

49. Long-term Variations in Benthic Macroinvertebrate Assemblages of Bombay, India

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Changes in composition, number, and biomass of macrobenthic infauna in relation to environmental deterioration in the coastal zone of Bombay, India were followed between 1974 and 1983. A time-dependent impoverishment in population density and faunal composition, with total depletion at many sites, was observed. Of the environmental parameters, dissolved oxygen concentration in the near-bottom water and organic matter composition of bottom deposits exhibited major changes, with deleterious effects on the biota. Macroinvertebrate infauna were comparatively more stable in offshore and deeper regions than in nearshore shallow areas. Polychaeta, a dominant taxon in offshore regions, was the only infaunal component of the most heavily affected nearshore region. The gradual deterioration of environmental quality resulting from the ever increasing anthropogenic perturbations has endangered the marine life.

INTRODUCTION

Increased human activity in coastal areas has produced deleterious effects on the marine biota (McIntyre 1977). This has generated interest among scientists to study the marine environment in relation to human interventions and changes, including pollution. Benthic organisms, largely sessile in habitat, are known to be reliable indicators of marine pollution (Lester and Beynan 1973). Knowledge about the scale and magnitude of seasonal and annual variations in benthic populations are needed for valid estimates of population shifts, which are presumably due to human activity (Maurer et al. 1979).

This paper presents and discusses the results of a decade-long study (1974-1983) on the changes in macrobenthic infaunal assemblages in relation to environmental consequences in the coastal zone of the metropolitan city of Bombay (18°55'N, 72°49' E).

MATERIAL AND METHODS

The sampling site locations are shown in figure 1. The first (January 1974) and second (May 1974) sets of benthic samples were collected on board the *I.N.S. Darshak*; subsequent sampling from February 1976 to January 1983 was on board the *R.V. Gaveshani*. Sampling stations were located on a transect, perpendicular to the coast, with the farthest station less than 130 km from the coastline and the nearest in the Bombay harbor basin.

Sampling was done by deploying a modified Peterson Oken grab (0.1 m² area) or La Fond Dietz snapper (0.017 m² area). A total of 55 stations in a depth range of 11 to 119 m were operated. All values on population density and biomass were raised to unit values of m². Analyses and processing of the benthic samples followed the method of Parulekar et al. (1976). Salinity and dissolved oxygen of near-bottom water were measured by conventional methods (Strickland and Parsons 1968); the organic matter in bottom deposits was estimated by the method of El Wakeel and Riley (1956).

RESULTS AND DISCUSSION

Physical-chemical characteristics

Dissolved oxygen concentrations during the study period showed a decreasing trend, most noticeable in the later years (figure 2). A maximum oxygen value of 4.77 ml/l was recorded in January 1974 at a depth of 25 m and a minimum of 0.76 ml/l in January 1983, at a depth of 32 m. Zingde et al. (1979) in reporting abnormally low dissolved oxygen values in the Bombay coastal waters attributed them to extremely high discharges of domestic and industrial effluents.

Observations on bottom salinity distribution indicated no changes in the values through the study period. The organic matter content in the sediments, estimated on three different occasions (table 1), exhibited an increasing trend in the percent composition, especially nearshore. An increasing trend in organic matter content is dependent on increased organic inputs in the Bombay harbor (Anon. 1975). Recently, Bhosle et al. (1983) observed very high lipid values in the marine environs of Bombay and traced them to anthropogenic inputs, such as industrial effluents, municipal sewage, and industrial-waste dumping in the coastal areas.

Population density and numbers

Faunal abundance (n/m²) and biomass (g/m²), by depth, are summarized in table 2. Average population density decreased from 1260/m² in

