

## Spatial & Temporal Changes in Benthic Macrofauna from Mandovi & Zuari Estuaries of Goa, West Coast of India

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Sixty nine species were recorded from 6 stations in the Mandovi and Zuari estuaries of Goa. Maximum density ( $2425 \text{ m}^{-2}$ ) was observed during pre- and post-monsoon and minimum ( $650 \text{ m}^{-2}$ ) during monsoon season. Polychaetes were dominant taxa in both estuaries followed by Crustacea and Mollusca. There was about 40% reduction in the population density and species composition as compared with an earlier study of 1971-73. The implication of this variability and the utilization of quantitative benthic information in pollution impact studies are discussed.

Knowledge of benthic community structure and their temporal variability is important to understand changes caused by human interference and natural fluctuations. Many reports, using benthos to measure the degree of pollution in an area, as indicated by its changes<sup>1,2</sup>, are on record.

In an earlier publication<sup>3</sup>, a full account of 2 y (1971-73) data on benthos from Mandovi and Zuari estuarine system of Goa, has been discussed. The present study, undertaken in 1982-83, is aimed at finding long term changes, both temporal and spatial, in the benthic environment in relation to the analogous results of earlier study<sup>3</sup>. The data are discussed in terms of use of benthic fauna to assess the impact of man-made changes on natural ecosystems.

### Materials and Methods

Samples were collected from 3 stations in each estuary, located in the lower, middle and upper regions (Fig. 1). Replicate samples, collected from all stations at monthly intervals (June 1982 to May 1983) using a Van Veen grab ( $0.04 \text{ m}^2$  area), were sieved through a 0.5 mm mesh screen. Animals retained on the sieve were identified wherever possible up to species, counted and weighed excluding hard parts. The wet weights of the major species were converted into carbon equivalent weights<sup>3</sup>.

Water temperature, dissolved oxygen (DO) and salinity of the bottom water (30 cm above substratum) were measured monthly at all stations following standard techniques. Sediment analysis was done by the method of Buchanan<sup>4</sup>.

Faunal similarity between the stations was measured by Kendall's coefficient of association 'T' in which similarity between stations is based on the presence or absence of species. The frequency data for

each species were used to calculate the sample values for diversity H (ref. 5). The evenness was measured by  $E = e^H - 1/S - 1$  and species richness by  $S - 1/1/nN$  (ref. 6, 7).

### Results

*Environmental features* — Bottom water temperature varied between 23.8 and 32.2°C with modest seasonal changes. There was a progressive increase in temperature in both estuaries from Jan. to May. Lowest temperature was during the peak monsoon (June-Sept; Fig. 2a). Temperature changes of up to 6°C were noticed during the period of observation.

DO values in the bottom water varied between 2.67 and 5.12  $\text{ml.l}^{-1}$  in Zuari estuary (Fig. 2b) with an annual average of 3.55  $\text{ml.l}^{-1}$ , while the same in Mandovi varied from 2.42 to 4.35  $\text{ml.l}^{-1}$ . There was a gradual decrease in DO from monsoon towards post (Oct.-Jan.) and premonsoon (Feb.-May) seasons. Generally the values were lower in the upper reaches as compared to lower reaches.

