

COEXISTENCE AND SUCCESSION OF COPEPOD SPECIES IN THE MANDOVI AND ZUARI ESTUARIES, GOA

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ABSTRACT

Observations were made on the copepod species association and succession at six stations in the Mandovi-Zuari estuarine system of Goa. A total of 55 species belonging to 25 genera and 18 families were encountered in the surface collections. Estuarine and estuarine marine forms constituted the bulk of copepod population. The neritic species were only stragglers in this environment. Some of the species of the same or of different families showed complete coexistence while others were negatively correlated or associated either over space or time.

The pattern of copepod succession based on species dominance revealed three main types with successional sequence of high saline species ($> 30\text{‰}$), low saline species ($> 5\text{‰}$) and species preferring medium salinity (6-30‰). The highest and lowest species diversity were seen during the premonsoon and monsoon periods respectively. The proliferation and succession of copepod species commences in the post monsoon season when some of the coastal forms intrude into the estuaries with decrease in monsoonal influx and consequent increase in salinity.

Key-words: Copepod, coexistence, succession, Mandovi-Zuari estuaries.

INTRODUCTION

Copepods by virtue of their number and species are the main index of utilization of aquatic biotope at the secondary trophic level. Extensive studies have been carried out by several investigators on the seasonal variations of estuarine copepod species in relation to physico-chemical features. However, information on their association and succession is scanty. Tranter and Abraham (1971) and Madhupratap, Haridas and Iyer (1975) gave an account of coexistence between members of major copepod families in Cochin backwaters. The present communication deals with the coexistence and succession of common copepod species in the Mandovi-Zuari estuarine system of Goa.

MATERIALS AND METHODS

Surface zooplankton samples were collected fortnightly for a period of two years (June 1971 to May 1973) at six stations (Fig. 1). The sampling was done with a modified HT net (mouth area 0.25 m² and mesh width 330 μ m), fitted with a calibrated 'TSK' flowmeter. Depending on the size of the sample, 1 to 4% of subsample was examined under the stereoscopic microscope for the enumeration of copepods and their dominant species. Coexistence between members of copepod families and species within each family was studied by constructing correlation matrices. For making the dendograms, the first species was chosen on the basis of its highest correlation coefficient. The similarity of

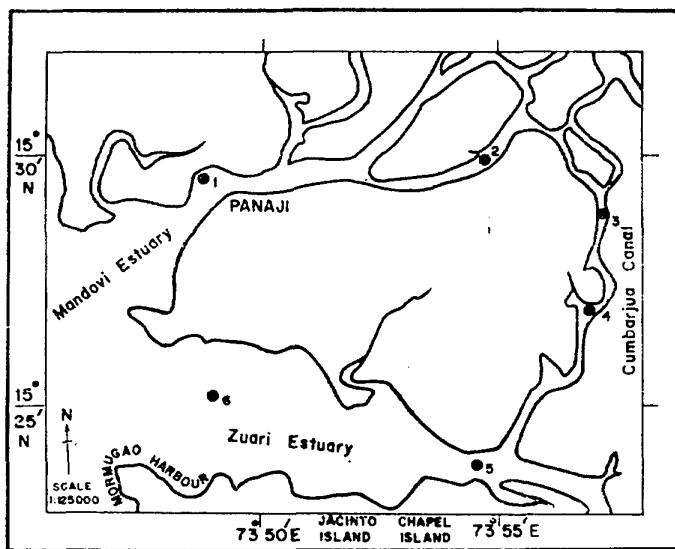


Fig. 1. Map showing location of stations.

one species with the other was worked out using the method of Sokal and Sneath (1963).

RESULTS AND DISCUSSION

A total of 55 copepod species belonging to 25 genera and 18 families were encountered in the surface collections, occurring in greater numbers in the samples taken at stations from the lower reaches of the estuaries where higher annual mean salinity values were recorded (Table I). Estuarine and estuarine marine forms contributed the bulk of copepod population, the stenohaline forms were only stragglers in this environment. Pillai (1971) gave a list of 62 calanoid copepod species recorded from the Indian estuaries. Some of the stenohaline forms, viz., *Undinula darwini* var *typica*, *U. valgaris*, *Acrocalanus gibber*, *Labidocera munuta*, *Pontella securifer*, *P. spinipes*, *Pontellina plumata* and *Lucicutia flavicornis* which have not been reported so far from other estuaries were present in the samples taken from the Zuari estuary. The copepod species observed during the present study belonged mostly to six copepod families of Paracalanidae, Centropagidae, Pontellidae, Pseudodiaptomidae, Acartiidae and Oithonidae. The coexistence between members of these families over space and time is given in Table II. An appraisal of the 'completeness' of coexistence must encompass both in space and time (Tranter and Abraham, 1971). Complete coexistence was noticed between Centropagidae, Pontellidae and Acartiidae indicating that they form a group by themselves and

