Population distribution of meiofauna in relation to some environmental features in a sandy intertidal region of Goa, west coast of India

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Received 2 January 1989; revised 31 July 1989.

Meiofauna population of Candolim beach mainly composed of nematoda (40.15%), harpacticoida (30.75%), turbellaria (23.35%) and other groups which included polychaeta, bivalvia and mystacocardia. The maximum total meiofauna population encountered was 3525.10 cm⁻². Temporal variation of meiofauna showed increase of meiofauna population from post to premonsoon season and it was maximum in April. The fauna was very poor in southwest monsoon season. Spatial distribution of meiofauna showed maximum densities at 10 m station. Two way ANOVA among the spatio-temporal variation showed significant variation between the seasons. Vertical distribution of meiofauna showed (i) aggregation of meiofauna population at lower depth, (ii) nematoda throughout the core depth and (iii) other taxa at lower depth. Among the environmental parameters studied grain size, porosity, slope of beach, salinity and availability of food were important factors in the distribution and abundance of meiofauna taxa in the intertidal region of Candolim beach.

There are few reports on meiofauna of sandy beaches along the Indian coast. Except for the work of Ansari et al., there is no information on Goa beaches. The present investigation deals with the spatial, temporal and vertical distribution of meiofauna population in relation to certain environmental parameters at Candolim beach. Candolim, situated at the central part of Goa (long. 73°50' E, lat. 15° 30'N), has a large stretch of marine beach exposed to direct wave action. Rainfall occurs mainly during southwest monsoon (June to September) with an annual average of 3000 mm. This results in heavy flooding, erosion and variation in salinity structure in the coastal waters. The wind blows mostly at a speed of 34-55 km.h⁻¹ with heavy swells and rough waves (3-4 m, height) in this period. The tides are of semidiurnal M2 types, showing tidal amplitude of 2.3 m, with intertidal exposure of 40-50 m, during the low tide.

Materials and Methods
Physico-chemical characteristics of Candolim beach were investigated at monthly intervals for 16 months (February 1981 to May 1982). Surf and interstitial waters were collected for the estimation of chlorophyll a, particulate organic carbon, salinity and dissolved oxygen. Temperature of surf, 0 and 10 m interstitial water was recorded. Water table was recorded at 10 m station. Sand samples corresponding to high, mid and low water marks were collected for organic carbon estimation and sand grain analysis. Beach profiles were measured following the method of La Fond and Prasad Rao and Emery. Meiofauna samples were collected at 10 m interval from high to low water mark by means of a perspex glass coring tube (5 cm diam.). The core samples were taken up to 15 cm sediment depth and cut into 3 equal sub-samples at an interval of 5 cm for the vertical distribution. The sediment samples for meiofauna were preserved in 10% rose-bengal seawater formalin with 10% alcohol, and meiofauna were analysed and processed. Population density of monthly variation was also converted into per meter transect (mt⁻¹) representing from high to low water mark. ANOVA analysis was made to establish the level of significance of the data.

Results
Environmental features—Temperature of sand and water ranged between 24.7° and 35.8°C which reflected the environmental temperature. Relatively, low temperatures were recorded during June, August and again in November and December. Salinity varied from 5 to 35.88 x 10⁻³, the values being low in southwest monsoon and the interstitial water salinity relatively higher, than the surf water. Dissolved oxygen varied from 1.07 to 5.2 ml.1⁻¹. The surf water values were always
higher than interstitial water (Fig. 1). The lowest value recorded was 1.07 ml\textsuperscript{1} in November 1981. Water table values changed depending on the slope of beach and grain size. In general, the changes in beach profile (Fig. 2) were cyclical in nature and characterised by erosion in southwest monsoon followed by a period of accretion in postmonsoon (October to January) and in premonsoon (February to May) with minor deviation.

The grain size varied between 0.18 and 0.89 mm, falling between fine sand and coarse sand. Spatial and temporal variations were evident (Fig. 3a). Relatively, grain size distribution was more unstable at low water region than at high water mark, and much coarse sand was observed at low water mark during monsoon. Organic carbon in the sand varied from 0.14 to 1.66 mg.g\textsuperscript{-1}. Spatial and temporal variations were apparent (Fig. 3b) and the values were relatively low during monsoon. The chl a and POC values varied from 0.76 to 4.18 and 0.53 to 4.29 mg.l\textsuperscript{-1} respectively. The values were low during monsoon and increased from post to premonsoon (Fig. 3c). Significant correlations between salinity and temperature (\(P<0.001, r=0.76\)) and salinity and chl a (\(P \leq 0.01, r=0.64\)) were observed.

