

## Distribution & Diversity of Copepods in the Mandovi-Zuari Estuarine System, Goa

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Truly estuarine and estuarine-marine species were the major components of copepods. Neritic and limnetic species were stragglers in this environment and showed fortuitous distribution. Monsoonal cycle induced seasonal rhythm on salinity and copepods. Copepod species number dwindled sharply during the rainy season (June to September) except in Zuari estuary where comparatively more saline conditions were recorded (1.33 to 29.84‰). Postmonsoon period (October to January) was characterised with copepod repopulation and proliferation with a gradual salinity recovery, attaining maximum species diversity during the dry premonsoon months. Spatial and temporal variations in the occurrence and abundance of copepod species are discussed.

Copepods are one of the major components in the zooplankton community in different ecosystems. Their occurrence and abundance are influenced mostly by the prevailing physico-chemical conditions, availability of food and seasons. Studies on the seasonal distribution of copepods have been carried out from the estuaries from the east<sup>1-3</sup> and west coast of India<sup>4-7</sup>.

Topographical features, ecology of zooplankton and their diel variations from Mandovi and Zuari estuarine area are reported<sup>8-10</sup>. The present communication deals with the seasonal distribution and diversity of copepods from the Mandovi and Zuari estuaries and the Cumbarjua Canal.

### Materials and Methods

Surface zooplankton samples were collected fortnightly, for 2 yr (June 1971 to May 1973) at 6 stations (Fig. 1). Sampling was done with a modified HT net (mouth area 0.25 m<sup>2</sup> and mesh width 330 μm) fitted with a calibrated flowmeter. Depending on the abundance of samples, a subsample of 5-25% was examined for the enumeration of copepods and their common species. The number was calculated for the whole sample and computed per m<sup>3</sup> using the flowmeter readings. Diversity indices ( $\alpha$ ) and species diversity ( $D$ ) values were calculated as per the formulae given by Fisher *et al.*<sup>11</sup> and Shannon and Weaver<sup>12</sup> respectively. The water samples for the determination of temperature and salinity were taken simultaneously along with the zooplankton collections. Salinity was estimated by standard method<sup>13</sup>.

### Results and Discussion

Copepods constituted the major component of the zooplankton population throughout the study period

with 2 distinct peaks. In the Mandovi estuary and the Cumbarjua canal, the first peak (3724/m<sup>3</sup>) was observed after (October/November) and the second (2815.6/m<sup>3</sup>) before (April/May) the advent of southwest monsoon. This compares well with reports from other areas<sup>1,2,14</sup>. However, in the Zuari estuary, the maximum abundance of copepods was recorded during the monsoon months (August/September) and during April/May (3616/m<sup>3</sup> and 3208/m<sup>3</sup> respectively). Copepod abundance during southwest monsoon as observed in the Zuari estuary has not been reported from other Indian estuarine systems. The greater copepod number (91.2%) in the Zuari estuary during the monsoon (June to September) season may be due to higher salinity range (1.33 to 29.84‰) during this period (Table 1) and the copepod population is mostly composed of brackish water forms. The copepod number fluctuated considerably and varied from 22 to 3724 individuals/m<sup>3</sup>. Higher copepod count was obtained at stations in the Mandovi and Zuari

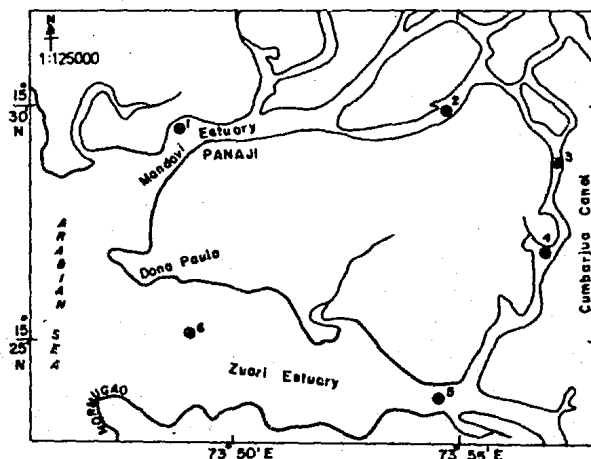


Fig. 1—Station positions

Table 1—Average Fortnightly Temperature (°C) and Salinity (‰) Values at Six Stations in the Mandovi-Zuari Estuarine Systems during 1971-73

