

1. Zooplankton variability and copepod assemblage in the coastal and estuarine waters of Goa along the central-west coast of India.

C.T. Achuthankutty, Neelam Ramaiah & G. Padmavati
National Institute of Oceanography, Dona Paula, Goa, 403 004, India.

KEY WORDS: Coastal and estuarine waters, upwelling, hydrography, zooplankton, copepod assemblage, Goa India.

ABSTRACT

Seasonal variations in zooplankton distribution and community structure of copepod species in coastal and estuarine waters of Goa along the central-west coast of India are compared in relation to water temperature, salinity and dissolved oxygen, which were fairly well mixed in both environments during the seasons. However, at the onset of the southwest monsoon, surface cooling and a sharp drop in bottom oxygen occurred in the coastal waters indicating that upwelling was active, while in the estuary, salinity attained almost limnetic conditions as the monsoon progressed and slowly recovered during the postmonsoon season.

These changes have tremendous influence on zooplankton production and copepod species distribution. While the highest zooplankton production was recorded in the coastal waters during the upwelling period (biomass: 2.6 ml.m⁻³; density: 1047 ind.m⁻³), the lowest was recorded in the estuary (biomass: 0.03 ml.m⁻³; density: 105 ind.m⁻³). Large carnivores and some typical coastal water taxa were rare in the estuary. Copepods were predominant in both areas, but the coastal water population comprised 45 species against 28 species in the estuary. The estuarine copepod population dwindles during the low salinity period and several species move into the high saline coastal waters. On recovery of the salinity, they repopulate and flourish in the estuary. Copepods are generally grouped on salinity preference, and in this case 3 categories are recognized viz. wide (5-36 ppt), medium (5-26 ppt) and high saline species (26-36 ppt).

INTRODUCTION

Coastal upwelling is the major event occurring along the west coast of India during the southwest (summer) monsoon (Ramamirtham & Jayaraman,

1960; Banse, 1968), bringing drastic changes in the hydrography, influencing various biological processes. Its effect is felt as far as the mouth region of the estuaries (Sanka-ranarayanan & Jayaraman, 1972; Mad-hupratap, 1978; Sankaranarayanan et al., 1978; Padmavati, 1992) inducing primary production and increasing secondary productivity in the coastal zooplankton (Devassy, 1983; Haridas et al., 1980; Madhupratap et al., 1990).

In the estuaries, on the other hand, salinity drops because of heavy precipitation and land runoff which affects the biological productivity in general and zooplankton composition and distribution in particular. Many estuarine species take refuge in the near-shore waters and re-establish their population after recovery of the conditions. In a recent review, Madhupratap (1987) has described various strategies adopted by different tropical species to tide over the extremities of nature, particularly salinity variations. Zooplankton studies in the coastal waters along the west coast of India are limited (Nair, 1978; Haridas et al, 1980; Nair et al, 1980; Goswami, 1985). In this paper, we compare the zooplankton composition and seasonal variation in an estuary and in the adjacent coastal region of Goa in the light of changing hydrographic conditions. Species distribution and assemblage of copepods in relation to salinity variations are also studied.

STUDIED AREA

Goa, along the central-west coast of

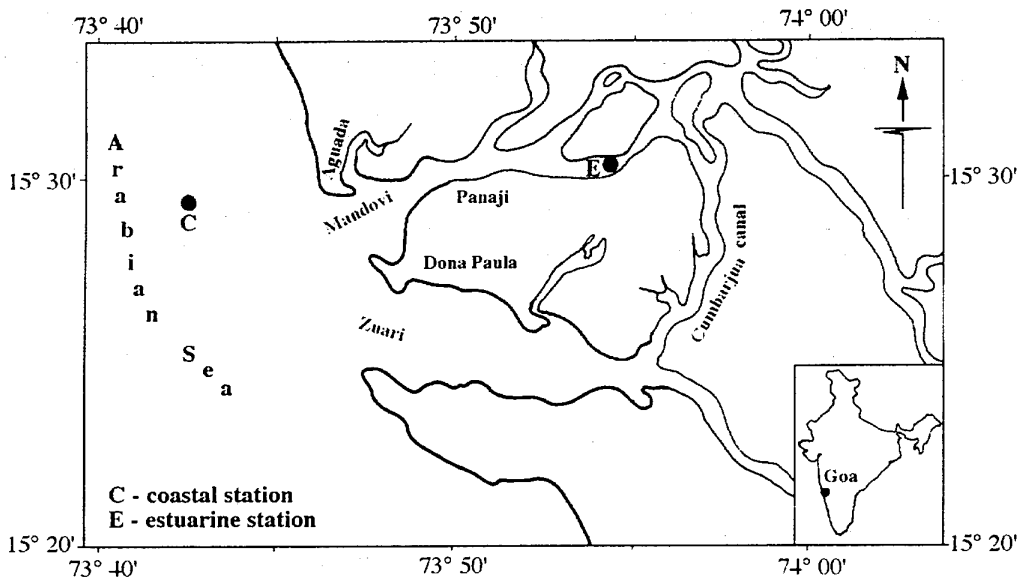


Fig. 1. Station locations. C: coastal station; E: estuarine station.

India, is situated in the tropical belt. The Mandovi and the Zuari are the two major estuaries which open directly and independently into the Arabian Sea (Fig. 1). The southwest or summer monsoon (May/June to September) is an annual phenomenon occurring all along the west coast of India considerably altering the hydrographic features of the coastal and estuarine waters and triggering coastal upwelling. The seasons are therefore arbitrarily classified into the southwest monsoon (June-September), postmonsoon (October-January) and premonsoon (February-May).

