes indicated an appreciably high biodiversity in the coastal regions as compared to the creek area ( Table 1). The diversity index of polychaetes for stations 1,2,3, and 4 were 0.87, 1.84, 1.21 and 0.67 respectively. Thus the lowest diversity of polychaetes was observed at station 4. The common and dominant species of polychaetes encountered at at HTS (Table 1) were *Ancistrosyllis constricta*, *Cossura coasta*, *Lumbriconereis latreilli*, *Prionospio pinnata*, *P. polybranchiata*, *Perinereis cavifrons*, *Diopatra neapolitana*, *Nephtys oligobranchia*, *Terebellides* sp., *Owenia* sp., *Nereis unifasciata*, *Glycera alba*, *G.longipinnis*, *Sabellaria cementarium*, and *Maldane* sp.

Crustaceans accounted for 16 to 49% and 0.5 to 85% of the total macrofaunal standing stock in terms of population and biomass respectively (Fig.10 & 11) Their percentage occurrence in the sample varied from 53 to 90 which in turn indicated their preference for the creek/nearshore coastal ecosystem as compared to the offshore coastal system. They were usually represented by copepods, mysids, amphipods, isopods, lobster larvae, decapod larvae; (*Exopalaemon*, *Macrobrachium* and *Leptochela*), crabs (*Xenopthalmoides moebii*, *Conchoete* sp. and *Dorippe* sp.) cladocerans, cumaceans, ostracods and *Acetes* sp.)

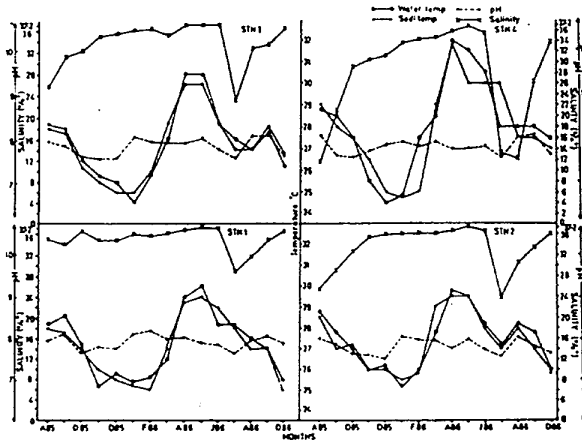


Fig. 2-Variations in temperature, pH and salinity at HTS.

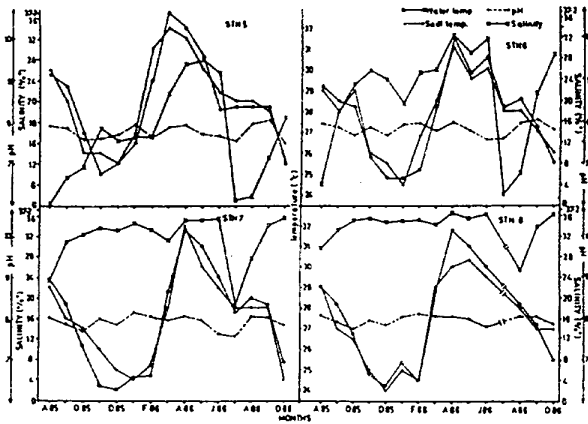


Fig. 3-Variations in temperature, pH and salinity at BCS.

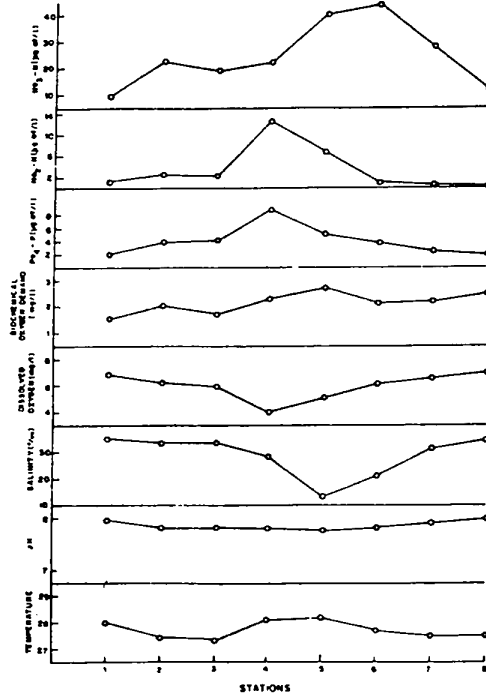


Fig. 4—Spatial variations in physico-chemical parameters (mean value) at HTS and BCS.