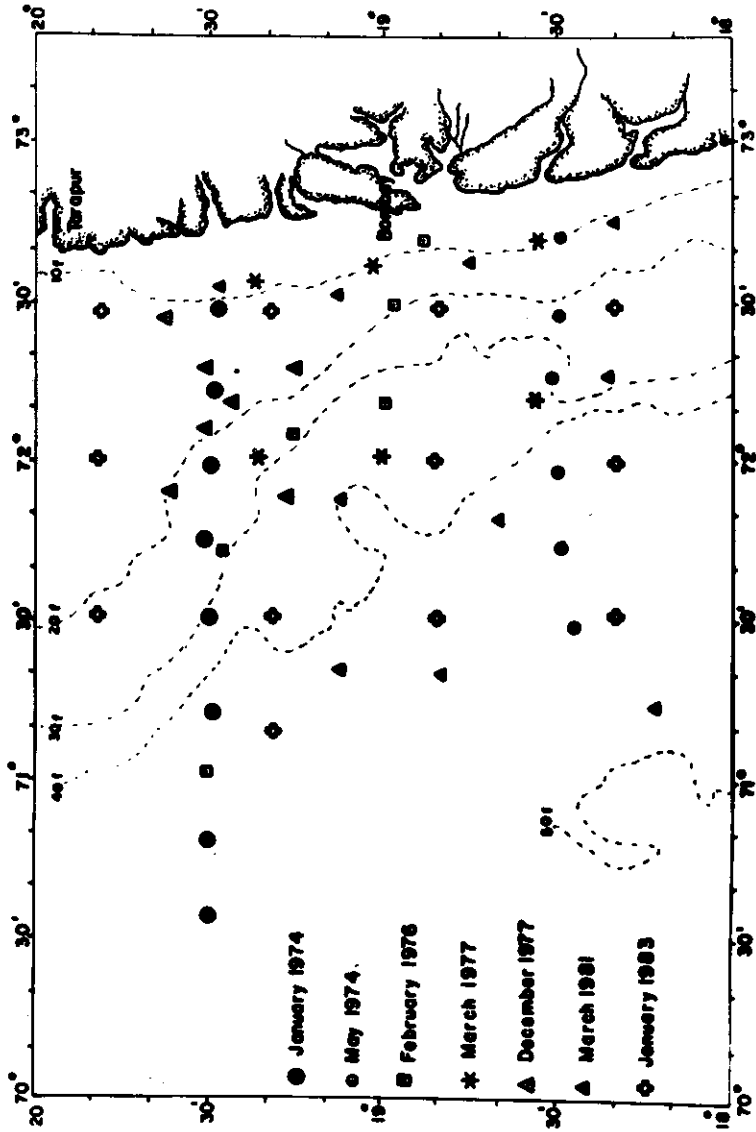


Figure 1. Macrobenthic sampling sites off Bombay coast. Yearly transect.

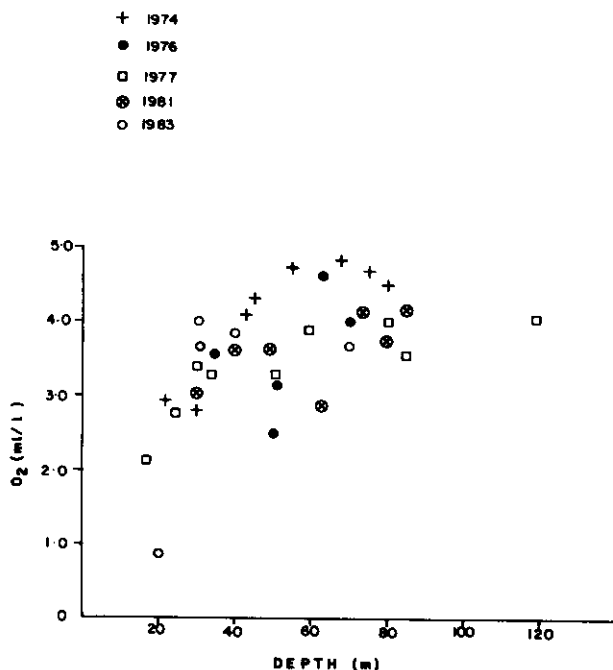


Figure 2. Dissolved oxygen distribution at different depths and in different years, off Bombay.

1976 to $173/\text{m}^2$ in 1983. Consequently, a decreasing trend in biomass (wet weight) was observed from 1976 ($42.27 \text{ g}/\text{m}^2$) to 1983 ($9.14 \text{ g}/\text{m}^2$). It should be noted that in a quantitative study such as ours, numbers are considered more valid than biomass values (Sanders 1960).

In overall analysis, the population density (table 2) progressively decreased from 1974 through 1983, with the most striking decline in the nearshore shallow region to 40 m depth. The zone between 40 and 60 m depth harbored a relatively high benthic population. Maximum

Table 1. Average value of organic matter percent (dry weight basis) \pm SD in sediments off Bombay.