MATERIALS AND METHODS

Two stations, one in the coastal waters located at about 30m depth and the other one in the middle of the Mandovi estuary, about 14 km away from the coastal station were sampled from February 1990 to January 1991 (Fig. 1).

The depth of the estuarine station was about 10m at the time of high tide. Sampling was done at a monthly interval, during the flood tide in the estuary. A Heron-Tranter net (mouth area 0.25m²; mesh width 0.3mm) with a calibrated flow meter (TSK, Japan) was used for zooplankton collecting. The

net was obliquely hauled from near-bottom to the surface.

Samples were preserved in 5% buffered formalin. Simultaneously, in situ measurements of temperature, salinity and dissolved oxygen of surface and bottom waters were made with a Hydrolab (Model 4041, Hydrolab Corporation, Texas).

Biomass of zooplankton was estimated as displacement volume. Enumerations for the various taxonomic groups were made either from an aliquot or from the whole sample. Copepods were identified to species. Biomass and density were converted to unit volume using the flow meter data. Diversity index H' (Shannon Weiner, 1963), and evenness E (Heip, 1974) were calculated for the copepod species. Clustering of copepod species was done by employing the method of Field et al., (1982). Mountford's (1962) method of average linkage clustering was used to select groups forming clusters.

RESULTS

Hydrography

Temperature variations were low (25-30°C) in the estuary. However, a significant drop occurred at the coastal sta-

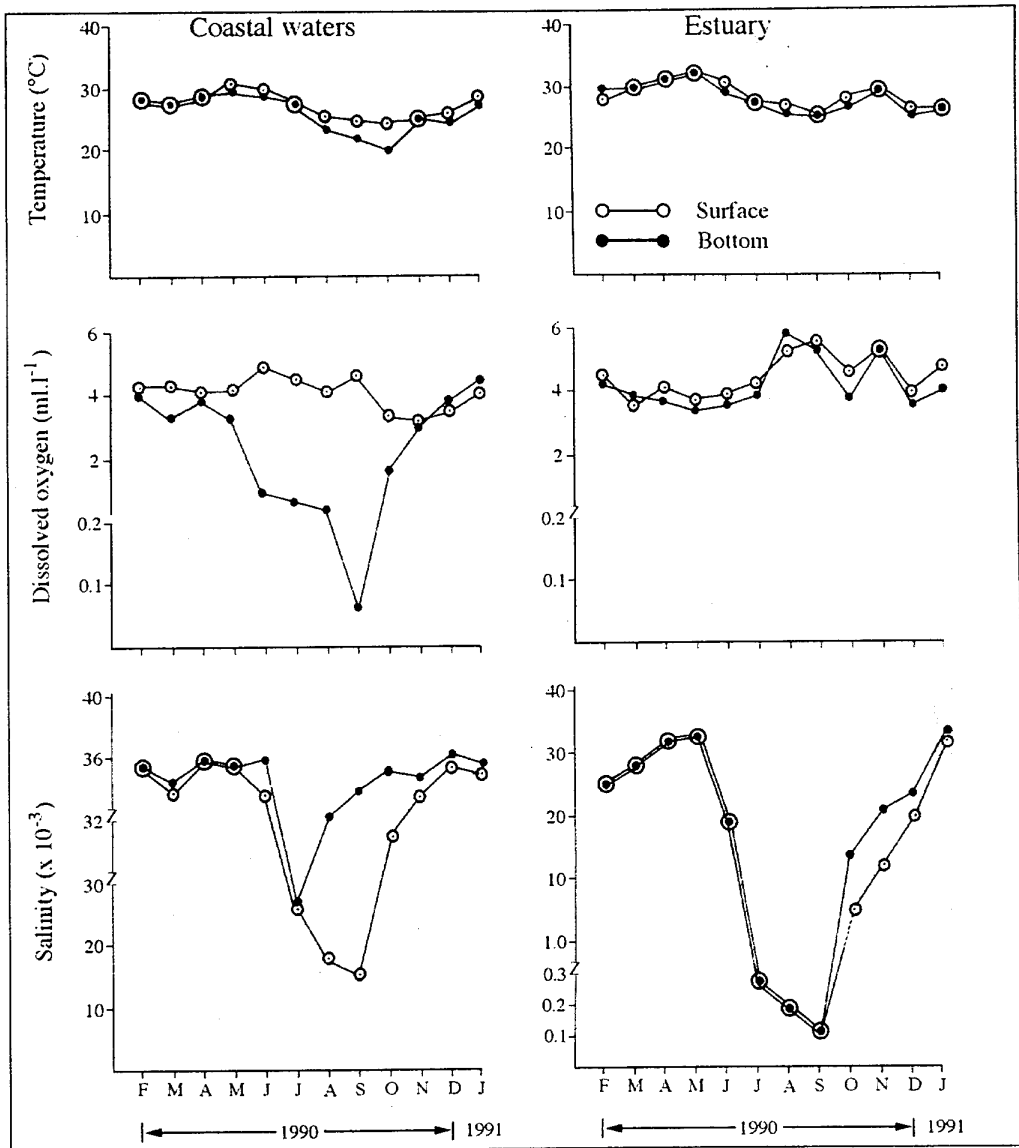


Fig. 2. Hydrography of the coastal and estuarine stations.

tion during the monsoon season leading to stratification. Between June and September the surface temperature dropped from 27.2 to 24°C while the bottom temperature dropped from 27.2 to 20°C (Fig. 2). This is an indication that upwelling was active during this season.

The effect of upwelling was also noticed in the dissolved oxygen (DO) concentration (Fig. 2). Generally, DO was high and more or less stable at both stations except during the monsoon season at the coastal station when it sharply dropped (0.96 in June to 0.06

ml.m⁻³ in September).