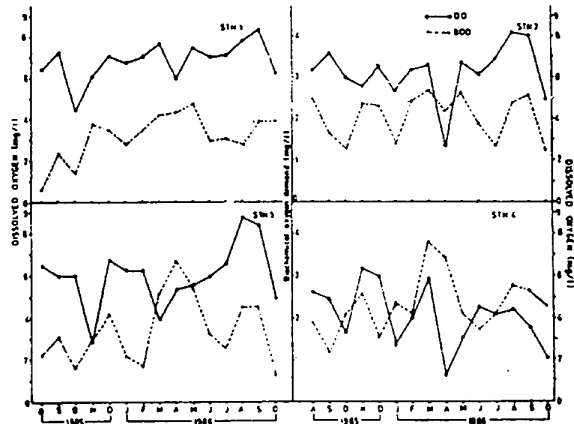


Fig. 5—Variations in DO and BOD at HTS.



Foraminiferans varied from 0.1 to and 0.1 to 5% respectively, in terms of population and biomass of the total macrofauna (Fig. 10 & 11). *Ammonia beccarii*, *Asterorotalia dentata*, *Poreponides lateralis* and *Eponides repandus* were the dominant species encountered in the area. Foraminiferans were very rarely noticed in small number at station 4 indicating their less preference to the polluted creek ecosystem.

Molluscs formed 1 to 44% of the total macrofauna in terms of population (Fig. 10) as well as contributed 0.5 to 68% of the total biomass (Fig. 11). Their percentage occurrence varied from 73 to 93 and their relative abundance was very high at station 4 as compared to rest of the stations indicating their higher preference to the creek ecosystem. The common bivalves noticed in the area (Table 2) were *Tellina* sp., *Nucula lalyardi*, *Meretrix meretrix*, *Macra* sp., *Pholas orientalis*, *Arca granosa* and *Paphia textile*, while the gastropods were generally represented by *Stenothyra deltae*, *Nassarius faveolatus*, *N.stolatus*, *Larna burmana* and *Cerideopsisilla cingulata*.

The contribution of sipunculids and nemertines to the total macrofauna was insignificant (< 3% population and < 1% biomass) and also patchiness in their distribution was evident (Fig.10 & 11). The rest of the faunal groups like echinoderms, pennatularians, turbellarians, fish larvae: barnacles and sea urchins were less numerous and occasionally encountered. Most of these groups were found confined to the coastal system away from the creek regions.

#### *Bassein creek - coastal system (BCS) :*

The mean macrofaunal population counts of 789 ( $\sigma$ 1050), 613 ( $\sigma$  1186), 2466 ( $\sigma$  4052) 70/m<sup>2</sup> ( $\sigma$  47/m<sup>2</sup>) and mean biomass of 3.7 ( $\sigma$  5.7), 3.3 ( $\sigma$  7), 1.8 ( $\sigma$  2.4) and 0.4 g/m<sup>2</sup> ( $\sigma$  0.4 g/m<sup>2</sup>) were encountered at stations 5 to 8 of BCS, respectively. Evidently stations 7 and 5 sustained the highest macropopulation and biomass, respectively .

Polychaetes were the most common group at BCS with an occurrence of 93 to 100%. They retained a faunal standing stock of 13 to 76% in terms of population ( Fig.10) and 9 to 68% in terms of biomass ( Fig.11). The polychaetes were well diversified and the obtained index (H') values for the stations 5,6,7 and 8, respectively, were 0.33, 0.59, 0.66 and 0.91. Evidently the lowest diversity of polychaetes in BCS was observed at the inner creek region (Station 5), whereas the coastal waters sustained relatively greater diversity of polychaetes (Table 1). The common species of polychaetes recorded at BCS were *Ancistrosyllis constricta*, *Prionospio pinnata*, *Paraheteromastus tenuis*, *Lumbriconereis lateilli*, *Cossura coasta*, *Prionospio polybranchiata*, *Diopatra neapolitana*, *Glycera longipinnis*, *G.alba*, *Terebellides* sp. and *Nephtys oligobranchia*.