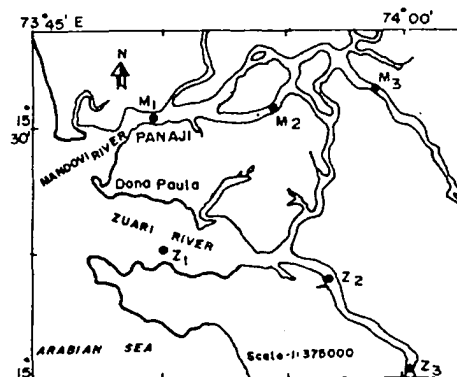


Fig. 1—Location of stations

Seasonal variation in salinity was very high (Fig. 2c). In Mandovi, the annual range in salinity was  $35 \times 10^{-3}$ , the lowest being in Aug. at st M<sub>3</sub> and highest in May at st M<sub>1</sub>. In Zuari, the lowest value (0.4‰) was in Nov. at st Z<sub>1</sub>. There was a continuous increase in salinity after the monsoon season and sts M<sub>1</sub> and Z<sub>1</sub> at the mouth regions simply became an extension of the sea during post and premonsoon seasons. In general, the salinity showed decreasing trend with increasing distance from the mouth towards upstream in both the estuaries. Average annual salinity in Mandovi estuary ( $17.22 \times 10^{-3}$ ) was lower than in Zuari estuary ( $20.76 \times 10^{-3}$ ). This is because the Mandovi river receives large amount of run off through a large tributary system<sup>10</sup>.

Sediment characteristics and its distribution in these estuaries were earlier reported<sup>8,9</sup>. Table 1 shows the average percentage of sand, silt and clay along with sediment type at each station. Percentage of sand was high at sts M<sub>2</sub> and Z<sub>1</sub>. Silt was high at sts M<sub>3</sub> and Z<sub>3</sub> in the upper reaches. Frequently, lateritic pebbles brought by runoff from mining refuge were collected from these stations.

**Faunal distribution**—Spatial and temporal distribution of macrobenthos is shown in Fig. 3. Faunal

density (no. m<sup>-2</sup>) varied between 0-2050 and 0-2425 in Mandovi and Zuari estuaries, respectively. The faunal density showed wide seasonal variation. The fauna was very poor especially in the upper reaches during monsoon season while in the post and premonsoon seasons there was a progressive increase in the population density. The fauna progressively decreased with increasing distance from the mouth towards upper reaches in both estuaries. These trends were clearer for densities than for the number of taxa.

Table 1—Sediment Characteristics at Different Stations

[Values (%) average of monthly samples]

ST	Av. depth (m)	Sand	Silt	Clay	Type
M <sub>1</sub>	10	13.13	36.72	50.15	SC
M <sub>2</sub>	6	80.44	11.26	9.30	S
M <sub>3</sub>	4	9.79	56.38	33.83	CS
Z <sub>1</sub>	9	72.58	14.25	13.17	SS
Z <sub>2</sub>	7	34.62	41.55	23.83	SSC
Z <sub>3</sub>	4	20.54	49.32	30.14	CS

CS=clayey silt, S=sand, SC=silty clay, SS=silty sand and SSC=sand silt clay.