Salinity values were generally lower in the estuary compared to the coastal station (Fig. 2). However, monsoon drastically reduced salinity and almost limnetic conditions were attained in September (18.8ppt in June to 0.1ppt in September). No stratification was seen during this season. Recovery, after the monsoon, was slow in the surface but much faster near the bottom, leading to stratification. In the coastal waters, on the other hand, monsoon effect was more evident in the surface (15-26.4 ppt) than near the bottom (26.4-35.9

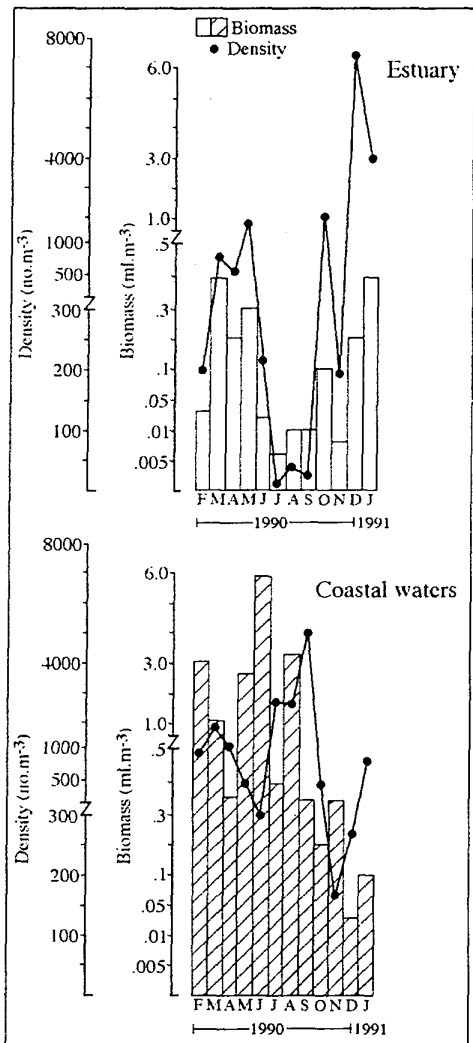


Fig. 3. Monthly variations in zooplankton biomass and density in coastal and estuarine stations.

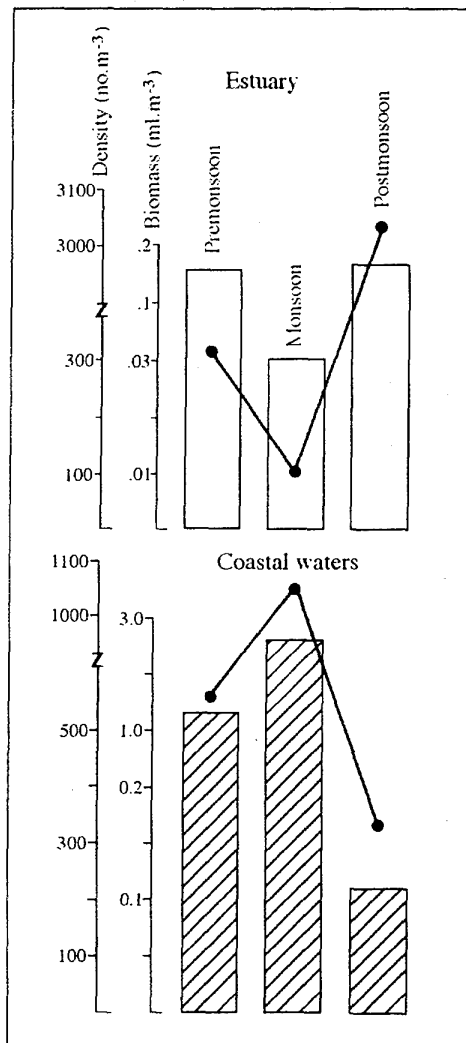


Fig. 4. Seasonal variations in zooplankton biomass and density in coastal and estuarine stations.

ppt).

Temporal and spatial variations in zooplankton

Biomass and density were much higher in the coastal waters than in the estuary (Fig. 3). Biomass ranged between 0.03 (December) to 5.9 ml.m⁻³ (June) and density between 173 (November) and 5004 ind.m⁻³ (September) in the coastal station. However, during some months, (e.g., February, May, June and August), biomass and density did not match because the high biomass was caused by the abundance of larger organisms, such as medusae, ctenophores, siphon-

ophores, chaetognaths, salps etc..

In the estuary, biomass varied from 0.007 (July) to 0.4 ml.m⁻³ (December). Generally, biomass and numerical abundance follow a similar pattern. However during the postmonsoon season some variation was observed. This is due to the predominance of copepods (December, 716 ind.m⁻³) and at times decapods also (October and January).

Seasonal occurrence in the coastal station and estuary shows a contrasting picture (Fig. 4). During the monsoon season while biomass (2.6 ml.m⁻³) and density (1040 ind.m⁻³) are highest in the coastal station, they are lowest (0.03 ml.m⁻³, 105 ind.m⁻³) in the estu-

Table.1. Seasonal occurrence (%) of zooplankton groups. Pre: Premonsoon; Mon: Monsoon; Post: Postmonsoon.

