

Distribution, Community Structure & Species Succession of Copepods from Cochin Backwaters

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Ecological aspects of copepods, the major group of zooplankton in Cochin backwaters, based on year round collections from its lower reaches are presented. Truly estuarine and estuarine and marine species form the bulk of the composition along with a couple of euryhaline marine species. Most of the marine species are only stragglers into the estuary. Variations in the abundance are compared with estuaries elsewhere. Based on the spatial and temporal abundance various species of copepoda fall into different groups which together dovetail to project their overall distribution in the estuary. Species of the family Acartiidae dominate the counts. Higher abundance of copepods are recorded during the saline summer period. The system remains practically virgin and underexploited at secondary level during low saline monsoonal period. Invasion of various species into the estuary and their succession begin by postmonsoon followed by diversification and habitat selections in premonsoon. Community structure and variations in diversity trends can be explained to some extent based on salinity distribution. Broadly, 3 seral stages can be recognised in the successional sequence consisting of high saline, low saline and medium saline species.

Copepods, by their sheer abundance and diversity constitute the most important group in any zooplankton community. They include mostly herbivorous and omnivorous forms along with some carnivorous species. They occupy an important position in the trophic structure and play a major role in the energy transfer of any aquatic environment. Because of their predominance, copepods form the chief index of utilization of biotope at secondary level. Some aspects of the ecology of estuarine copepods of India have been reported¹⁻⁷ Results of detailed studies on distribution of major species, community structure, diversity and species succession in Cochin backwaters are presented in this paper.

Materials and Methods

Zooplankton collections were made during day and night at barmouth, Cochin, Aroor and Narakkal (Fig. 1) every month from November 1971 to October 1972 (series A). Samples were taken with a HT net (mesh size $300\ \mu$) in oblique hauls from bottom to surface lasting 5 min with a flow meter attached. Copepods and other zooplankton in each sample were counted to species level. Average numbers of day and night hauls were used. Aspects of another set of collections (series B) taken from mouth to head of the estuary in 1972 (ref.1) were also used as supplementary data to augment certain aspects of the results. Physical parameters of the environment such as salinity, temperature and oxygen were also recorded⁸.

Results and Discussion

Community and abundance—Copepods were the most dominant group in the zooplankton of the estuary constituting 55 to 85% of the total annual zooplankton counts at the 3 stations (annual mean to total counts - 74.5%). They formed the bulk of the zooplankton biomass.

In the backwaters, 49 species of copepoda belonging to 22 genera were observed. Calanoid copepods comprising 41 species belonging to 11 families constituted the majority. Six species of cyclopooids

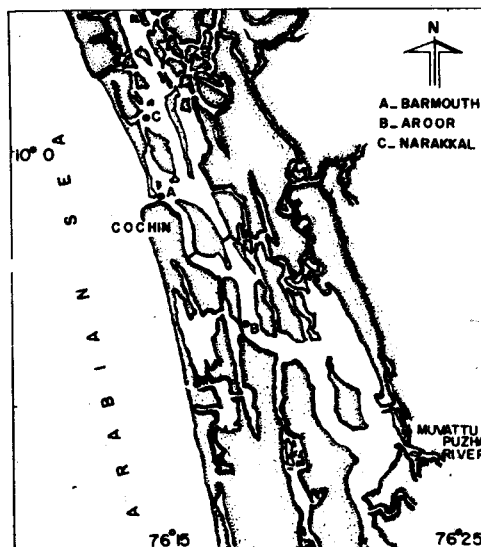


Fig. 1—Station location map

belonging to 3 genera and 2 genera of harpacticoids each represented by a species constituted the remainder of the composition. About 50% of the species occurred sporadically or in small numbers. Most species of copepods occurring in the estuary were listed¹. The species not reported earlier were *Canthocalanus pauper*, *Undinula vulgaris*, *Eucalanus monachus*, *E. crassus*, *E. subcrassus*, *Calanopia elliptica*, *C. minor* and *Labidocera kroyeri* var. *gallensis* which are essentially marine forms and occurred at the mouth of the estuary occasionally. *Archidiaptomus aroorus* an interesting new pseudodiaptomid⁹ and the hardy harpacticoid *Nitochra spinipes* which is seen mostly associated with the decays of the weed *Salvinia* flushed into the estuary by the monsoon.