Table I. Monthly mean temperature and salinity values in Mandovi-Zuari estuarine system during June 1971 to May 1972.

Months	STATIONS											
	Temperature (°C)						Salinity (‰)					
	1	2	3	4	5	6	1	2	3	4	5	6
June '71	27.2	27.0	27.0	27.8	29.0	29.0	17.16	3.28	3.20	1.68	7.73	17.57
July	27.5	27.6	27.7	27.0	27.5	27.1	6.01	1.14	0.31	0.49	5.76	12.59
Aug.	26.3	26.5	27.1	26.6	27.5	27.2	3.96	0.84	0.23	1.92	4.64	12.57
Sep.	27.5	29.1	30.0	30.0	30.1	29.0	25.39	5.01	5.20	8.58	19.07	24.05
Oct.	26.5	28.5	30.0	30.1	28.7	27.2	28.82	7.75	10.98	18.73	23.55	28.52
Nov.	26.8	28.0	29.2	29.3	28.2	27.6	31.61	12.62	18.49	25.41	31.91	34.40
Dec.	25.4	25.7	25.9	26.5	26.9	26.8	33.14	21.79	25.30	27.89	31.28	32.85
Jan. '72	25.0	26.1	26.1	26.6	26.4	26.8	32.30	25.51	26.92	28.98	30.40	32.62
Feb.	25.7	26.5	27.0	27.2	27.4	27.8	34.17	24.18	27.90	31.16	32.45	33.44
Mar.	28.3	29.5	30.2	30.0	29.2	29.2	34.00	27.48	30.97	32.70	34.45	35.16
Apr.	29.0	29.8	30.0	30.8	31.0	30.5	34.99	31.86	35.47	35.93	35.81	35.58
May	30.6	31.4	31.9	31.4	31.4	31.4	35.66	33.51	35.87	35.29	36.13	36.12
Mean	27.1	27.9	28.5	28.6	28.6	28.3	26.43	16.24	18.40	20.73	24.43	27.95

Table II. Correlation matrix for six major copepod families over space (Station 1-6) and time (June 1971 — May 1973)

Families	Paracalanidae	Centropagidae	Pseudodiaptomidae	Pontellidae	Acartiidae	Oithonidae
SPACE						
Paracalanidae	—					
Centropagidae	0.848*	—				
Pseudodiaptomidae	0.397	0.184	—			
Pontellidae	0.591	0.827*	0.425	—		
Acartiidae	0.795*	0.893*	0.531	0.946*	—	
Oithonidae	0.507	0.658	0.673	0.936*	0.882*	—
TIME						
Paracalanidae	—					
Centropagidae	0.882§	—				
Pseudodiaptomidae	0.678*	0.623*	—			
Pontellidae	0.598*	0.801*	0.330	—		
Acartiidae	0.801‡	0.740‡	0.775‡	0.654*	—	
Oithonidae	0.883§	0.972§	0.713‡	0.808‡	0.911§	—

§ -- Significant at 0.1% level; ‡ -- Significant at 1% level; * -- Significant at 5% level.

can occur together in this estuarine system. The family Acartiidae gave significant positive correlation with most of other copepod families in time. The species of families Acartiidae and Pseudodiaptomidae dominated the copepod counts and occurred in the samples invariably throughout the year. The correlation matrix was also obtained for species of these two families. A high degree of correlation was found among most of the high saline species of these

two families and they maintained their separate identity from the medium and low saline forms. *Acartia spinicauda* and *A. negligens* gave significant positive correlation both over space and time (Table III). They were recorded in greater numbers during premonsoon months when other species of genus *Acartia* were sparse. The negative correlation between the estuarine species *A. plumosa* and euryhaline marine forms *A. spinicauda* and *A. centrura* would mean that these species do not coexist in this estuarine system. *Acartiella gravelyi* gave a negative correlation with most of the species of family Acartiidae but was significantly correlated with an allied species, *Acartiella sewelli* and was the common species during monsoon period. On the basis of significant correlation both over space and time, the species of Pseudodiaptomidae can be divided into two main groups. The high saline forms such as *Pseudodiaptomus serricaudatus*, *P. mertoni* and *P. ardjuna* constitute one group while low saline species, viz., *P. binghami* and *P. amandalei* the other (Table IV).