Months	Temp. (°C)						Sal. (0/00)					
	1	2	3	4	5	6	1	2	3	4	5	6
June	27.2	27.0	27.0	27.8	29.0	29.0	17.1	3.3	3.2	1.7	7.8	17.6
July	27.5	27.6	27.7	27.0	27.4	27.1	6.0	1.1	0.3	0.5	5.7	12.6
Aug.	26.3	26.5	27.1	26.6	27.5	27.2	4.0	0.9	0.3	1.9	4.6	12.6
Sept.	27.5	29.6	30.5	30.0	30.1	29.5	25.4	5.0	5.2	8.5	19.0	24.0
Oct.	26.5	28.5	30.0	30.1	28.7	27.2	28.8	7.7	10.9	21.7	23.5	28.5
Nov.	26.8	28.0	29.2	29.3	28.2	27.6	31.6	12.6	18.5	15.4	31.9	34.4
Dec.	25.4	25.7	25.9	26.5	26.9	26.8	33.1	21.8	25.3	27.9	31.2	32.8
Jan.	25.0	26.1	26.1	26.6	26.4	26.5	32.3	25.5	27.0	28.9	30.4	32.6
Feb.	25.7	26.5	27.0	27.2	27.4	27.8	34.1	24.2	27.9	31.1	32.4	33.4
March	28.8	29.5	30.2	30.0	29.2	29.2	34.0	27.5	30.9	32.7	34.4	35.1
April	29.0	29.7	30.0	30.8	31.0	30.5	35.0	31.8	35.4	35.9	35.7	35.6
May	30.6	31.4	31.4	31.4	31.4	31.4	35.6	33.5	35.8	35.4	36.1	36.1

estuaries than at those of Cumbarjua canal and the annual mean count was 1271.5, 569.3 and 1187.3/m<sup>3</sup> at sts 1,3,6 respectively. These values are lower than the reported average copepod counts of 1631/m<sup>3</sup> from the Cochin backwaters<sup>15</sup> and more than 1,00,000 copepods/m<sup>3</sup> for summer months from Vellar estuary<sup>2</sup>. Grindley and Wooldridge<sup>16</sup> reported higher count (42,700/m<sup>3</sup>) for an estuarine copepod species from Richard's Bay, S. Africa. The copepods were always abundant at all stations of the Mandovi-Zuari estuarine systems during premonsoon months (February to May) when the temperature and salinity values were higher (Table 1). To trace any relationship between the copepod abundance, temperature and salinity, the correlation coefficient (*r*) values were calculated. Significant correlation values (0.1% level) were obtained indicating copepod abundance during the period of higher temperature and salinity regime. Based on the total copepod counts from all the stations, their higher (56.13%) and the lowest (12.1%) percentages were obtained during the premonsoon and monsoon seasons.

A total of 55 copepod species were encountered in the surface collections, of which 43 calanoid species belonging to 18 genera formed 97.8% of the total annual copepod counts. The remaining 2.2% was constituted by 4 genera and 9 species of cyclopoid copepods (1.8%) and 3 genera and 3 species of harpacticoid copepods (0.4%). Goswami and Selvakumar<sup>9</sup> earlier recorded 49 copepod species at 2 stations in Mandovi and Zuari estuaries. The 6 additional species obtained during the present investigations are *Undinula vulgaris* var. *Typica* Sewell, *Allodiaptomus mirabilipes* Kiefer, *Temora stylifera* (Dana), *Oithona plumifera* Baird, *Laophonte setosa* (Boeck) and *Harpacticus* sp. Earlier calanoid copepods have been reported from Godavari estuary<sup>3</sup> and