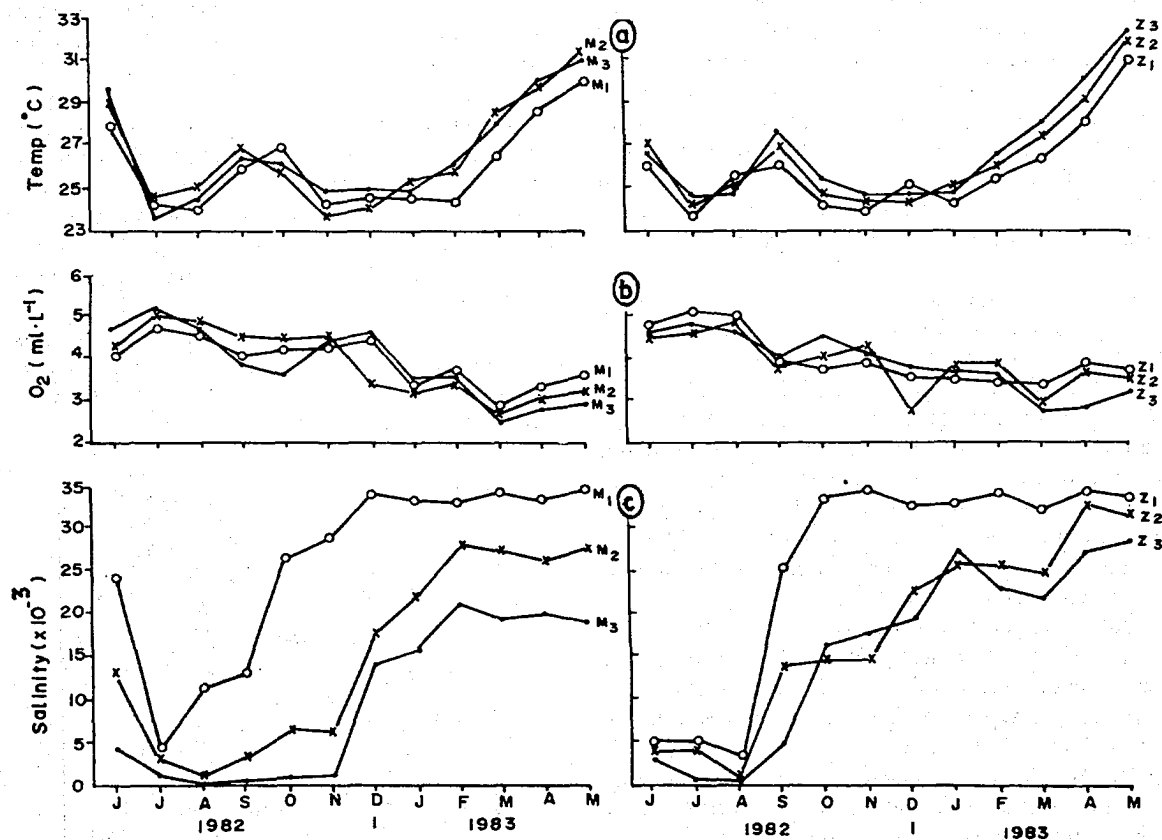


Fig. 2—Monthly variations in the (a) bottom water temperature (b) dissolved oxygen and (c) salinity at 6 different stations