Year	Nearshore ($< 30 \text{ m}$ depth)	Offshore ($> 30 \text{ m}$ depth)
1977	1.85 ± 0.56	1.21 ± 0.32
1981	2.12 ± 0.28	1.38 ± 0.49
1983	2.77 ± 0.49	1.58 ± 0.41

Data were analyzed by paired 't' test. Differences in values were significant at $p=0.10$.

Table 2. Average population density (n/m^2) and biomass (g/m^2), by depth, of macrobenthos off Bombay.

Depth (m)	1974		1976		1977		1981		1983	
	P	B	P	B	P	B	P	B	P	B
0-20	—	—	169	21.65	28	0.24	89	0.18	nil	nil
21-40	297	2.94	1537	15.37	174	2.03	30	0.15	23	0.12
41-60	1094	22.30	1872	15.26	493	8.64	1302	11.65	236	4.04
61-80	406	6.94	1464	8.97	325	6.05	337	3.34	436	4.98
81-100	—	—	—	—	177	2.72	—	—	—	—
>100	—	—	—	—	174	11.02	—	—	—	—

P = population density (n/m^2), B = biomass on wet weight (g/m^2).

population density ($1872/m^2$) was recorded in the 41-60 m depth zone in 1976 and the minimum ($23/m^2$) at 21-40 m depth during 1983. These results clearly indicate the deterioration of benthic infauna in near-shore shallow regions to 40 m depth in the later part of the investigation. Parulekar et al. (1976) reported a mean population density of $58/m^2$ for the depth regions within 40 m off Bombay. Thus, in less than 7 years, the population density decreased by more than 50 percent. This could be explained by the high magnitude of sewage and industrial pollution of recent years in the Bombay coastal zone (Zingde et al. 1981).

Faunal composition

In the harbor and nearshore region, the infaunal population was dominated (with a low population density) by polychaete worms. This is the region having maximum impact from sewage and industrial effluents (Anon. 1975), which generally result in considerable damage to benthic fauna (Bozzini 1975). Only some of the polychaete species, especially deposit feeders (Mearns 1981), are found near sewage outfalls and can thrive well under such environmental conditions. McIntyre (1977) observed that seawater in the environs of a highly industrialized city is not conducive to the well-being of benthic organisms. Such conditions probably contribute not only to the overall dominance of more resistant organisms such as polychaetes but also to the overall impoverishment of sea-floor life. We observed this during the later years of our study.

In 1974 three faunal taxa were recorded from nearshore regions as against only one taxon in 1983. Parulekar et al. (1976) also reported 3 taxa from a shallow region, below 40 m depth, off Bombay. Similarly, Sanders (1968) found a polychaete-bivalve fraction contributing more than 80 percent to the total macrobenthic fauna at a 25 m depth station off Bombay. Near the end of our study, a total absence of bivalves from comparable shallow depths was recorded. These differences in distribution and faunal composition could be a consequence of the drastic changes in the marine environmental conditions off Bombay (Gajbhiye et al. 1981). Environmental perturbations arising out of anthropogenic activities are reported (Anderson et al. 1978) to cause depopulation and major changes in the community structure of benthic assemblages.

Above 40 m, the fauna are comprised of polychaetes (58.2 percent), bivalves (16.3 percent), crustacea (10.6 percent), echinoderms (8.7 percent), and other taxa (6.2 percent). Hence, no major time-linked changes in faunal composition were discernible in offshore regions. This composition is in agreement with earlier reports for Bombay offshore regions (Parulekar et al. 1976).

Spatial and temporal variations

Qualitative and quantitative differences in the macrobenthic infauna collected at different times, and even from the same site, were observed. Such differences could either be due to biological interactions or to seasonal behavioral patterns (Masse 1972, Lie and Evans 1973). This was true particularly in the nearshore regions where Watling (1975) observed striking seasonal changes of recurring nature in a number of benthic species. Therefore, gradual but retrogressive changes in macrobenthic infaunal assemblages with the passage of time, and subsequent disappearance of fauna at some nearshore sites appear to be the result of environmental changes caused by various human activities, including pollution off Bombay (Anon. 1975).

Variations in the abundance of macroinvertebrate infauna, in relation to depth distribution, are presented in figure 3. In 1974, the fauna were moderately rich, even in the nearshore shallow regions, with the highest population density in the 30-50 m depth zone. Moreover, fauna were recorded from all sampling sites. With passage of time, some of the areas, particularly in the nearshore regions to 40 m depth, started showing a gradual decline in fauna, and by 1983 only two sites out of seven were found to harbor any macroinvertebrate infauna.