Cochin backwaters<sup>4,6</sup>. *Canthocalanus pauper*, *Undinula vulgaris*, *Eucalanus monachus*, *Lucicutia flavicornis*, *Acartia negligens* and *Tortanus forcipatus* were observed in the zooplankton samples from the Mandovi-Zuari estuarine systems but have not been recorded from the Cochin backwaters. *Paracalanus crassirostris* f. *cochinensis*, *Pseudodiaptomus jonesi*, *P. tollingarae*, *Acartia pacifica*, *A. bilobata*, *Centropages alcocki* described from the Cochin backwaters were not recorded from the area studied. *Pseudodiaptomus binghami malayalus*, *Acartia bilobata*, *Acartiella keralensis* and *Isias cochinensis* were reported to be endemic to Cochin backwaters<sup>17</sup>. However, *P. binghami malayalus* have been reported to occur in the Mandovi-Zuari estuarine systems<sup>9</sup> and *P. tollingarae* from the Godavari estuary<sup>3</sup>. *Paracalanus dubia*, *Acrocalanus inermis* and *Pontella andersoni* obtained from the Hooghly<sup>1</sup> and Godavari estuaries<sup>3</sup> on the east coast were not recorded either from the Cochin backwaters<sup>4-7</sup> or from the Mandovi and Zuari estuaries<sup>8-10</sup>.

Spatial variations in the distribution of copepod species were also observed at all stations. The high saline (>30‰) species, viz. *Canthocalanus pauper*, *Undinula vulgaris*, *Eucalanus monachus*, *Lucicutia flavicornis*, *Labidocera kroyeri* var. *gallensis*, *Acartia negligens*, *Pontella spinipes*, *Oncaea venusta* and *Oithona plumifera* showed restricted distribution and occurred only in the samples taken at st 6. *Undinula darwini* var. *typica*, *Cañadacia bradyi*, *Pseudodiaptomus serricaudatus* and *Temora stylifera* were obtained from the zooplankton collections taken from the lower reaches of both the estuaries (sts 1 and 6). The brackish water forms such as *Pseudodiaptomus binghami*, *Acartiella gravelyi* and *Ac. sewelli* were either absent or recorded in negligible numbers at these 2 stations. *Pseudodiaptomus mertonii* and *Acartia southwelli* were

2 of the most common species from the Mandovi estuary. The euryhaline and low saline species dominated copepod counts from the Cumbarjua canal. Some of the copepod forms like *Acrocalanus gibber*, *Pseudodiaptomus ardjuna*, *Pontella danae* var. *ceylonica*, *P. securifer*, *Acartia erythraea* and *Euterpina acutifrons* were poorly represented in the samples from the Cumbarjua canal while *Diaptomus* sp. and *Cyclops* sp. occurred only in the canal.

In addition to the spatial differences, temporal variations in the occurrence and abundance of copepod species were also noticed. The high saline species mentioned above were immigrants into this estuarine system and were recorded during the premonsoon season, *Heliodiaptomus cinctus*, *Allodiaptomus mirabilipes*, *Pseudodiaptomus binghami*, *Acartiella graveleyi*, *Ac. sewelli*, *Diaptomus* sp. and *Cyclops* sp. were observed during the monsoon months. *Ac. graveleyi* flourished well in this environment during the raining season. *Pseudodiaptomus binghami* extended its distribution to the early part of postmonsoon (October and November) when the copepodid stages and adults of *P. annandalei*, *Centropages trispinosus*, *Laophonte setosa* and *Harpacticus* sp. were present in the collections. In the latter half of postmonsoon, forms like *Paracalanus aculeatus*, *Eucalanus crassus*, *Pseudodiaptomus ardjuna*, *P. mertoni*, *Temora turbinata*, *Labidocera pectinata*, *Centropages tenuiremis*, *Corycaeus danae* and *Corycaeus* sp. were dominant. Some of these species also competed successfully with species recorded during premonsoon. *Acrocalanus gibber*, *Centropages orsinii*, *C. furcatus*, *Tortanus forcipatus*,