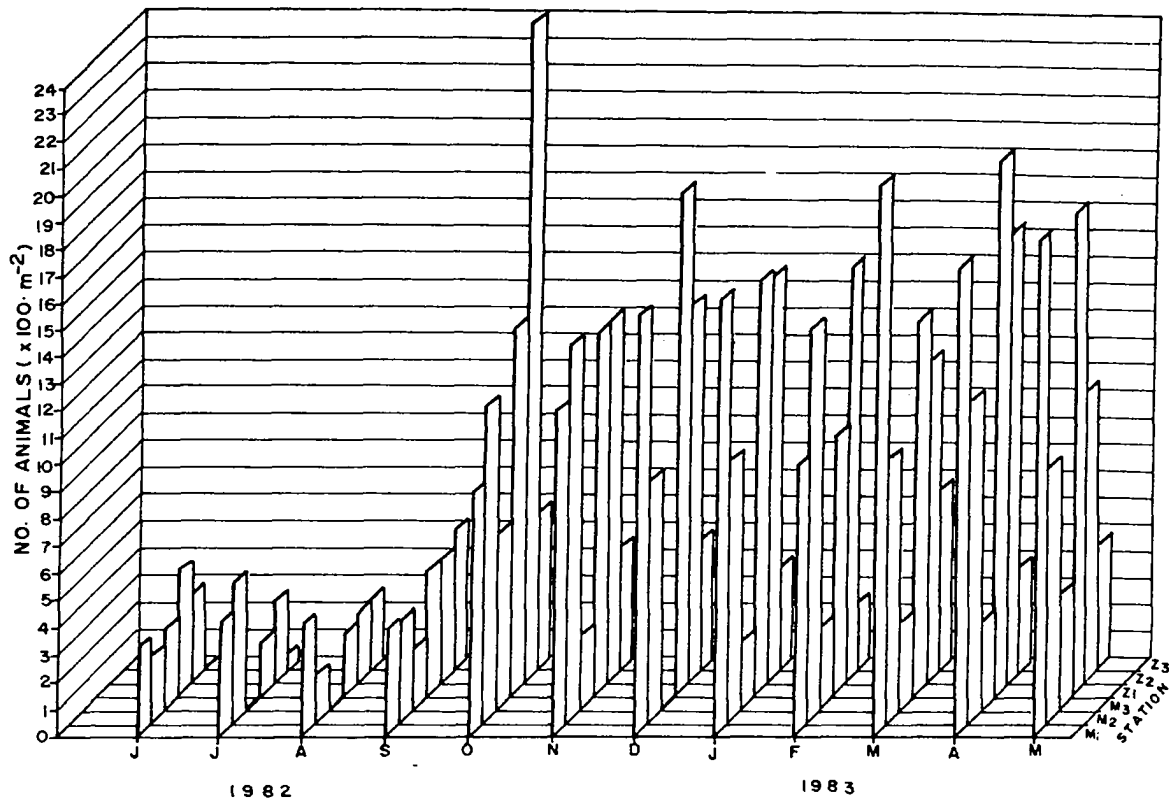


Fig. 3—Seasonal changes in the macrobenthic density at 6 different stations

The mean site values showed considerable differences between stations (Table 2). The species showed decreasing trend from mouth (sts  $M_1$  and  $Z_1$ ) toward upstream both in abundance and biomass. Changes observed in the number of species and abundance were accompanied by changes in diversity statistics also.

The percentage faunal contribution in different seasons at each station is given in Fig. 4. Polychaetes were the most dominant group at all stations except during premonsoon at st  $M_1$ . Next in abundance were crustaceans followed by molluscs. The percentage contribution of polychaetes was higher in Zuari estuary than in Mandovi estuary in all the seasons. Other faunal groups were Nemertinea, Echiurida, Coelenterata and Gobid fishes.

*Species composition*—Altogether 69 species were collected from 6 stations. Species regularly observed in the samples were *Diopatra neapolitana*, *Lepidonotus tenuisetosus*, *Marphysa sanguinea*, *Meretrix casta*, *Gafrarium pectinatum* and the post larvae and juveniles of *Metapenaeus dohsoni* and *Penaeus merguensis* at st  $M_1$ ; *Nephtys polybranchia*, *Glycera alba*, *Cerithidea fluviatilis* and *M. dohsoni* at st  $M_2$  and *Lumbriconereis polydesma*, *G. alba* and *Corophium* sp. at st  $M_3$  in

Table 2.—Mean Number of Species Per Sample ( $\bar{S}$ ), Density ( $D \cdot m^{-2}$ ), Biomass ( $B$ ,  $gC \cdot m^{-2}$ ), Diversity ( $H$ ), Evenness ( $E$ ) and Species Richness ( $SR$ ) of Total Count

St	$\bar{S}$	$\bar{D}$	B	H	E	SR
$M_1$	16	1108	14.63	4.76	2.99	3.86
$M_2$	13	918	34.29	4.37	2.98	3.07
$M_3$	7	264	3.74	4.12	3.28	2.14
$Z_1$	18	1143	113.45	4.96	3.32	4.48
$Z_2$	12	1029	6.02	4.28	2.39	3.11
$Z_3$	8	372	2.12	4.12	2.89	2.34

Mandovi estuary. The common and the numerically dominant species in Zuari estuary were *Prionospira pinnata*, *D. neapolitana*, *N. polybranchium*, *C. fluviatilis*, *G. pectinatum*, *Paphia textile* and *Melita* sp. at st  $Z_1$ ; *G. longipinnis*, *P. pinnata*, *M. casta* and *Melita* sp. at st  $Z_2$  and *P. polybranchiata*, *L. simplex*, *Dendronereis* sp., *Corophium* sp. *Apseudes chilensis* at st  $Z_3$ . Three species, *M. casta*, *C. fluviatilis* and *A. chilensis* are estuarine endemic<sup>3</sup> which were recorded from all stations. Zuari estuary was richer in terms of number of species than the Mandovi estuary.