Density of copepod population varied greatly with seasons (Table 1). Minimum densities noticed were 3, 10 and 1/m³ at barmouth, Aroor and Narakkal respectively during monsoon season. Maximum densities went up to 18607/m³ (night, April) at barmouth, 15021/m³ (day, February) at Aroor and 4287 m³ (night, March) at Narakkal. But in series: B, maximum density of copepod population observed was only 874/m³ even though the period of sampling overlapped. This indicates the wide range of fluctuations of population possible in a complex aquatic environment like an estuary. Tranter and Abraham⁵ also observed wide variations in copepod population in this estuary. The highest copepod density observed by them was 55390/m³ at the middle reaches during postmonsoon whereas minimum density observed in the same season at a nearby station was only 2/m³. Subbaraju and Krishnamurthy¹⁰ observed the average copepod population from Vellar estuary on the east coast during summer months to be > 100000/m³ with maximum density as 286000/m³. During the rest of the year also copepod densities were comparatively high in this water ranging between 30000 and 50000/m³. Copepods constituted 90% of the zooplankton population in Porto Novo waters. Grindley and Wooldridge¹¹ have recorded high density (42700/m³) of a single estuarine copepod *Pseudodiaptomus charteri* from Richards Bay, S. Africa.

Average copepod counts from the 3 stations were 1631/m³ for the whole year, 4046/m³ for premonsoon (January-April) 436/m³ for monsoon (May-October) and 391/m³ for postmonsoon (November-December). The apparent decrease during postmonsoon compared to monsoon season was due to the presence of higher densities of copepod population at the mouth during early monsoon period. The averages from the 2 stations inside the estuary showed copepod densities to be 84/m³ for monsoon and 278/m³ for postmonsoon.

Distribution and species associations—Greater abundance of copepoda was observed between

Table 1—Copepod Density (No./m³) and Relative Percentage Based on Total Zooplankton Counts (1971-72)

Month	Barmouth		Aroor		Narakkal	
	D	%	D	%	D	%
Nov.	245	30.5	489	44.3	2	100
Dec.	979	59.7	607	66.7	12	40
Jan.	688	66.4	9109	81.6	974	52.8
Feb.	3300	81	10775	94.5	1147	61.3
March	3531	96.5	3460	87.8	2148	58.8
April	9890	95.5	2669	77.4	858	46.3
May	3590	89	176	58.6	8	53.3
June	523	96	267	56.5	45	56.9
July	2436	88.5	390	51.3	26	23.8
Aug.	3	0.5	74	56.4	1	50
Sept.	6	14	270	40.9	1	11.1
Oct.	285	50.5	10	62.5	86	48.5
Annual mean	2123	64	2328	64.9	442	50.2
Per cent to annual total		85.4		83		55.1

D = Density

February and April at the mouth and January to April at Aroor and Narakkal (Table 1). Thus, the distribution of copepoda showed higher abundance during the saline premonsoon period. The increase and decrease in their abundance was closely associated with the salinity intrusion in the estuary. Earlier observations^{6,12} also showed salinity to be the chief factor controlling the zooplankton abundance in the estuary. During premonsoon, although a salinity gradient was present from mouth to the head of the estuary¹³, the total counts of copepods over space were more or less uniform. This was possible because different species could fill the different niches owing to their differences in salinity tolerance and preference.

Distribution of 17 more common species of copepods at the 3 stations are given in Fig. 2, and 13 of them over the whole estuary in Fig. 3. The salinity range in which the common species occurred and their salinity preference based on abundance are given in Table 2.