On the basis of significant correlation, the different copepod species from this estuarine system form 3 major clusters. The level of significance between 1 and 2 cluster is 0.25 and between 2 and 3, it is 0.4 (Fig. 2).

The mechanism responsible for coexistence among the related forms is not properly understood. Food may not be a constraint as the rate of primary production in the estuaries far exceeds the rate of consumption by the zoo-

Table III. Correlation matrix for species of family Acartiidae over space (Stations 1-6) and time (June 1971-May 1973).

Species	<i>centrura</i>	<i>spinicauda</i>	<i>erythraea</i>	<i>southwelli</i>	<i>plumosa</i>	<i>negligens</i>	<i>Acartia</i>	<i>sewelli</i>	<i>gravelyi</i>
SPACE									
<i>Acartia centrura</i>	—								
<i>A. spinicauda</i>	0.362	—							
<i>A. erythraea</i>	0.599*	0.348	—						
<i>A. southwelli</i>	0.129	0.217	0.447	—					
<i>A. plumosa</i>	-0.529	-0.419	-0.411	0.327	—				
<i>A. negligens</i>	0.236	0.864†	0.574	0.582	-0.869*	—			
<i>Acartia</i> sp.	0.051	-0.575	0.364	0.346	0.072	-0.428	—		
<i>Acartiella sewelli</i>	-0.611*	-0.695*	0.816†	0.283	0.381	-0.387	0.600*	—	
<i>Ac. gravelyi</i>	-0.637*	-0.323	-0.916§	-0.159	-0.768*	-0.463	-0.505	0.107	—
TIME									
<i>A. centrura</i>	—								
<i>A. spinicauda</i>	0.175	—							
<i>A. erythraea</i>	-0.188	0.563	—						
<i>A. southwelli</i>	-0.383	-0.662*	-0.392	—					
<i>A. plumosa</i>	-0.889§	-0.456	-0.342	0.772†	—				
<i>A. negligens</i>	-0.118	0.708*	0.594*	-0.404	-0.388	—			
<i>Acartia</i> sp.	0.556	-0.266	-0.446	0.397	0.545	-0.479	—		
<i>Acartiella sewelli</i>	-0.324	-0.530	-0.279	0.949§	0.796†	-0.316	0.492	—	
<i>Ac. gravelyi</i>	-0.160	-0.695*	-0.376	0.681*	0.762†	-0.427	0.348	0.694*	—

§ — Significant at 0.1% level; † — Significant at 1% level; * — Significant at 5% level.

Table IV. Correlation matrix for species of family Pseudodiaptomidae over space (Stations 1-6) and time (June 1971-May 1973).

Species	<i>aurivilli serricaudatus</i>	<i>amandalei</i>	<i>mertoni</i>	<i>ardjuna</i>	<i>binghami</i>
SPACE					
<i>Pseudodiaptomus aurivilli</i>	—				
<i>P. serricaudatus</i>	0.900§	—			
<i>P. amandalei</i>	-0.564	-0.557	—		
<i>P. mertoni</i>	0.787†	0.682*	-0.162	—	
<i>P. ardjuna</i>	0.020	-0.295	-0.420	-0.258	—
<i>P. binghami</i>	-0.399	-0.385	0.897‡	0.154	-0.386
TIME					
<i>P. aurivilli</i>	—				
<i>P. serricaudatus</i>	0.082	—			
<i>P. amandalei</i>	-0.521	-0.346	—		
<i>P. mertoni</i>	0.104	-0.344	0.488	—	
<i>P. ardjuna</i>	0.774†	-0.198	-0.256	0.235	—
<i>P. binghami</i>	0.510	-0.275	0.929§	0.224	-0.344