Moluscs contributed 0.1–78% and 0.1–85% of the macrofaunal standing stock in terms of numerical count and biomass respectively (Fig. 10 & 11) Their percentage of occurrence

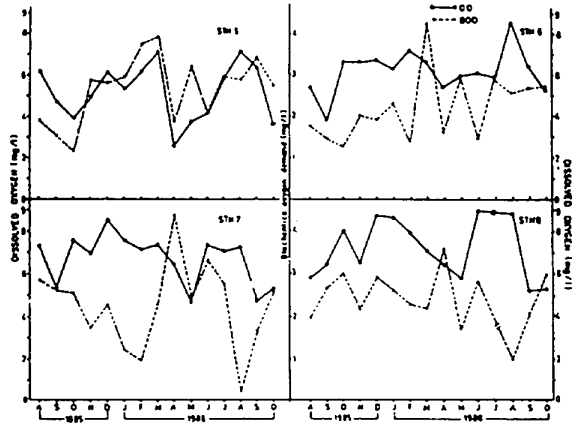


Fig. 6—Variations in DO and BOD at BCS.

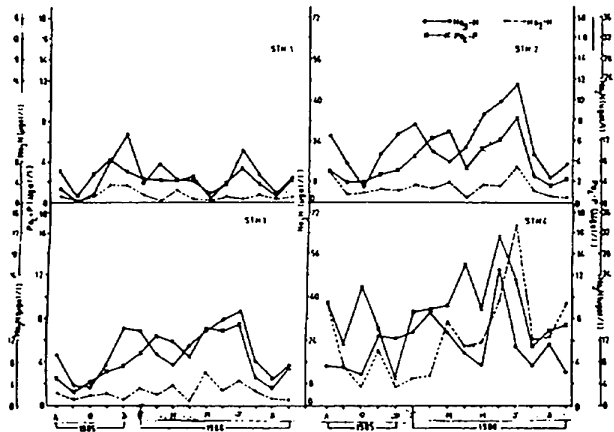


Fig. 7—Variations in essential nutrients at HTS.

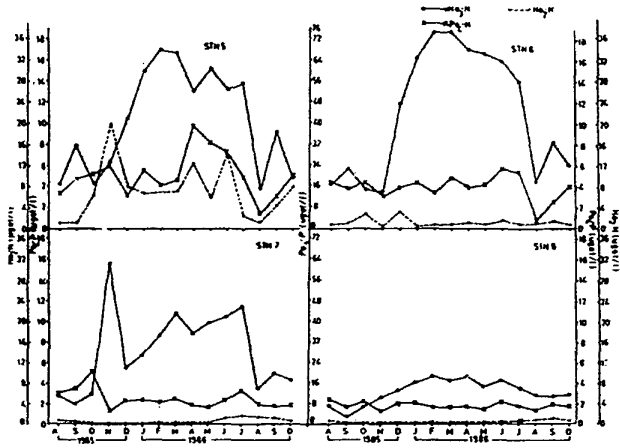


Fig. 8 - Variations in essential nutrients at BCS.

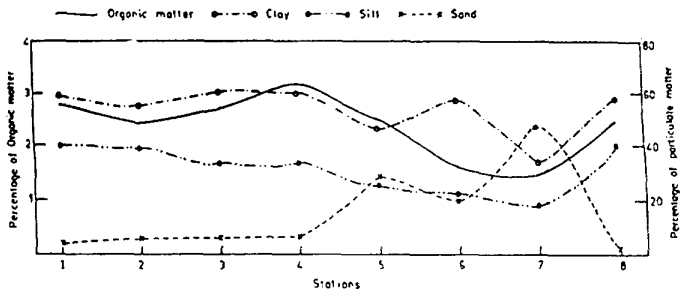


Fig. 9 - Organic matter - Particle size relationship of sediment.