**Meiofauna**—It was mainly composed of Nematoda (40.15\%), harpacticoida (30.75\%), turbellaria (23.35\%) and other groups (5.95\%) which included polychaeta, bivalvia and mystacocarida.
Spatial and temporal variation—Nematoda: These were observed throughout the year except during monsoon when their abundance reduced considerably (Fig. 4a). Temporal peak was observed in April 1982 ($4.021 \times 10^5$ mt$^{-1}$) and in the same month, spatial peak was noticed at 10 m station ($23.76 \times 10^4$ m$^{-2}$). Seasonality was also evident from ANOVA analysis ($P<0.1$ $F=1.82$) though this was not significant between stations. Further, it was also evident from dispersion study that the fauna showed contagious distribution ($ID=1$).

Harpacticoida: They were found concentrated either at high or low water mark with poor density during monsoon. Temporal ($2.208 \times 10^3$ mt$^{-1}$) and spatial maximum ($10.78 \times 10^4$ m$^{-2}$) were noticed in February 1982 and at 0 m station in April 1981, respectively (Fig. 4b).

Turbellaria: Though present throughout the year, the abundance was rather poor during monsoon. Spatial distribution showed that they were dense at low tide level. Temporal and spatial peaks were observed in May 1981 and in March 1982 at 40 m station respectively (Fig. 5a). Spatial and temporal variations in respect of other groups (Fig. 5b) were negligible in monsoon and increased from pre to postmonsoon. The total meiofaunal distribution (Table 1) showed mean temporal maximum in March 1982 and spatial peak at 10 m station. Two way ANOVA for total population showed a significant seasonal variation ($P<0.01$ $F=13.55$) though it did not show much significant difference between the stations. In general fauna increased from post to premonsoon and it was low during monsoon. The vertical distribution pattern indicated maximum aggregation of total meiofauna in the lower layer of the core sediment. However, relatively, at high water mark station the vertical movement of meiofauna was discernible (Fig. 6). This is also evident from ANOVA analysis ($P<0.81$ $F=15.13$). Similarly comparative vertical distribution showed (Fig. 7) the presence of nematoda throughout the core depth, whereas turbellaria, harpacticoida and other group were found at lower depths.

Discussion

Environmental features were fairly normal and followed regular seasonal cycle as reported earlier along the beaches on the west coast of India$^{17-20}$. The beach sands tend to become fine at low tide region corroborating the finding of earlier workers$^{1,18,20}$. Distribution of grain size and changes in beach profile are attributable to hydrodynamics processes prevailing on the beach$^{21}$. It is also evident that open sea exposed beach, having steeper
Table 1—Total meiofauna density no. × 10^4 m^-2 for different stations at Candolim beach

<table>
<thead>
<tr>
<th>Stations</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>( \bar{x} )</th>
<th>± SD</th>
</tr>
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<td>Feb.</td>
<td>13.76</td>
<td>10.09</td>
<td>4.88</td>
<td>1.53</td>
<td>4.68</td>
<td>+ +</td>
<td>6.98</td>
<td>4.87</td>
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<td>7.04</td>
<td>8.14</td>
<td>4.68</td>
<td>1.90</td>
<td>+ +</td>
<td>4.50</td>
<td>3.16</td>
</tr>
<tr>
<td>April</td>
<td>21.81</td>
<td>4.69</td>
<td>6.84</td>
<td>3.89</td>
<td>3.19</td>
<td>2.75</td>
<td>7.19</td>
<td>7.30</td>
</tr>
<tr>
<td>May</td>
<td>3.75</td>
<td>8.87</td>
<td>7.40</td>
<td>9.84</td>
<td>7.68</td>
<td>4.18</td>
<td>6.95</td>
<td>2.47</td>
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<td>June</td>
<td>0.35</td>
<td>11.20</td>
<td>5.17</td>
<td>1.62</td>
<td>1.32</td>
<td>1.01</td>
<td>3.44</td>
<td>4.15</td>
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<tr>
<td>July</td>
<td>0.56</td>
<td>4.65</td>
<td>2.39</td>
<td>2.88</td>
<td>2.44</td>
<td>+ +</td>
<td>2.56</td>
<td>1.45</td>
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<td>0.56</td>
<td>0.30</td>
<td>+</td>
<td>0.24</td>
<td>+ +</td>
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<td>0.13</td>
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<tr>
<td>Sept.</td>
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<td>0.93</td>
<td>1.78</td>
<td>3.01</td>
<td>4.48</td>
<td>4.61</td>
<td>5.46</td>
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<tr>
<td>Oct.</td>
<td>12.4</td>
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<td>8.05</td>
<td>7.86</td>
<td>9.32</td>
<td>7.84</td>
<td>2.95</td>
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<tr>
<td>Nov.</td>
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<td>24.04</td>
<td>6.30</td>
<td>6.38</td>
<td>6.90</td>
<td>+ +</td>
<td>9.49</td>
<td>8.21</td>
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<td>3.90</td>
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<td>6.63</td>
<td>3.31</td>
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<td></td>
<td></td>
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<tr>
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<td>5.39</td>
<td>6.62</td>
<td>5.08</td>
<td>3.48</td>
<td>+ +</td>
<td>5.21</td>
<td>1.13</td>
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<td>6.72</td>
<td>13.34</td>
<td>17.17</td>
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<td>11.72</td>
<td>6.05</td>
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<tr>
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<td>12.92</td>
<td>8.02</td>
<td>5.30</td>
<td>35.25</td>
<td>+ +</td>
<td>13.93</td>
<td>12.22</td>
</tr>
<tr>
<td>April</td>
<td>30.81</td>
<td>19.02</td>
<td>10.40</td>
<td>11.21</td>
<td>13.20</td>
<td>4.16</td>
<td>14.80</td>
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<td>20.12</td>
<td>11.56</td>
<td>15.39</td>
<td>10.60</td>
<td>13.52</td>
<td>+ +</td>
<td>14.23</td>
<td>3.76</td>
</tr>
<tr>
<td>( \bar{x} )</td>
<td>8.48</td>
<td>9.74</td>
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<tr>
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<td>4.47</td>
<td>9.00</td>
<td>3.07</td>
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</tr>
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</table>