Thus, during a time span of 10 years (1974-1983) the faunal composition underwent radical changes. In 1974 most of the nearshore stations had more than three faunal taxa, which by 1983 were reduced to a single one, i.e., polychaetes, which are known to occur even in polluted waters (Reish 1972, Pearson and Rosenberg 1978). Such changes indicate a slow deterioration of the environment and the biota. At this rate, in the next few years the bottom fauna in Bombay's marine environs may completely disappear. Total depletion of benthic fauna due to intense anthropogenic perturbations is recorded from the Baltic Sea (Anderson et al. 1978).

The extent to which benthic assemblages are affected by environmental disturbances is rather difficult to quantify because of the lack of detailed knowledge on individual species responses to varying environmental stresses (Rainer 1981). However, on a macroscale, complex benthic patterns have been observed to occur due to large-scale changes in environmental conditions (Parulekar et al. 1980). Therefore, it can reasonably be surmised that environmental disturbances arising out of increasing anthropogenic perturbations are the important causative factors for adverse effects of impoverishment and depletion of macroinvertebrate infaunal assemblages in the coastal zone of Bombay.

In such a long-term study credit is due to many individuals, especially our colleagues, to whom we owe gratitude.

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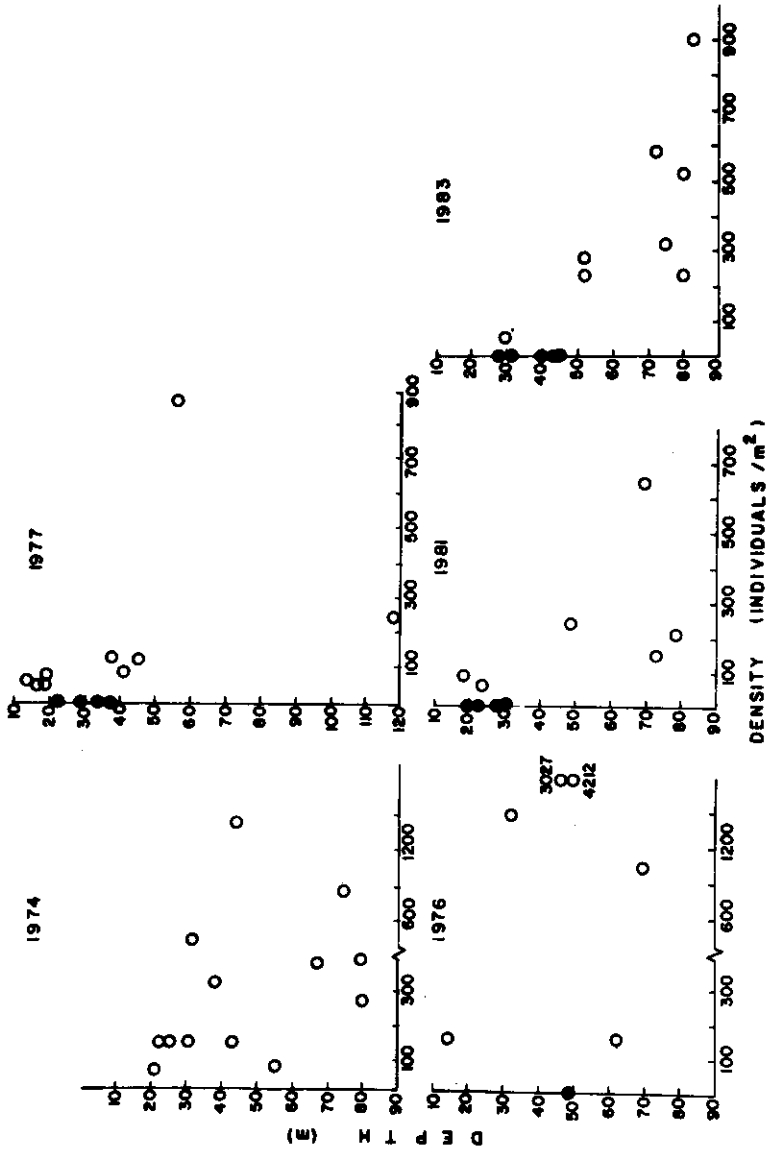


Figure 3. Abundance of macroinvertebrate fauna, by depth and year, off Bombay coast. Open circles indicate presence and closed circles absence of fauna.