Table 3- Comparison of marine environments between HTS and BCS.

Parameter	H T S		B C S	
	Range	Mean	Range	Mean
<b>Water quality</b>				
Temperature (°C)	24.5 – 32.0	27.5	24.0 – 32.8	27.7
pH	7.52 – 8.23	7.84	7.51 – 8.23	7.87
Salinity (ppt)	6.69 – 37.6	32.6	0.18 – 36.89	25.04
Dissolved oxygen (mg/l)	1.3 – 9.4	5.8	2.4 – 9.9	6.3
Biochemical oxygen demand (mg/l)	0.1 – 8.8	1.9	0.1 – 6.4	2.4
Phosphate phosphorus (µg at/l)	0.27 – 15.85	4.79	0.69 – 9.91	3.29
Nitrate nitrogen (µg at/l)	0.19 – 52.87	18.59	2.17 – 78.59	31.48
Nitrite nitrogen (µg at/l)	0.03 – 34.45	4.72	0.01 – 22.76	2.17
<b>Sediment quality</b>				
Temperature (°C)	24.8 – 31.8	27.4	24.0 – 32.0	27.7
Organic matter (%)	1.8 – 4.1	2.8	0.04 – 3.7	2.0
<b>Texture (%)</b>				
Sand	0.4 – 11.5	4.6	0.2 – 70.4	24.5
Silt	23.7 – 49.4	36.2	11.6 – 52.7	26.5
Clay	44.5 – 69.8	59.2	18.1 – 73.8	49.0
<b>Macrofauna</b>				
Population (no/m <sup>2</sup> )	12 – 5118	892	6 – 11760	984
Biomass (g/m <sup>2</sup> )	0.01 – 230.1	13.6	0.01 – 25.2	2.3

Parameter	H T S		B C S	
	Range	Mean	Range	Mean
Composition (%)				
Foraminiferans	<0.01 – 56.2	21.0	<0.1 – 86.1	24.3
Polychaetes	18.0 – 43.1	30.7	12.9 – 76.4	40.9
Molluscs	1.3 – 43.7	13.8	<0.1 – 78.0	23.8
Crustaceans	13.3 – 49.2	28.5	0.3 – 11.8	7.1
Sipunculids	<0.1 – 3.2	0.9	<0.1 – 4.4	1.1
Nemertines	1.5 – 3.4	2.5	<0.1 – 6.9	2.5
Species diversity of polychaetes (no. species)	10 – 17	14	9 – 14	12
Species diversity of molluscs (No species)	1 – 13	6	1 – 5	3

varied from 13 to 67 and they occurred more frequently at the inner creek as compared to the outer creek and the adjacent coastal systems. They were mostly represented (Table 2) by *Mactra* sp. *Nucula layardi* and *Stenothyra deltae*.

Foraminiferans accounted for 0.1 to 86% in terms of population and 0.1 to 30% in terms of biomass of the total macrofauna at BCS (Fig. 10 & 11). Their percentage of occurrence varied from 6 to 66 with the highest value confined to a sandy bottom at station 7. Usually the inner creek supported relatively very less foraminiferans as compared to the outer creek and the open coastal system. The common species encountered at BCS were *Ammonia beccarri* and *Poreponides lateralis* while *Eponides repandus* and *Asterorotalia dentata* were rarely observed.

The contribution of crustaceans (Fig. 10 & 11) to total macrobenthos varied from 0.3 to 12% (population) and 0.3 to 22% (biomass) while their percentage of occurrence varied from 33 to 53 indicating their preference to the creek/ coastal system as compared to the offshore regions. They were mostly represented by crabs (*Philyra globulosa* and *Ocyroda cordimana*) mysids, amphipods, isopods, copepods, cumaceans, ostracods megalopa larvae, porcellanid zoea and decapods (Hippolytidae, Paguridae, Pasiphaeidae,