*Euterpina acutifrons* and *Corycaeus gibbulus* were recorded in the zooplankton samples collected from Mandovi estuary and Cumbarjua canal only during the premonsoon but in the Zuari estuary these species were also present in the collections taken during the postmonsoon season. Depending on the occurrence and abundance during different months of the year, the copepod species can be grouped into 3 main categories—(1) species which were recorded either throughout the year or for the most part of the year, (2) species which occurred only during certain months of the year and (3) species which were rare and occurred sporadically in the collections. The species of the 1st category constituted 50-60% of the total copepod counts and were recorded invariably from the entire estuarine system. They exhibited almost a similar pattern of distribution, occurring in greater numbers in the plankton samples taken from October to June (Fig. 2). Most of the species gave significant correlation with salinity in the Cumbarjua canal (Table 2) implying that these species occurred in greater number during the high saline period, with similar situation reported elsewhere<sup>2-4</sup>. The copepod species of the 2nd category were immigrants from the coastal waters and were abundant during February to May. The species belonging to the 3rd category were mostly limnetic species (<0.5‰) and showed fortuitous distribution.

Diversity indices ( $\alpha$ ) and species diversity ( $D$ ) values varied from 2.1 to 5.9 and from 1.19 to 4.41 respectively (Fig. 3). The copepod species number and consequently the diversity values were higher during May/June. The maximum of 29 species were recorded in May but with the onset of southwest monsoon in