§ — Significant at 0.1% level; † — Significant at 1% level; * — Significant at 5% level.

plankters (Qasim, 1970). Peter, Iyer, John and Radhakrishnan (1977) stated that feeding habits rather than the quantity of food are responsible for the coexistence among planktonic organisms. Tranter and Abraham (1971) studied the morphological variations in the mandibular structure in the coexisting species of family Acartiidae and reported that the differences which did exist were not sufficient to establish niche separation. The range of salinity tolerance in the congeneric species may lead to niche selection and ecological differences. These species exist as competitors and utilize the available food resources. Jeffries (1967) also observed that congeneric forms efficiently utilise the biotope by competing for common resources. Salinity is one of the important factors for the distribution and abundance of copepod species in the Mandovi-Zuari estuarine system (Goswami and Singbal, 1974 and Goswami and Selvakumar, 1977). Depending on the salinity tolerance and dominance, the common copepod studied can be put under three main types namely: high saline species (> 30‰), species preferring medium salinities (6-30‰) and low saline species (< 5‰). The diagrammatic representation of dominance and succession of copepod species is shown in Fig. 3. The copepod population in the surface layers was quite poor in this estuarine system during the monsoon months as also reported for other Indian estuaries (Shetty, Saha and Ghosh, 1963; Ganapati, 1964; Pillai, Qasim and Nair, 1973; Silas and Pillai, 1975; Rao, Madhupratap and Haridas, 1975 and Chandramohan, 1977). *Heliodiaptomus cinctus*, *Allodiaptomus mirabilipes*, *Pseudodiaptomus binghami*, *Acartiella gravelyi*, *Ac. sewelli* and *Diaptomus* sp. were mostly present in the plankton samples. With the decrease in monsoonal influx followed by an increase in salinity, the brackish and euryhaline forms such as *Acartia plumosa*, *A. southwelli*, *Paracalanus parvus*, *Acrocalanus gracilis*, *Pseudodiaptomus auri-*

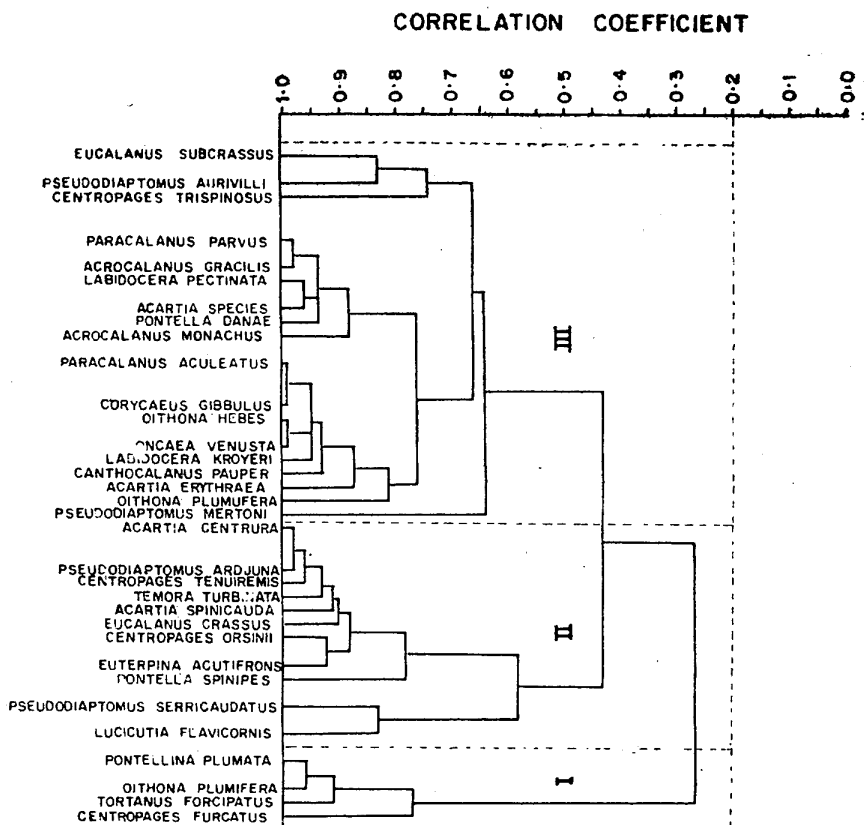


Fig. 2. Correlation coefficient between common copepod species in the Mandovi-Zuari estuarine system of Goa.