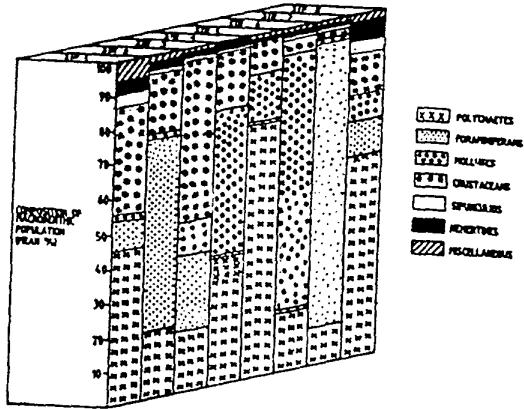


Fig. 10- Composition (mean %) macrofaunal population.

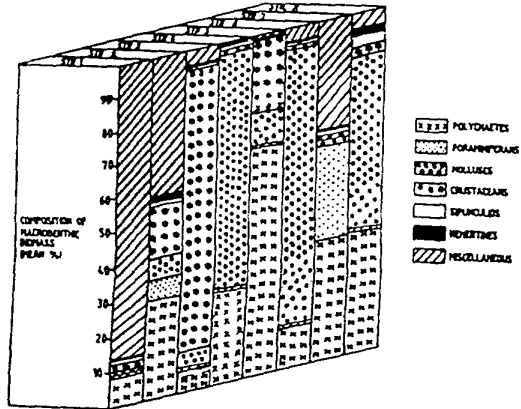


Fig. 11- Composition (mean %) of macrofaunal biomass.

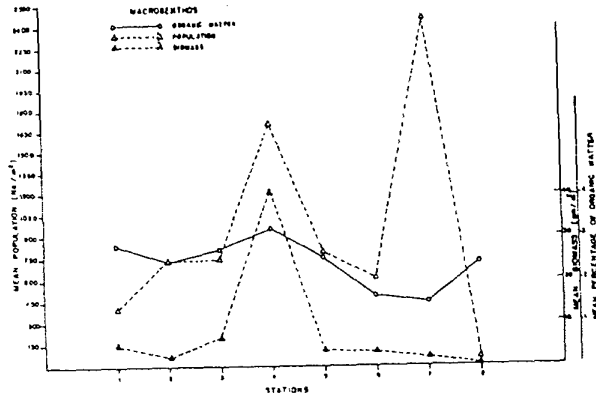


Fig. 12- Relationship of macrofaunal standing stock with sediment organic matter.

Palaemonidae, Apheidae and *Acetes* sp.) The faunal groups like sipunculids, nemertines and fish larvae were less common in BCS.

The foregoing results indicated wide fluctuations in macrofaunal abundance and distribution of the study region. The faunal distribution indicated that the frequency of occurrence of various faunal groups as polychaetes (95%) > molluscs (58%) > crustaceans (57%) > foraminiferans (41%) > nemertines (39%) > sipunculids (20%). In general, polychaetes were the most abundant and widely distributed group as compared to the rest of the macrofaunal groups which showed restricted distribution and abundance both in terms of temporal and spatial components (Fig. 10 & 11). Such wide fluctuations, in macrofaunal density and biomass in the region studied could be correlated to the physicochemical characteristics of the coastal and creek waters (Fig. 4). The results on environmental parameters viz ; DO, BOD, nutrients etc. clearly indicated (Fig 5 to 8) a possible stress induced high benthic productivity especially in Thana creek (station 4) due to industrial and domestic waste disposals. Similarly, earlier investigations<sup>9,13</sup>, have also revealed pollution induced high biological productivity especially at primary (194.31 tonnes C km<sup>-2</sup> y<sup>-1</sup>) and secondary levels both in terms of zooplankton (17.23 tonnes C km<sup>-2</sup> y<sup>-1</sup>) and benthos (0.376 g cm<sup>-2</sup> y<sup>-1</sup>) at Thana creek. Thus the present results on macrobenthos clearly support the pollution induced ecological changes at Thana creek (station 4). A comparison of the two systems such as the HTS and BCS showed almost comparable mean macro population count rather than the biomass (Fig. 12, Table 3). The high macro population count encountered at BCS (Table 3) was mainly attributed to the abundance of foraminiferans (Fig. 10) associated with a sandy bottom at station 7. In fact, contribution of foraminiferans to the benthic standing stock especially in terms of biomass is quite negligible<sup>22,23</sup>. The observed macrofaunal biomass in HTS (Fig. 12) was about six times more than that of BCS (Table 3). Evidently HTS was reported<sup>24</sup> to be biologically more productive as compared with BCS (Table 3). However, within HTS the Thana creek alone sustained greater biological potential than the harbour system<sup>8</sup>. Therefore, the observed high benthic productivity at Thana creek could be related to the high primary productivity associated with rich sediment organic matter (Fig. 12) through waste disposals. Apart from this considerable influence of adjacent vast mangrove ecosystem on the general productivity of the Thana creek system cannot be ruled out. A rich nutrient supply<sup>25,26</sup> higher primary productivity<sup>26,27</sup> and enriched sediment organic matter<sup>23,28</sup> supporting greater benthic standing stock have been widely reported earlier.