	Coastal station			Estuary		
	Pre	Mon	Post	Pre	Mon	Post
Density (no.m ⁻³)	2479	3253	1079	859	77	3390
Medusae	0.90	0.04	0.26	0.34	0.13	-
Ctenophora	0.02	0.09	-	0.05	-	-
Siphonophora	1.2	1.18	0.55	-	-	-
Polychaeta	0.05	0.74	0.015	0.13	-	0.01
Chaetognatha	1.7	1.7	1.95	1.13	0.85	1.43
Copepoda	85.1	83.2	66.4	70.6	72.84	87.0
Cladocera	0.47	2.37	1.2	-	0.06	0.32
Mysidacea	0.003	0.03	-	0.83	0.1	-
Stomatopoda	0.11	-	0.02	0.05	-	0.01
Decapoda	6.3	7.9	23.8	19.5	21.8	9.6
Ostracoda	0.44	0.96	-	-	-	-
Cirripidae	0.003	-	0.48	4.82	0.13	0.6
Mollusca	0.06	-	-	0.69	1.5	0.85
Tunicata	3.85	1.17	2.06	1.11	-	0.06
Fish eggs & larvae	0.53	0.54	3.23	0.42	2.55	0.12
Miscellaneous	0.07	0.08	-	0.3	0.04	0.02

ary. On the other hand, when they are high in the estuary during the postmonsoon season (0.17 ml.m⁻³; 3034 ind. m⁻³), they are low in the coastal station (0.11 ml.m⁻³; 330 ind.m⁻³). Higher abundance of zooplankton during the monsoon season in the coastal station is also an indication of upwelling.

Composition of zooplankton groups

Composition of various taxonomical groups during the three seasons is tabulated for coastal and estuarine stations (Table 1). In both stations, copepods dominate (66.4-87%) followed by decapods. Because of the abundance of brachyuran zoëae in the estuary, decapods form a significant portion during the premonsoon (19.5%) and monsoon seasons (21.8%). Chaetognaths were dominated by *Sagitta bedoti* Beraneck (1895) which breeds in the estuaries (Nair & Selvakumar, 1979)

In the coastal waters palaemonids and penaeids constitute a large portion of the decapods (23.8%) during the postmonsoon season. Carnivores such as medusae, ctenophores and siphonophores always form part of the coastal zooplankton community but were

sparse in the estuary. Chaetognaths are an integral component at both stations. Compared to the coastal region, fewer taxonomic groups occur in the estuary. Groups like tunicates (pre- and postmonsoon), cladocerans (monsoon), fish eggs and larvae (postmonsoon) forming swarms of varying densities are observed at the coastal station and cirripede larvae (premonsoon), fish eggs and larvae (monsoon) are found in the estuary.

Composition and distribution of copepod species

The copepod population consisted of 45 species at the coastal station and 28 species in the estuary (Table 2). Species belonging to the genera *Paracalanus*, *Acrocalanus*, *Centropages*, *Pseudodiaptomus*, *Acartia*, *Oithona* and *Corycaeus* were common. Among them, *Paracalanus* spp., *Acrocalanus* spp., *Pseudodiaptomus sewelli* Walter, 1984, *Acartia centrura* Giesbrecht, 1888, *A. bowmani* Abraham, 1976, *A. tropica* Ueda & Hiromi, 1987, *Acartiella keralensis* Wellershaus, 1969 and the cyclopoid *Oithona* spp., were the only species which occurred abundantly in the estuary during certain seasons. Pro-