+ = Absence of fauna  
+++ = Samples not collected

Fig. 6—Spatio-temporal vertical distribution of total meiofauna population (pre-premonsoon, mon-monsoon and post-postmonsoon. A=0, B=10, C=20, D=30, E=40, F=50 m stations)

Fig. 7—Comparative vertical distribution of different meiofauna taxa (N-Nematoda, H-Harpacticoida, T-Turbellaria, O-Other group. A=0, B=10, C=20, D=30, E=40, F=50 m stations)
slope, possesses coarse sand grains. Temperature of interstitial waters remained within fairly narrow range except at high water mark station, where it showed wide range of variation depending on the time of observation. Salinity changes were mainly influenced by southwest monsoon where it showed wide range of variation depending on salinity changes in the sand column and capillary suction and community metabolism. The changes in chl a and POC were due to physico-chemical characteristics of the area, and there was significant \( P<0.05 \ r=0.64 \), correlation between chl a and POC as observed earlier. Sand organic carbon values were relatively high at low tide region and comparable to earlier reports.

It is evident that nematoda and harpacticoida formed the dominant and codominant taxa as observed by many workers in other Indian beaches and elsewhere. Relatively high proportion of harpacticoida suggests that this could be related to substrate property, beach gradient and exposure of beach. The interstitial space and porosity of the sediment are considered to be important environment, which facilitates the meiofauna to modify their shape and movement in the sediment.

Wieser stated that 200 \( \mu \text{m} \) (medium grain size) is critical grade for the meio-benthos which corresponds to the values observed in the present study where the present values also lie within this. Sediment characteristics have been regarded as cardinal factor in the distribution and abundance of meiofauna. A single parameter cannot be viewed independently in the field as several other factors are also involved. However, laboratory experiments have revealed that animals react to different grades of sands while other parameters remain constant.

The maximum density \( 3525.10 \text{ cm}^{-2} \) (35.35 \( \times \) 10^4 \text{ m}^{-2} \) of meiofauna encountered is in close conformity with earlier observations. However, it is about 10 times more than that reported for Waltair beach. Distribution of total meiofauna and different taxa on these beaches is by no means uniform and each taxon tends to occupy a characteristic water level station and depth level in the sand. Nematoda occurs everywhere and tends to be most common on the surface sand. Other meiofauna taxa generally occur below the upper layer, as \( P<0.01 \ F=15.13 \) evident from ANOVA. Seasonal vertical distribution was also evident \( (P<0.01 \ F=13.55) \). Wetting and drying of sand column and sand temperature seem to be important factors for such type of distribution in sandy intertidal zone. Other important factors are porosity dissolved oxygen, and grain size. The fauna increased from post to premonsoon showing very poor fauna during monsoon coinciding with fall in salinity which is a common phenomenon. Hence, salinity is one of the factors which influences the functional physiology and reproductive activity, thereby affecting faunal abundance.

The other factor is availability of food. The meiofauna are known to feed on diatoms, bacteria, protozoa, detritus and dissolved organic carbon. High abundance in population also coincides with high chl a, POC and organic carbon in the sediment. This supports that availability of food is one of the limiting factors in the distribution and abundance of meiofauna population.

Acknowledgement
The authors are grateful to Dr B N Desai, Director, NIO, for encouragement.

References
7 Davies J L, Geographical variation in coastal development (Oliver & Boyd Publication, Edinburgh) 1972, 204.
11 Folk R L, in Petrology of sedimentary rocks (Hemphill Austin, Texas) 1968, 170.
26 McIntyre A D, Biol Rev, 44 (1969) 245.
37 Fenchel T, Ophelia, 6 (1969) 1.