Considerable seasonal variations in benthic standing stock at HTS and BCS were observed. In general significant reduction in population count was noticed during monsoon chiefly associated with change in substratum and heavy freshwater influx as compared to pre- and post-monsoon periods (Fig. 13 to 15). Similar trend in macrofaunal standing stock during the south-west monsoon period was reported earlier along the west coast of India<sup>9,29,30</sup>. The inner creek segments of both HTS (station 4) and BCS (station 5 and 6)

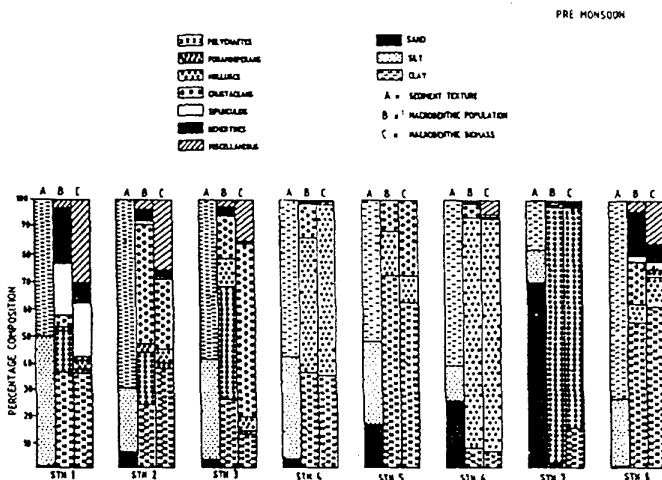


Fig. 13— Macrofauna and sediment texture during premonsoon.

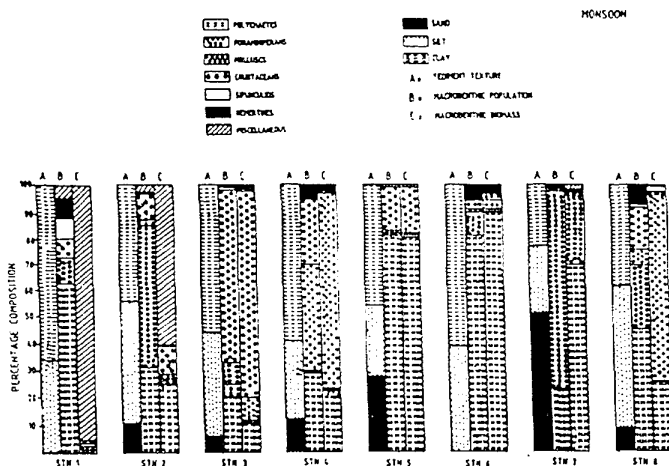


Fig. 14 – Macrofauna and sediment texture during monsoon.