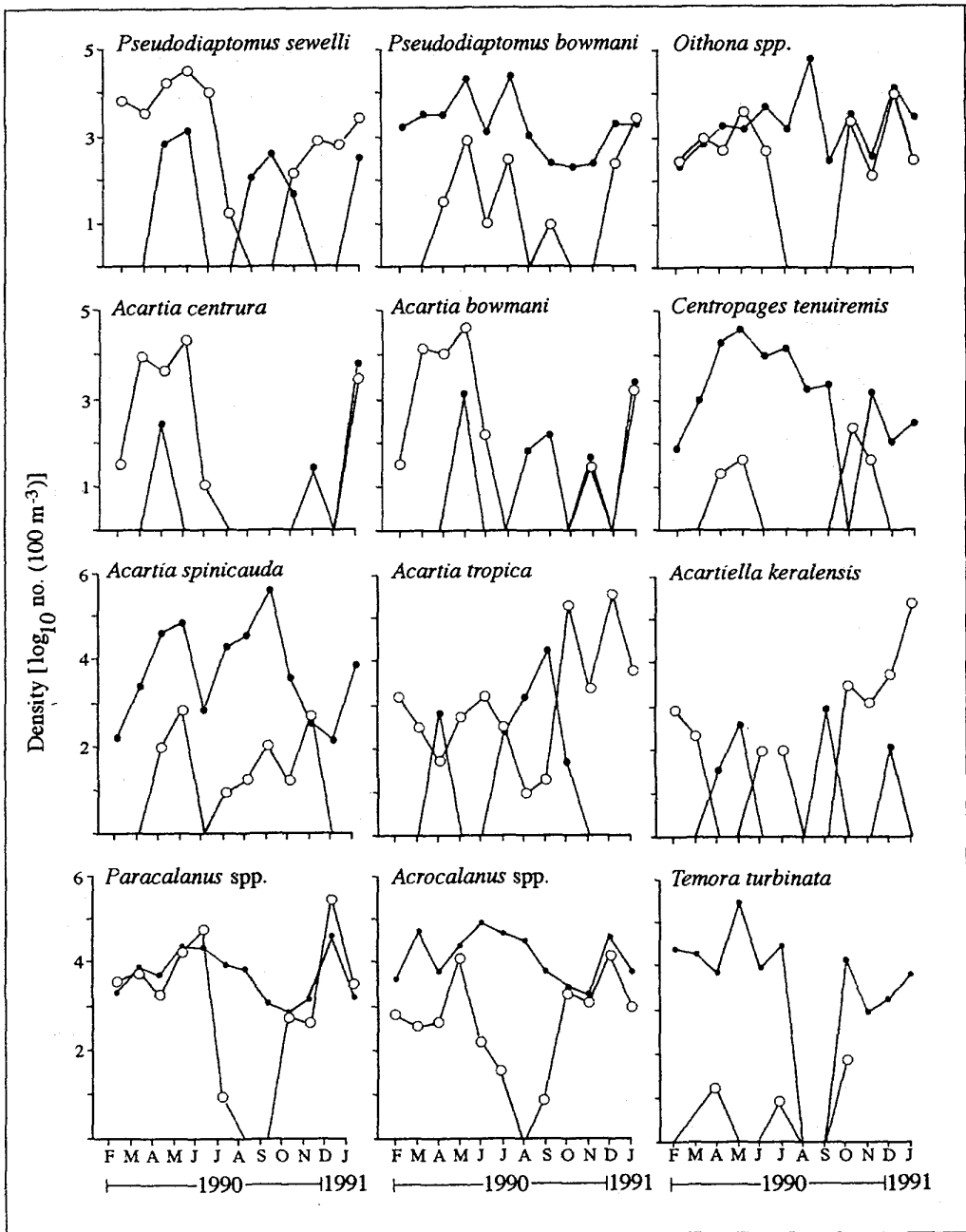


Fig. 5. Monthly occurrence of common copepod species in coastal (●) and estuarine (○) stations.

minent among them were *Paracalanus* spp. ($728.m^{-3}$), *A. tropica* ($1373.m^{-3}$) and *Ac. keralensis* ($631.m^{-3}$), all occurring in large numbers during the post-monsoon season. Most other species were either sparse or absent which indicates that their occurrence in the middle of the estuary was accidental. Similarly, occurrence of small numbers of calanoids such as *Pseudodiaptomus*

binghami malayalus Wellershaus, 1969, *P. annandalei* Sewell, 1919, *P. tollingeriae* Sewell, 1919, *Acartiella graveleyi* Sewell, 1919 and *Heliodiaptomus cinctus* (Gurney, 1907) in the estuary during the monsoon and/or postmonsoon seasons suggest that they are endemic to the low salinity upper reaches and are brought into the midreaches because of monsoon flush-

Table 2. Seasonal abundance of copepod species. Pre: Premonsoon; Mon: Monsoon; Post: Postmonsoon. VA: Very abundant (>100 ind.m⁻³); AB: Abundant (50-100 ind.m⁻³); MA: Moderately abundant (10-50 ind.m⁻³); SP: Sparse; AS: Absent; * >500 ind.m⁻³; ** >1000 ind.m⁻³; *** >2000 ind.m⁻³.

Copepod species	Coastal station			Estuary		
	Pre	Mon	Post	Pre	Mon	Post
<i>Canthocalanus pauper</i>	VA	AB	MA	AS	AS	AS
<i>Undinula vulgaris</i>	SP	AS	SP	AS	AS	AS
<i>Eucalanus pileatus</i>	AS	AS	SP	AS	AS	AS
<i>E. subcrassus</i>	MA	MA	SP	AS	SP	AS
<i>E. elongatus</i>	AS	AS	SP	AS	AS	AS
<i>Paracalanus</i> spp.	AB	VA	VA	AB	SP	VA*
<i>Acrocalanus</i> spp.	VA	VA*	VA	MA	SP	AB
<i>Clausocalanus</i> spp.	SP	SP	SP	AS	AS	AS
<i>Temora turbinata</i>	VA*	VA	AB	SP	SP	SP
<i>T. discaudata</i>	SP	SP	MA	AS	AS	AS
<i>Metacalanus aurivilli</i>	SP	AS	AS	AS	AS	AS
<i>Centropages orsinii</i>	MA	SP	MA	AS	AS	SP
<i>C. furcatus</i>	MA	SP	MA	SP	AS	AS
<i>C. tenuiremis</i>	VA	AB	SP	SP	AS	SP
<i>C. alcocki</i>	AS	SP	AS	AS	AS	AS
<i>Pseudodiaptomus sewelli</i>	SP	SP	SP	VA	MA	SP
<i>P. bowmani</i>	AB	AB	MA	SP	SP	SP
<i>P. serricaudatus</i>	MA	MA	AB	AS	SP	SP
<i>P. jonesi</i>	AS	SP	AS	SP	SP	SP
<i>P. binghami malayalus</i>	AS	AS	AS	AS	SP	SP
<i>P. annandalei</i>	AS	AS	AS	SP	SP	AS
<i>P. tollingerae</i>	AS	AS	AS	AS	SP	AS
<i>Calanopia elliptica</i>	MA	AS	AS	AS	AS	AS
<i>Pontellopsis herdmani</i>	SP	SP	SP	AS	AS	AS
<i>Euchaeta concinna</i>	SP	SP	AS	AS	AS	AS
<i>E. rimana</i>	AS	SP	AS	AS	AS	AS
<i>Labidocera pectinata</i>	SP	AS	SP	SP	SP	SP
<i>L. stylifera</i>	SP	SP	SP	AS	AS	AS
<i>L. acuta</i>	SP	AS	SP	AS	AS	AS
<i>L. minuta</i>	SP	SP	SP	AS	AS	AS
<i>Candacia bradyi</i>	SP	SP	SP	AS	AS	AS
<i>Acartia spinicauda</i>	VA	VA***	MA	SP	SP	SP
<i>A. centrura</i>	SP	AS	MA	AB	SP	SP
<i>A. bowmani</i>	SP	SP	SP	VA	SP	SP
<i>A. erythraea</i>	MA	MA	SP	SP	SP	SP
<i>A. tropica</i>	SP	AB	SP	SP	SP	VA**
<i>A. pacifica</i>	MA	AB	SP	AS	AS	AS
<i>A. amboinensis</i>	SP	SP	SP	AS	AS	AS
<i>Acartiella keralensis</i>	SP	SP	SP	SP	SP	VA*
<i>Ac. gravelyi</i>	AS	AS	AS	AS	SP	SP
<i>Heliodyptomus cinctus</i>	AS	AS	AS	AS	SP	AS
<i>Tortanus forcipatus</i>	MA	MA	AS	AS	SP	SP
<i>Oithona</i> spp.	MA	VA	AB	MA	SP	MA
<i>Oncaea</i> spp.	SP	SP	MA	AS	AS	SP
<i>Corycaeus</i> spp.	MA	AB	MA	SP	SP	SP
<i>Sapphirina</i> sp.	AS	SP	SP	AS	AS	AS
<i>Microsetella</i> sp.	SP	AS	AS	AS	AS	AS
<i>Macrosetella</i> sp.	SP	AS	SP	AS	AS	AS
<i>Clytemnestra scutellata</i>	AS	AS	SP	AS	AS	AS
<i>Euterpina acutifrons</i>	SP	SP	MA	SP	AS	SP