Acrocalanus similis, *Acartia bowmani*, *A. centrura* and *A. bilobata* were the most successful species in terms of abundance at the lower and later at lower middle reaches during saline period in the estuary. Of these, *Acartia* spp occurred at the mouth by October. By late postmonsoon (December) or early premonsoon (January) they flourished in the interiors of the estuary along with salinity incursion. *Acrocalanus similis* appeared in December and this species could also successfully compete with other species present in the estuary during premonsoon. *Acartia spinicauda* also showed similar distribution, but was less abundant.

Another group which was also predominantly high saline consisted of species such as *Paracalanus aculeatus* f. *major*, *P. crassirostris* f. *cochinensis*,

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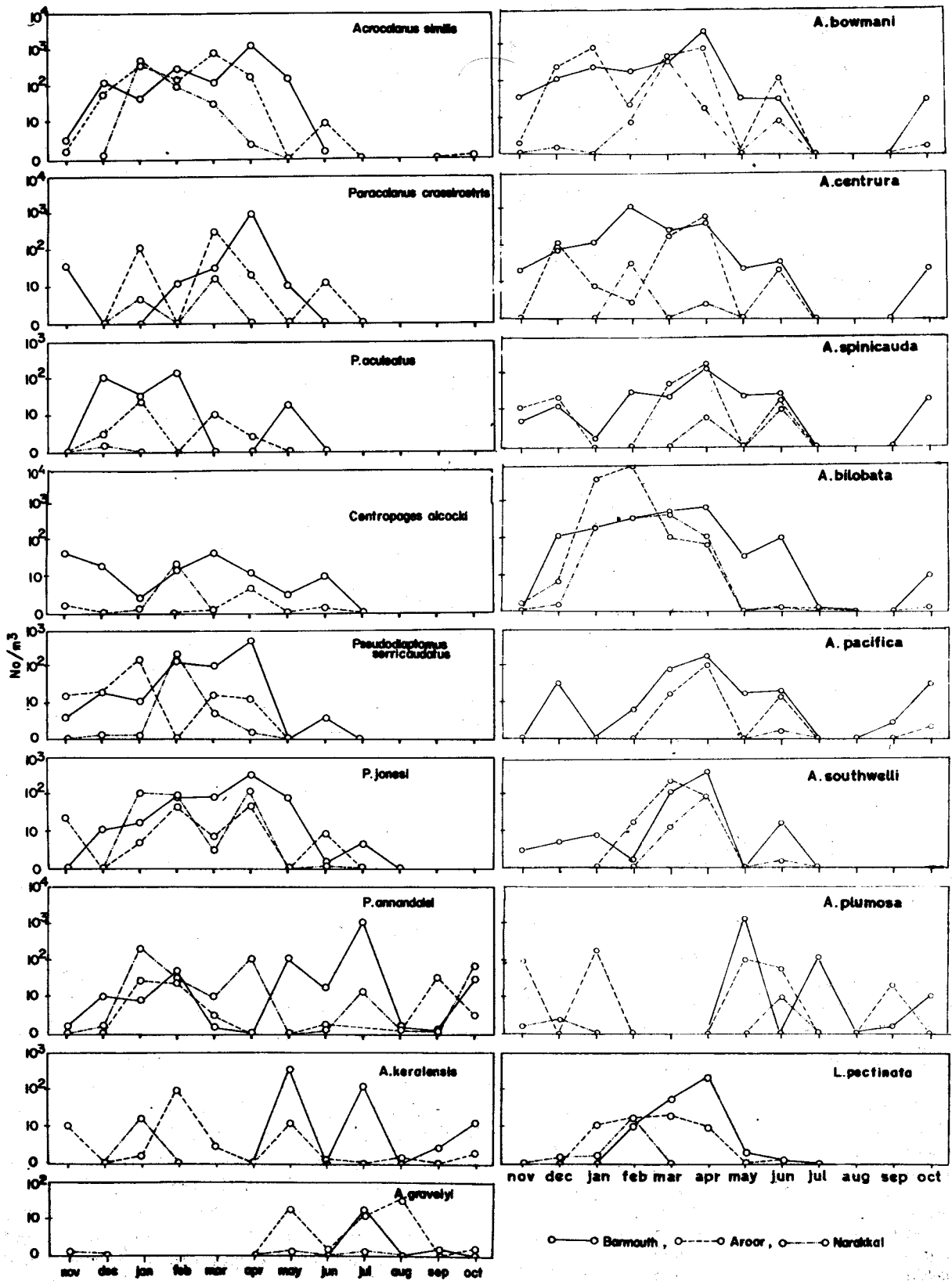