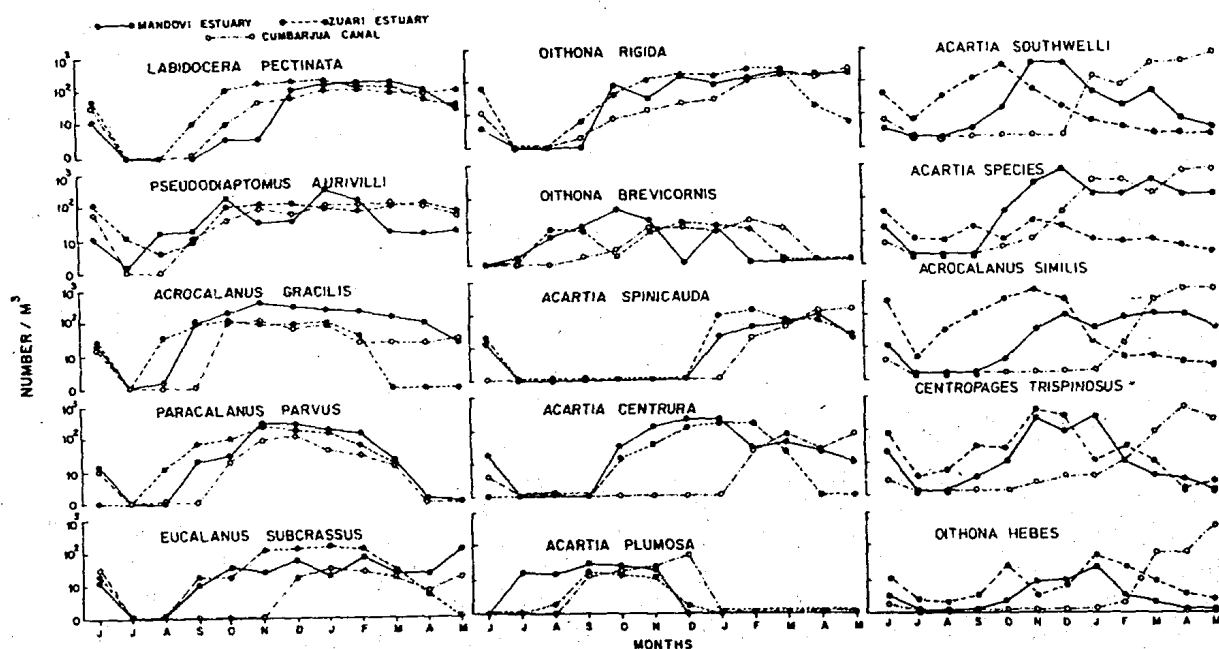


Fig. 2—Seasonal distribution of common copepod species in the Mandovi-Zuari estuarine systems

Table 2—Correlation Coefficient (r) Values Between Some Common Copepod Species and Salinity

Species	Stations					
	1	2	3	4	5	6
<i>Eucalanus subcrassus</i>	0.619*	0.536	0.132	0.536	0.441	0.221
<i>Paracalanus parvus</i>	0.401	0.057	0.159	0.445	0.483	0.262
<i>Acrocalanus gracilis</i>	0.519	0.235	0.796†	0.351	0.136	-0.327
<i>Pseudodiaptomus aurivilli</i>	0.318	0.324	0.751†	0.732†	0.554	0.297
<i>Centropages trispinosus</i>	0.354	0.609*	0.431	0.515	0.639*	0.432
<i>Labidocera pectinata</i>	0.473	0.139	0.815†	0.730†	0.785†	0.449
<i>Acartia spinicauda</i>	-0.408	0.032	0.625*	0.603*	0.478	0.412
<i>A. centrura</i>	0.345	0.162	0.468*	0.621*	0.537	0.417
<i>A. plumosa</i>	0.448	0.342	0.564	0.448	0.224	0.446
<i>Oithona rigida</i>	0.704*	0.691*	0.907‡	0.664*	0.284	0.426
<i>O. brevicornis</i>	0.013	-0.072	0.219	0.496	-0.548	0.372

P=\*5, † 1 and ‡ 0.1%

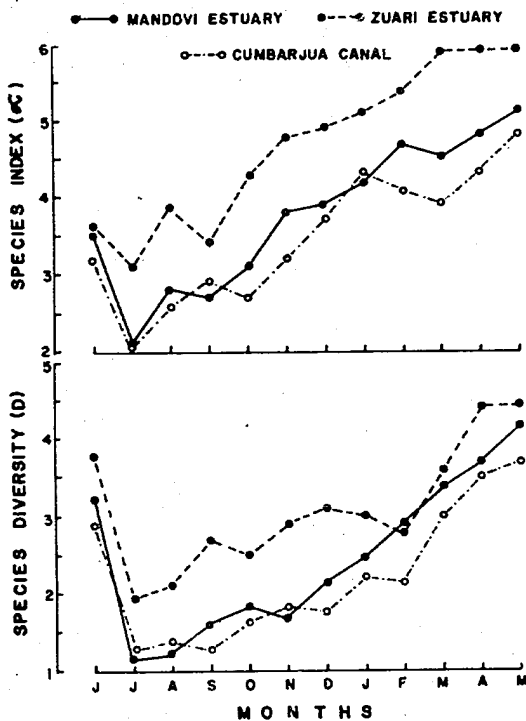


Fig. 3—Copepod species diversity and species indices values in the Mandovi-Zuari estuarine systems

late June, the values decreased abruptly especially at stations in the Mandovi estuary and the Cumbarjua canal where low diversity values were obtained from July to September. With the salinity recovery, the copepod species and diversity values increased again from October onwards. At stations in the Zuari estuary, no sudden decrease in the species indices and species diversity values was observed during the monsoon (July-September). It may be due to comparatively more saline conditions prevailing there.

The present study has indicated that salinity exerts the maximum influence on the occurrence and abundance of copepods in the estuarine systems of Goa. However, location of sampling stations, turbidity, currents and availability of food may be the other controlling factors.

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