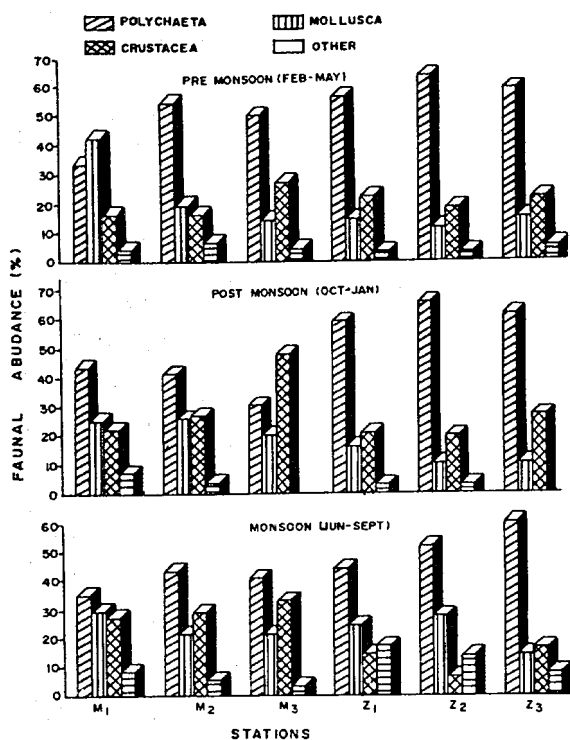


Fig. 4—Percentage contribution of major macrobenthic groups in different seasons at 6 different stations

Monthly and seasonal changes in the overall abundance of species occurred at all stations throughout the study (Fig. 5). A number of species showed variation in their sample abundance. Mean number of species per sample was highest in the premonsoon season and lowest in the monsoon season. Maximum number of species (25) was recorded in May at st Z<sub>1</sub>. Species abundance showed decreasing trend from the mouth towards upper reaches of the estuary. At st M<sub>3</sub>, no species were found in July and August and at st Z<sub>3</sub>, no fauna was observed in June.

**Faunal similarity**—Faunal similarity was measured using 2 × 2 contingency table and the values were tested by  $T_e = (\chi^2 \cdot 0.05/S)^{1/2}$  with one degree of freedom at 5% probability level. Coefficient for Kendall's Tau values are given in Table 3. Most of the values showed a significant relation and strong association between the stations. However, sts M<sub>3</sub> and Z<sub>3</sub> yielded insignificant results in association with st Z<sub>1</sub>. The adjacent stations showed greater similarity than stations situated at distance. This was mainly because a number of species coexisted and were common at other stations. The great abundance of polychaete, *D. neapolitana*, *G. alba* and crustaceans at sts M<sub>1</sub> and Z<sub>1</sub> accounted for the high similarity indices between these stations.

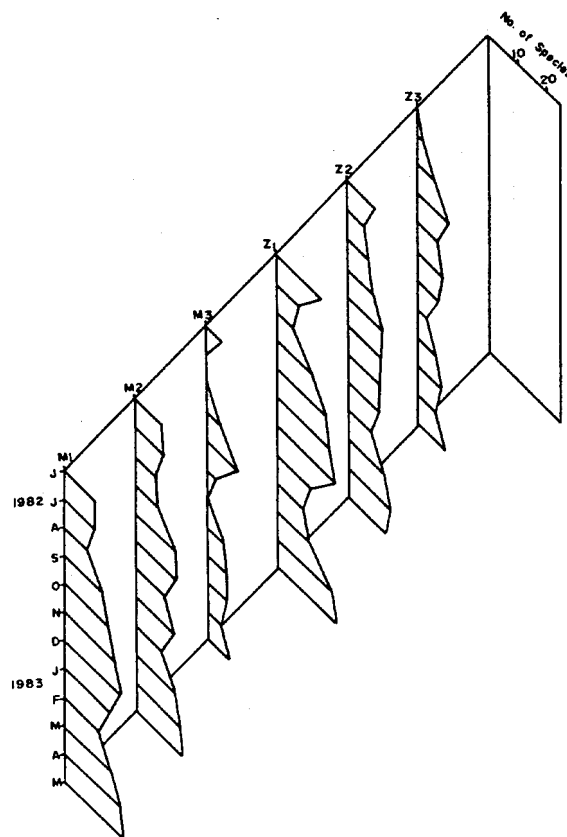


Fig. 5—Seasonal fluctuation in the total number of species at 6 different stations