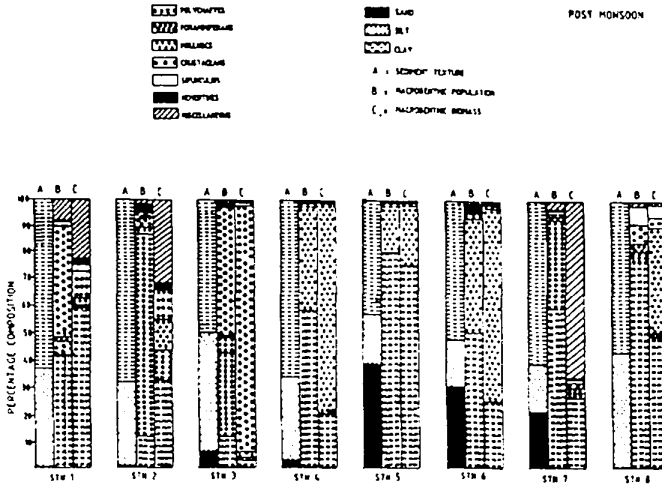


Fig. 15- Macrofauna and sediment texture during postmonsoon.

showed high benthic standing stock especially in terms of biomass during pre-monsoon when the environmental stress due to waste disposal was quite significant. Obviously, the various environmental factors like salinity pH and nutrients would have played a major role in supporting high primary productivity in turn the benthic productivity of the inner creek regions especially during pre-monsoon period. A similar trend in biological productivity was reported earlier from a polluted estuary<sup>28</sup> and a creek ecosystem<sup>23</sup>.

A decrease infaunal group diversity was usually noticed from the coastal to the inner creek system of both HTS and BCS (Figs. 10 & 11). An inverse relationship between species diversity and numerical abundance of polychaetes was noticed in the study region and the inner creek sustained invariably very high numerical abundance (Fig.10) with less species diversity (Table 1). Occurrence of less diversity with higher numerical abundance

of polychaetes in polluted ecosystems as compared to unpolluted regions has been well documented earlier<sup>9,23,31,32</sup>. It has been reported<sup>32</sup> that if the amount of waste disposal exceeds 40 mld, the biomass and population of polychaetes increase with decrease in diversity. Thana creek with a waste loading rate of more than 190 mld showed significant ecological modifications including the abundance and distribution of polychaetes as evident from the present results (Fig. 10, 11 Table 1).

In general, the dominance of polychaete species like *Prionospio pinnata*, *P. polybranchiata*, *Ancistrosyllis constricta*, *Nereis unifasciata*, *Perinereis cavifrons*, *Pista indica*, *Nephtys oligobranchia* and *Sabellaria cementarium* was noticed in the study area especially at the inner creek region (Table 1). These species can be considered as highly tolerant to environmental stress due to waste disposals. Similarly, the abundance of *Prionospio sp.* in the polluted regions of Cochin backwater has been reported earlier<sup>33,34</sup>.

On contrast to polychaetes, molluscs showed an increase in diversity (Table 2) at the inner creek regions as compared to the rest of the creek and coastal systems. This could mainly be attributed to the prevailing calm conditions due to sluggish circulation and weak tidal currents at the inner creek regions<sup>1</sup> apart from high organic enrichment, high nutrient levels and high biological productivity especially at lower trophic levels<sup>5,8,9</sup> which could possibly favoured the larval settlement; metamorphosis and colonisation of molluscs. The studies on zooplankton<sup>5</sup> further confirm with the decreasing abundance of molluscan larvae due to their active and preferential settlement at the inner creek regions as compared to the rest of the coastal system. Since many of the molluscs are highly tolerant to environmental stress it is quite likely that the prevailing pollution load could not have reached an alarming state in order to impair the colonization of selected molluscs at the inner creek system. However, the study reveals considerable environmental stress due to waste disposals on the creek ecosystem of both Thana and Bassein especially in terms of low species diversity of polychaetes as well as less group diversity of macrobenthos associated with very high biomass of pollution tolerant species which clearly indicates noticeable ecological modification of the creek ecosystems.

Therefore, the present study warrants alternate mode of waste disposals with strict pollution control measures in order to safeguard the deteriorating inner creek ecosystems of both Thana and Bassein. In addition, a periodic pollution monitoring studies of the coastal marine ecosystem of harbour-Thana-Bassein complex are to be formulated for an effective pollution control and management programmes.

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