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LITERATURE CITED

- Anderson, A.B., J. Lassig, L. Pakkonen and H. Sandler. 1978. The decline of macrofauna in the deeper parts of the Baltic proper and the Gulf of Finland. *Kieler Meeresforsch* 4: 23-49.
- Anonymous. 1975. Oceanographic and waste-water disposal studies around Bombay. NIO Proj. Rep., pp. 23.
- Bozzini, G. 1975. Enrichment phenomena and danger of eutrophication in marine environments. Pages 193-196 in E.A. Pearson and De Frajor Frangipane, eds. *Marine Pollution and Waste Disposal*. Pergamon Press, New York.
- Bhosle, N.B., Classy D'Silva and C.V.G. Reddy. 1983. Preliminary study on marine lipids. *Indian J. Mar. Sci.* 12. (in press).
- El Wakeel, S.K. and J.P. Riley. 1956. The determination of organic carbon in marine muds. *J. Cons. Per. Int. Explor. Mar.* 22: 180-183.
- Gajbhiye, S.N., Jiyalal Ram and B.N. Desai. 1981. Distribution of copepods from the polluted and unpolluted regions off Bombay. *Indian J. Mar. Sci.*, 10: 346-349.
- Lester, T.E. and L.R. Beynan. 1973. Pollution and the offshore oil industry. *Mar. Pollut. Bull.* 4(2): 23-25.
- Lie, U. and R.A. Evans. 1973. Long-term variability in the structure of subtidal benthic communities in Puget Sound, Washington, U.S.A., *Mar. Biol.* 21: 122-126.
- Masse, H. 1972. Quantitative investigations of sand bottom macrofauna along the Mediterranean northwest coast. *Mar. Biol.* 15: 209-220.
- Maurer, D., Wayne Leathern, Kinner Peter and Jeffrey Tinsman. 1979. Seasonal fluctuations in coastal benthic invertebrate assemblages. *Estuarine Coastal Mar. Sci.* 8: 181-193.
- McIntyre, A.D. 1977. Effects of pollution on inshore benthos. Pages 301-312 in B.C. Coull, ed. *Ecology of Marine Benthos*. University of South Carolina Press.
- Mearns, A.J. 1981. Ecological effects of ocean sewage outfall: observations and lessons. *Oceanus* 24: 45-49.
- Parulekar, A.H., S.A. Nair, S.N. Harkantra and Z.A. Ansari. 1976. Some quantitative studies on the benthos off Bombay. *Mahasagar. Bull. Nat. Inst. Oceanogr.* 9: 51-56.
- Parulekar, A.H., V.K. Dhargalkar and S.Y.S. Singbal. 1980. Benthic studies in Goa estuaries: Part III. Annual cycle of macrofaunal distribution, production and trophic relations. *Ind. J. Mar. Sci.* 9: 189-200.
- Pearson, T.H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environ-

- ment. *Oceanogr. Mar. Biol. Ann. Rev.* 16: 229-311.
- Rainer, S. 1981. Temporal pattern in the structure of macrobenthic communities of an Australian estuary. *Estuarine Coastal Mar. Sci.* 13: 597-619.
- Reish, D.J. 1972. The use of marine invertebrates as indicators of varying degrees of marine pollution. Pages 203-207 in M. Ruivo, ed. *Marine Pollution and Sea Life*. Fishing News Book, London.
- Sanders, H.L. 1960. Benthic studies in Buzzards Bay. III. The structure of the soft-bottom community. *Limnol. Oceanogr.* 5: 138-153.
- Sanders, H.L. 1968. Marine benthic diversity: a comparative study. *Am. Nat.* 102: 243-282.
- Strickland, J.D.H. and T.R. Parsons. 1968. A Practical Handbook of Sea Water Analysis. *Bull. Fish. Res. Bd. Canada*. pp. 11-39.
- Watling, L. 1975. Analysis of structural variations in a shallow estuarine deposit feeding community. *J. Exp. Mar. Biol. Ecol.* 19: 275-313.
- Zingde, M.D., S.K. Trivedi and B.N. Desai. 1979. Physico-chemical studies on coastal pollution off Bombay. *Ind. J. Mar. Sci.* 8: 271-277.
- Zingde, M.D. and B.N. Desai. 1981. Mercury in Thane Creek, Bombay harbor. *Mar. Poll. Bull.* 12: 237-241.