Table 3—Matrix of Kendall's Coefficient of Association Tau

	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	Z <sub>1</sub>	Z <sub>2</sub>	Z <sub>3</sub>
M <sub>1</sub>	—	0.62013	0.40717	0.63369	0.52208	0.37790
M <sub>2</sub>		—	0.54298	0.57583	0.42374	0.46513
M <sub>3</sub>			—	0.21798*	0.57543	0.53477
Z <sub>1</sub>				—	0.56633	0.22368*
Z <sub>2</sub>					—	0.57280
Z <sub>3</sub>						—

\*Lack of association at 0.5% significance level.

**Diversity, evenness and species richness**—The H values are given in Table 4. The index varied from nil at sts M<sub>3</sub> and Z<sub>3</sub> to 4.19 at st M<sub>1</sub>. It showed changes at all the stations. The changes were more pronounced in the upper reaches. It followed changes in the number of species and their spatial heterogeneity.

The evenness index (E) used here was derived from Shannon's index<sup>6</sup>. There were some spatial differences in the E values (Table 5) although they did not vary appreciably. These values ranged between 0 and 4 at all stations. It shows that the macrobenthic population was more evenly distributed in the lower reaches of the

Table 4—Diversity Index (H)

	Station					
	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	Z <sub>1</sub>	Z <sub>2</sub>	Z <sub>3</sub>
1982						
June	3.69	3.18	2.73	4.16	3.33	0
July	3.24	3.15	0	2.80	2.62	1.92
Aug.	2.93	2.72	0	3.08	2.91	2.44
Sept.	3.73	2.97	1.43	3.49	2.59	2.59
Oct.	3.85	3.61	3.43	3.65	2.52	3.15
Nov.	3.84	3.51	3.23	3.75	3.12	3.68
Dec.	4.19	3.19	0	4.08	3.51	2.83
1983						
Jan.	3.86	3.29	3.24	3.27	3.71	2.63
Feb.	3.58	3.04	2.52	3.29	2.72	2.36
March	3.31	3.76	2.16	3.14	3.28	2.87
April	3.48	3.66	3.57	3.78	3.23	3.09
May	4.05	3.81	3.57	3.98	3.90	3.52

Table 5—Evenness (E) Values at Various Stations

	Stations					
	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	Z <sub>1</sub>	Z <sub>2</sub>	Z <sub>3</sub>
1982						
June	3.00	2.56	2.06	3.53	2.71	0
July	2.47	2.25	0	2.59	2.13	1.94
Aug.	2.22	2.36	0	2.60	2.50	2.10
Sept.	3.11	2.32	1.60	2.91	1.76	2.06
Oct.	2.57	2.40	2.50	1.98	1.14	2.23
Nov.	2.40	2.33	2.43	1.97	1.83	2.97
Dec.	2.95	1.96	0	2.79	2.51	2.29
1983						
Jan.	2.34	2.35	2.46	1.96	2.66	2.16
Feb.	1.89	2.00	2.29	2.00	0.46	1.93
March	1.44	2.63	1.92	1.84	1.97	2.38
April	2.37	2.57	2.67	2.26	1.74	1.92
May	2.99	2.77	2.89	2.19	2.69	2.73

Table 6—Species Richness Values

	Station					
	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	Z <sub>1</sub>	Z <sub>2</sub>	Z <sub>3</sub>
1982						
June	2.14	1.55	1.18	2.81	1.65	0
July	1.65	1.56	0	1.16	1.03	0.62
Aug.	1.30	1.08	0	1.38	1.22	0.90
Sept.	2.14	1.30	0.36	1.81	1.15	0.98
Oct.	2.57	2.09	1.84	2.59	1.28	1.54
Nov.	2.65	1.88	1.51	2.85	1.64	1.96
Dec.	3.06	1.70	0	2.80	1.74	1.10
1983						
Jan.	2.64	1.59	1.58	1.80	1.97	0.92
Feb.	2.09	1.37	0.87	1.79	1.34	0.89
March	1.84	2.2†	0.71	1.66	1.83	1.18
April	2.90	2.09	1.95	2.47	1.87	1.73
May	2.91	2.28	1.94	3.14	2.51	1.87