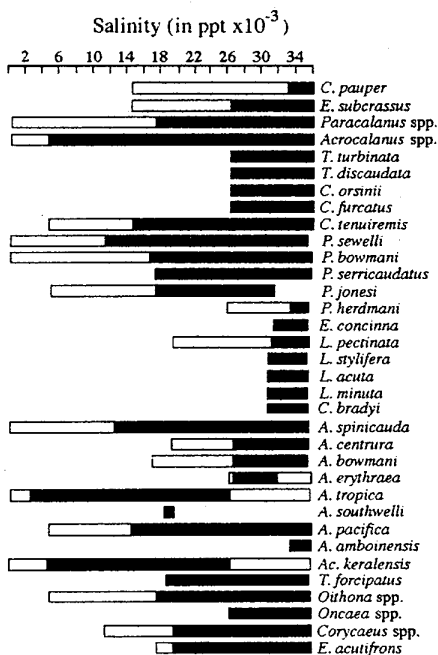


Fig. 6. Salinity ranges of different copepod species. Shaded area indicates the range of higher abundance.

Table 3. Mean species diversity indices during different seasons. N: Number of species; H': species diversity; E: Evenness; Pre: Premonsoon; Mon: Monsoon; Post: Postmonsoon.

	Coastal station			Estuary		
	Pre	Mon	Post	Pre	Mon	Post
N	28	19	22	13	11	14
H'	2.0	1.6	2.1	1.5	1.1	0.9
E	0.2	0.2	0.4	0.3	0.2	0.1

ing and therefore, never occurred in the coastal region. But, all other species were found in varying numbers at the coastal station.

When the monthly distribution (Fig. 5) and seasonal abundance (Table 2) of common species are compared, three interesting seasonal trends emerge. In the first case, those species which had higher abundance in the coastal waters during the pre- and postmonssoons maintained a fairly constant population during the monsoon season also, when they were sparse or absent in the estuary. *Paracalanus spp.*, *Acrocalanus spp.*, *C. tenuiremis* and *P. bowmani* are examples of this pattern. In the second

case, the only deviation noticed from the above was that during the monsoon season their population increases in the coastal waters. *A. spinicauda* and *Oithona spp.* are examples of this behaviour. The third group represented by *A. bowmani*, *Ac. keralensis* and *P. sewelli* has a higher abundance in the estuary during the pre- and postmonsoon seasons, but when their population dwindled during the monsoon season, they are found in large numbers in the coastal waters.

Copepod species occurrence in relation to salinity

The most common 34 species were considered in relation to salinity variation. Although most of them occurred in wide ranges of salinity, the range in which the species are present in large numbers was considered as the preferred range (Fig. 6). Based on this 3 categories are recognized, viz. wide (5-36 ppt), medium (5-26 ppt) and high saline species (26-36 ppt). Thirteen (out of 34) species belong to the wide saline category and live both in estuarine and in coastal conditions. Only 3 species fell in the medium saline category, viz. *Acartia southwelli* Sewell, 1914, *A. tropica* and *Ac. keralensis*. These are the true estuarine species which moved into the coastal region only during the saline period. The remaining 18 species belong to the high saline category but a few species such as *Canthocalanus pauper*, *Pontellopsis herdmanni* Thomson & Scott, 1903, *Euchaeta concinna* Dana, 1849, *Labidocera pectinata* Thomson & Scott, 1903, *L. stylifera* Thomson & Scott, 1903, *L. acuta* (Dana, 1849), *L. minuta* Giesbrecht, 1888, *Candacia bradyi* A. Scott, 1902 and *Acartia amboinensis* Carl, 1907 occur only in a very narrow high saline range (30-36 ppt), and are the true coastal species. Other species, flourished in the estuary also during the high saline period.

Diversity and assemblage of copepod species

Mean species diversity indices are calculated for different seasons for the coastal and estuarine stations (Table 3). The species diversity index (H') is gen-

erally high for the coastal station. However, during the monsoon season, there is a drop (1.6) caused by the absence of some coastal species. In the estuary, H' values are lower compared to the lowest value in coastal waters even during the stable premonsoon season since only a few euryhaline species could thrive in the estuary. During the monsoon and postmonsoon seasons a further reduction occurs because of the disappearance of many species.

Evenness in abundance is generally low in both environments, but it followed more or less a similar trend as species diversity. Relatively higher values were observed during the postmonsoon season in the coastal station (0.4) and the premonsoon season in the estuary (0.3).