villi, *Centropages tenuiremis*, *C. trispinosus*, *Labidocera pectinata*, *Laophontia setosa* and *Harpacticus* sp. dominated and succeeded the low saline species in the plankton samples. In the later part of the postmonsoon and early premonsoon when vertical homogeneity was recorded for salinity, copepod species, viz., *Pseudodiaptomus mertoni*, *P. ardjuna*, *Centropages orsinii*, *Temora turbinata*, *Acartia spinicauda*, *A. centrura*, *Oithona rigida*, *O. brevicornis* and *Corvcaeus gibbulus* were abundant. From the month of March to the first fortnight of June, the stable environmental conditions with relatively high temperature and salinity values provide ideal conditions for the propagation and maintenance of neritic forms, viz., *Undinula vulgaris*, *Eucalanus monachus*, *Acrocalanus gibber*, *Pseudodiaptomus serricaudatus*, *Labidocera kroyeri*, *Acartia negligens*, *Pontella danae*, *Pontellina plumata*, *Tortanus forcipatus*,

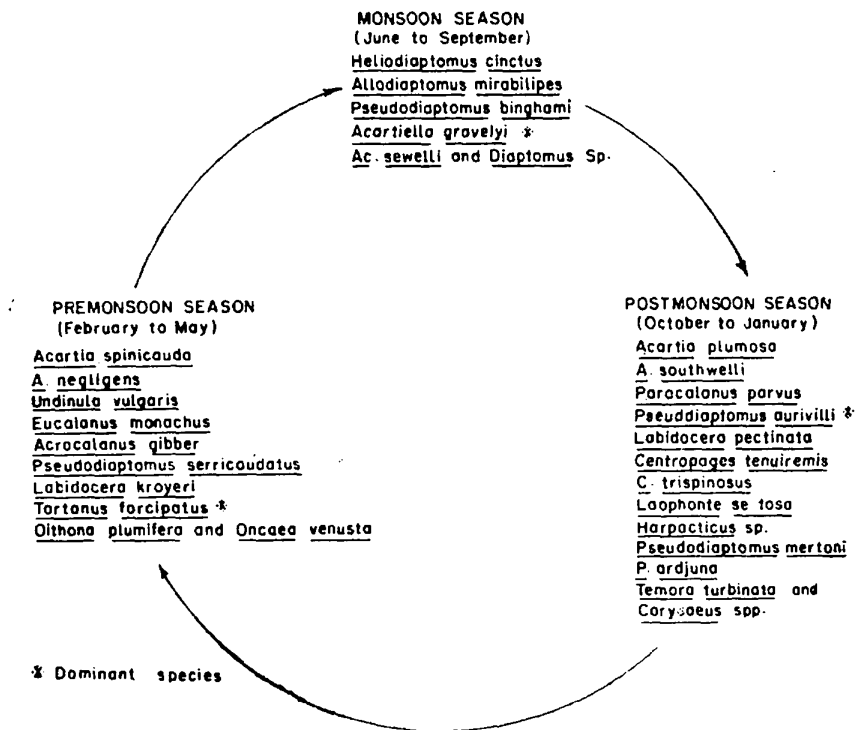


Fig. 3. Diagrammatic representation of copepod species succession in the Mandovi-Zuari estuarine system of Goa.

Olithona hebes, *O. nana*, *O. plumifera* and *Oncaea venusta* which intrude in this estuarine system from the coastal waters. Flushing rate, circulation pattern and predation are the important factors controlling the intrusion and maintenance of coastal marine forms in the Cochin backwater (Silas and Pillai, 1975). The advent of southwest monsoon in the second fortnight of June or in early July has profound influence on the hydrography and total copepod counts. The above mentioned neritic species are either flushed out to the nearby inshore areas or they migrate down to the more saline lower layers. These are succeeded by the low saline monsoonal forms and a similar cycle of succession of copepod species starts again.

The present study indicates that there is a definite successional sequence of copepod species in the Mandovi-Zuari estuarine system. The salinity appears to play an important role in the distribution and abundance of copepod species.

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