Table 7—Normality Test for Diversity, Evenness and Species Richness Distribution

	Skewness	Kurtosis
Diversity	0.30*	3.36†
Evenness	0.51 <sup>δ</sup>	2.61‡
Species richness	0.06*	2.79‡

Level of significance: \*P=2%, †P=1% and ‡P=1%, <sup>δ</sup>=Not significant.

from normality. This confirms that the samples were drawn from a normally distributed population.

### Discussion

Macrobenthic communities in the 2 estuaries studied are characterised by temporal and spatial changes in their component population. These patterns of estuarine distribution can be explained in terms of distribution and abundance of euryhaline, stenohaline and opportunistic species of marine and estuarine origin<sup>11</sup>. During the present study, the noteworthy trend was the changes in species abundance accompanied by changes in diversity indices. It shows that the fauna was unstable in the 2 estuaries. The fauna in the present study comprised a number of marine forms such as *Turritella attenuata*, *Astropecten indica*, *Nemertinea* sp. and *Echiurida* sp. which were concentrated in the region of river mouth. The mobile forms like *Penaeus merguensis*, *M. dobsoni*, *Alpheus malabarica* and *Mesopodopsis* sp. were more of opportunistic type than regular estuarine benthic species<sup>3</sup>. The estuarine endemic species which were consistently observed in the estuarine region were *M. casta*, *C. fluvialis* and *A. chilensis*. These species tend to be dominant in the middle and upper regions of the estuary.

estuaries. In general E gave similar pattern of distribution as H.

The Margalef index (species richness) depends on the number of individuals present in addition to the number of species and is given in Table 6. These values clearly reveal the abundance of species in the lower reaches (sts M<sub>1</sub> and Z<sub>1</sub>) than in the upper reaches (sts M<sub>3</sub> and Z<sub>3</sub>).

To test the normality of the distribution of diversity, evenness and species richness, the skewness (B<sub>1</sub>) and kurtosis (B<sub>2</sub>) were calculated based on a sample size of 68 observations (Table 7). Since the population from which the sample was drawn, was assumed to be normal, the sample should also follow normal distribution with B<sub>1</sub>=0 and B<sub>2</sub>=3. Although the calculated values did not follow the normal distribution strictly, there was no significant departure

The occurrence of larvae and juveniles of crustacea in the samples and their seasonal variability in the present study confirm the earlier findings of Rodrigues<sup>12</sup>. Seasonality in both reproduction and larval settling is known to occur in many marine benthic species<sup>13</sup>. It is quite likely then, that the population may decline to very low densities between recruitments, thus resulting in great fluctuation in population sizes as observed in the present study. While the temporal variations are due to the seasonal distribution of various species and their reproduction and larval settlement, the spatial differences are governed mainly by the regional effects.

**Comparison with earlier data**—A comparison of the present data with the one reported earlier<sup>3</sup> indicates that the general trend in the abundance and distribution of fauna and species has changed considerably (Table 8). The polychaetes and bivalves accounting for more than 70% dominated the fauna during 1971-73. The present study shows that although polychaetes remained the dominant group the bivalves were replaced by crustaceans as the second most dominant group. A considerable decline in commercial clam beds from Mandovi and Zuari estuary due to increase in silt load has recently been reported<sup>14</sup>. A reduction of about 40% in both population density and species number is envisaged in the present study. Frankenberg and Scott Leiper<sup>15</sup> while comparing the benthic fauna of Georgia continental shelf for two different year study, reported variation 1 or more orders of magnitude in population density and suggested that the density of benthic population may fluctuate from season to season, year to year and place to place. Fluctuation in population density is a common feature in shallow epifaunal community<sup>16</sup>. Out of 69 species, 20 species (11 of polychaetes and 9 of crustaceans) were not recorded in 1971-73 indicating the changes that have taken place.