At the coastal station, 3 separate assemblages of species are observed (Fig. 7). Cluster I is represented by a group of strongly associated species (>65% similarity), most of them preferring wide salinity ranges. All coastal species together form cluster II, and Cluster III is an assemblage of low and medium saline species. In the estuary (Fig. 8) clusters I and II are composed of both wide and medium saline species while cluster III is formed exclusively by low saline species.

DISCUSSION

Coastal upwelling associated with the southwest monsoon is an annual phenomenon occurring along the west coast of India (Banse, 1959; 1968; Ramamirtham & Jayaraman, 1960). which is mainly responsible for nutrient enrichment of surface layers and boosting the biological productivity, compared to other seasons and non-upwelling areas (Madhupratap et al., 1990). Our results support the above observations. Upwelling creates a nutrient-rich environment (Sankarana-rayanan & Jayaraman, 1972; Devassy, 1983) ideal for phytoplankton growth resulting in zooplankton proliferation, particularly herbivores.

The copepod community in the coastal waters was dominated by herbivores. During the upwelling period their number multiplied as is the case

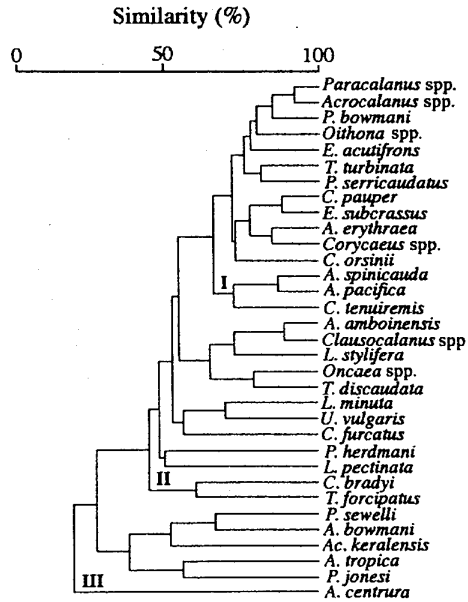


Fig. 7. Hierarchical cluster analysis showing affinities among copepod species and formation of groups in coastal station.

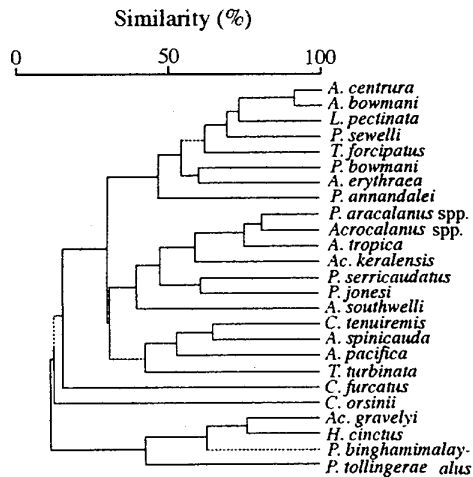


Fig. 8. Hierarchical cluster analysis showing affinities among copepod species and formation of groups in the estuary station.

for *Paracalanus*, *Acrocalanus*, *Pseudodiaptomus* and *Acartia*. Most of these taxa sustained higher densities during the initial stages of upwelling (June-August) than later in the season. However, *Acartia spinicauda*, *A. pacifica* and *A. tropica* continued to be present in good numbers, during the late upwelling period also. *Temora turbinata*

ta, *Centropages tenuiremis*, *Oithona* spp. and *Corycaeus* spp. were abundant during the initial phase of upwelling. However, carnivores like *Euchaeta*, *Candacia* and *Oncaea* were sparsely distributed. Many larger carnivores such as siphonophores, ctenophores, Medusae and chaetognaths also made their appearance in the beginning of upwelling, established their population as upwelling intensified and continued to remain in the zooplankton community even after weakening of upwelling. This points to the fact that herbivores and carnivores can thrive together in the actively upwelling areas because food is plentiful and a time lag, as observed by Madhupratap et al., (1990) may not therefore be necessary for the establishment of the tertiary community.

The total dominance of carnivores in the zooplankton community may be an indication of the slackening phase of upwelling which however, was not observed in this study.

Abundance of suspension feeders like tunicates and cladocerans as observed in this study has been recorded earlier in other upwelling areas (Madhupratap et al., 1980; Paffenhofer et al., 1984). Other organisms such as euphausiids, ostracods, pteropods, etc. which are common in upwelling areas are rare or absent in this region. In the upwelling areas, a few opportunistic species which can efficiently exploit the available resources dominate (Madhupratap et al., 1990). This was reflected in low species diversity and poor equitability in distribution.

Although the influence of upwelling is felt near the mouth regions of the Mandovi and Zuari estuaries (Sankaranarayanan & Jayaraman, 1972; Sankaranarayanan et al., 1978; Devassy, 1983), the interior of these estuaries is generally unaffected. The overall production is much lower compared to the coastal region because only a few euryhaline species dominate. However, the population structure during the monsoon season is quite different from the coastal waters. Many groups disappeared during this period and those occurring are not very abundant. The sudden drop in salinity coupled with strong downward currents

and heavy flushing made this environment unstable and unsuitable for many species. For instance, many common and abundant copepods were absent during this season, but at the same time, they either maintained or multiplied in the coastal waters.

The salinity prevailing in the coastal region was close to that of the stable estuarine condition during this period and hence these euryhaline species took refuge so as to tide over the extreme salinity variations. When the conditions stabilized after the monsoon, they re-established their population and propagated. This has resulted in a sudden increase in biomass and population density in the estuary. Some estuarine species vanish completely during the low saline period but gradually reappear during the stable period. Such species may be able to produce diapause (resting) eggs as in the case of some common calanoids in the inland sea of Japan (Kasahara et al., 1974; Uye et al., 1979), a suggestion put forward by Madhupratap (1987). However this needs confirmation.