Further, an attempt has been made to compare the density of some dominant species at sts M<sub>1</sub>, M<sub>2</sub>, Z<sub>1</sub> and Z<sub>2</sub> which were sampled during 1971-73 also (Table 9). Large changes occurred in the typically dominant species in the 2 estuaries. Among polychaetes, *D. neapolitana* and *G. alba* were significantly less common ( $P < 0.05$  Mann Whitney U test) while *P. pinnata* has increased significantly ( $P < 0.05$ ). The bivalves *M. casta*, *P. malabarica* and the top shell, *C. fluviatilis* showed significant reduction ( $P < 0.05$ ). There was considerable reduction in the number of molluscan species. In a similar study in Cochin backwater, significant faunal changes caused mainly by human interference including pollution have also been reported<sup>17</sup>.

**Environmental disturbance and community structure**—The effects of severe environmental stress

Table 8—Comparison of Quantitative Data on Macrofauna during Different Periods

	1971-73*	1982-83
Maximum faunal density.m <sup>-2</sup>	4382	2425
Maximum av. biomass (g.m <sup>-2</sup> )	233.79	113.45
Total number of species	111	69
Dominant taxa	Polychaete bivalves	Polychaete crustacea

\*Earlier study<sup>3</sup>.

Table 9—Comparison of Total Density of Dominant Species during Different Periods

	1971-73	1982-83	U-test
<i>Diopatra neapolitana</i>	4357	1175	12.5*
<i>Glycera alba</i>	1384	750	16.00*
<i>Prionospio pinnata</i>	783	1500	8.5**
<i>Cerithidea fluviatilis</i>	1359	309	7.0*
<i>Meretrix casta</i>	893	326	7.6*
<i>Paphia malabarica</i>	2467	350	2.5*
	Earlier study <sup>3</sup>		

\*Significantly less in present study ( $P < 0.05$ ).

\*\*Significantly more in present study ( $P < 0.05$ ).

are usually judged by low diversity or the presence of particular indicator species<sup>18</sup>. The pattern of diversity indices in the present study have shown some decreasing trend from mouth towards more estuarine region. The general trend in the macrobenthic distribution was manifested by decreasing individuals and species along the salinity gradient from the mouth of the estuary towards upper reaches. The more abrupt changes, as could be seen, were governed by low salinity condition caused by monsoon in this region. Apparently the up estuary limit of marine and estuarine organisms are set by the tolerance of low salinity and the down estuary limits of freshwater species are generally set by the tolerance of high salinity<sup>8,11</sup>.

The other environmental disturbance that could be seen in the 2 estuaries was the activity of iron ore mining and its loading and unloading operations in the upper reaches. Because of this, a lot of mine waste find its way into the estuarine system especially during monsoon season<sup>15</sup>. There is also excavation of sand gravel in the middle and upper reaches of these estuaries. All these activities, increase water turbidity and sediment precipitation which exert a major control on faunal distribution pattern in these estuaries. This is especially so in the case of filter feeders which are particularly prone to clogging of their filtering apparatus. Parulekar *et al.*<sup>19</sup>, have reported high

degree of benthic defaunation caused by environmental disturbances in the inshore waters of Bombay coast. It may also be noted that while no obvious pollution was observed in the present study, a number of species, especially *P. polybranchiata*, *Lycastis indica*, *Parahetromastus* sp. and *A. chilensis* have been reported as indicator organisms of pollution from Cochin backwater<sup>20</sup>. Their abundance at some stations indicates certain degree of pollution which may affect the benthic organisms.

While it is possible that the sedimentology, hydrography, reproduction and recruitment to benthic population may cause fluctuations in the population density, it is felt that the changes in the occurrence of species and their spatial and temporal variation in the present study are mainly due to the disturbances caused by mining refuse, sand excavation and extractions in the 2 estuaries.

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