Species associations are based on their salinity preferences although niche overlap and competition between them is a possibility (Madhupratap, 1987) and no single factor may be able to influence the coexistence of species (Peter et al., 1977). Species diversity is very poor in the estuary during all the seasons, because only a few euryhaline species (8) are common and abundant. Equitability is also low which is normally expected in a tropical estuary where opportunistic species take advantage of the frequent variations in the biotic and abiotic conditions and multiply rapidly and hence do not get sufficient time for stability and diversification.

REFERENCES

- BANSE, K., 1959. On upwelling and bottom trawling off the southwest coast of India. *J. Mar. Biol. Ass. India*, 1: 33-49.
- BANSE, K., 1968. Hydrography of the Arabian Sea shelf of India and Pakistan and effects on demersal fisheries. *Deep-Sea Res.*, 15: 45-79.
- DEVASSY, V.P., 1983. Plankton production

associated with cold water incursion into the estuarine environment. *Mahasagar-Bull. Natn. Inst. Oceanogr.*, 16: 221-233.

FIELD, J.G., K.R. CLARKE & R.M. WARWICK, 1982. A practical strategy for analysis of multi-species distribution patterns. *Mar. Ecol. Prog. Ser.*, 8: 37-52.

GOSWAMI, S.C., 1985. Zooplankton standing stock and composition in the coastal waters of Goa, west coast of India. *Indian J. Mar. Sci.*, 14: 177-180.

HARIDAS, P., P.G. MENON & M. MADHUPRATAP, 1980. Annual variations in zooplankton from a polluted coastal environment. *Mahasagar-Bull. Natn. Inst. Oceanogr.*, 13: 239-248.

HEIP, C., 1974. A new index measuring evenness. *J. Mar. Biol. Ass. U.K.*, 54: 555-557.

KASAHARA, S., S. UYE & T. ONBE, 1974. Calanoid copepod eggs in sea bottom muds. *Mar. Biol.*, 26: 167-171.

MADHUPRATAP, M., 1978. Studies on the ecology of Cochin Backwaters. *Mahasagar-Bull. Natn. Inst. Oceanogr.*, 11: 45-66.

MADHUPRATAP, M., 1987. Status and strategy of zooplankton of tropical Indian estuaries. *Bull. Plank. Soc. Japan*, 34: 65-81.

MADHUPRATAP, M., V.P. DEVASSY, S.R.S. NAIR & T.S.S. RAO, 1980. Swarming of pelagic tunicates associated with phyto-plankton bloom in the Bay of Bengal. *Indian J. Mar. Sci.*, 9: 69-71.

MADHUPRATAP, M., S.R.S. NAIR, P. HARIDAS & G. PADMAVATI, 1990. Response of zooplankton to physical changes in the environment: Coastal upwelling along the central west coast of India. *J. Coastal Res.*, 6: 413-426.

MOUNTFORD, M.D., 1962. An index of similarity and its application to classificatory problems. In: F.W. Murphy (ed.). *Progress in soil science*. Butterworths, Kent: 43-50.

NAIR, V.R., 1978. Zooplankton from the nearshore waters of Karwar. *Indian J. Mar. Sci.*, 7: 283-287.

NAIR, V.R. & R.A. SELVAKUMAR, 1979. The

ecology of chaetognaths in the estuarine system of Goa. *Mahasagar-Bull. Natn. Inst. Oceanogr.*, 12: 17-24.

NAIR, S.R.S., C.T. ACHUTHANKUTTY, V.R. NAIR & V.P. DEVASSY, 1980. Plankton composition in the coastal waters of India, between Jaigarh and Rajapur. *Mahasagar-Bull. Natn. Inst. Oceanogr.*, 13: 343-352.

PADMAVATI, G., 1992. Zooplankton ecology of the estuarine, nearshore and adjacent coastal waters of Goa. Ph.D. Thesis, Berhampur University: 1-175.

PAFFENHOFFER, G.-A., B.T. WESTER & W.D. NICHOLAS, 1984. Zooplankton abundance in relation to state and type of intrusion on to the southeastern United States shelf during summer. *J. Mar. Res.*, 42: 995-1017.

PETER, K.J., K.H. IYER, S. JOHN & E.V. RADHAKRISHNAN, 1977. Distribution and co-existence of planktonic organisms along the southwest coast of India. *Proc. Symp. Warm Water Zooplankton, NIO*: 80-86.

RAMAMIRTHAM, C.P. & R. JAYARAMAN, 1960. Hydrographical features of the continental shelf waters off Cochin during the years 1958 and 1959. *J. Mar. Biol. Ass. India*, 2: 199-207.

SANKARANARAYANAN, V.N. & R. JAYARAMAN, 1972. Intrusion of upwelled water in the Mandovi and Zuari estuaries. *Curr. Sci.*, 41: 204-206.

SANKARANARAYANAN, V.N., D.P. RAO & M.K. ANTONY, 1978. Studies on some hydrographical characteristics of the estuarine and inshore waters of Goa during the southwest monsoon 1972. *Mahasagar-Bull. Natn. Inst. Oceanogr.*, 11: 125-136.

SHANNON, C.E. & W. WEINER, 1963. *The mathematical theory of communication*. VI-117. University of Illinois Press, Urbana.

UYE, S., S. KASAHARA & T. ONBE, 1979. Calanoid copepod eggs in sea-bottom muds. IV. Effects of some environmental factors on the hatching of resting eggs. *Mar. Biol.* 51: 151-156.