Fig. 2—Distribution of common species of copepods at barmouth, Aroor and Narakkal (1971-72)

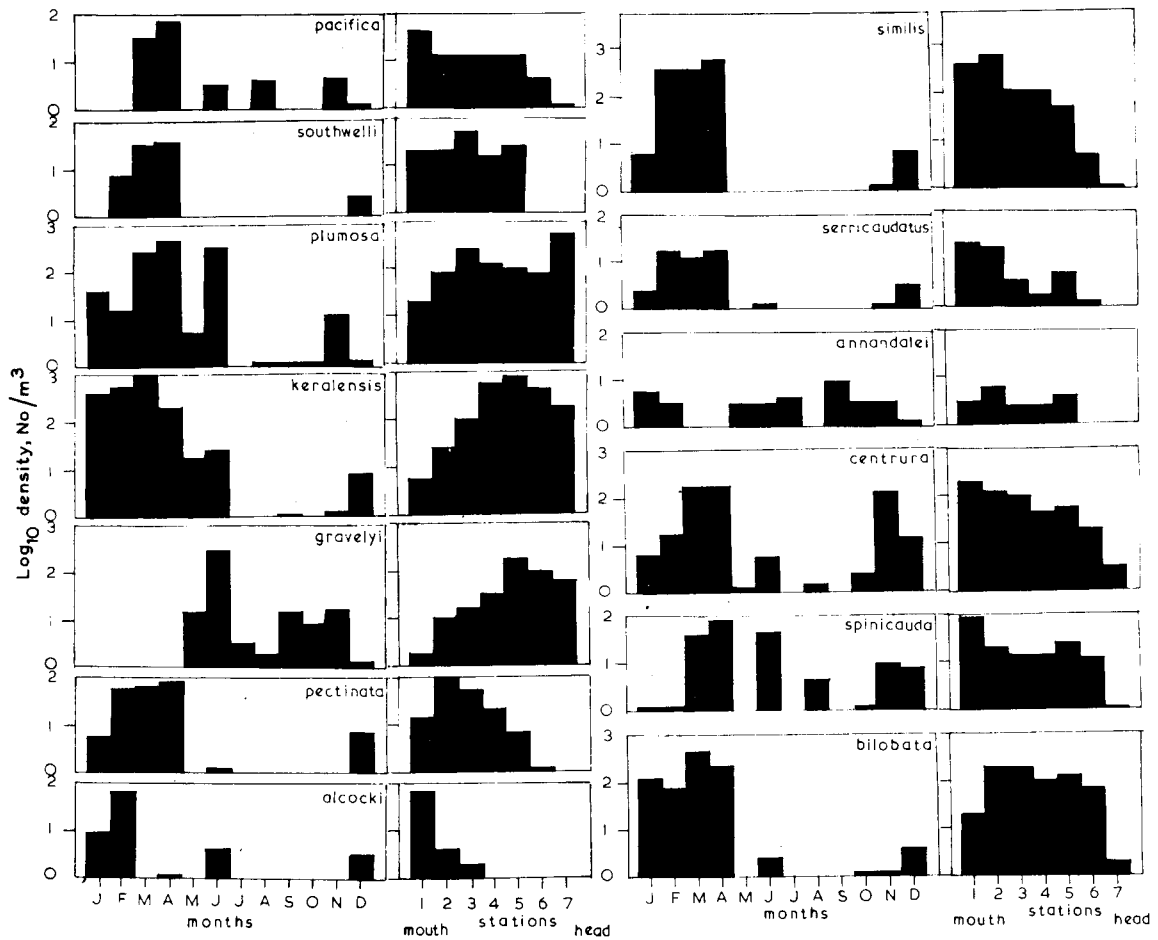


Fig. 3—Distribution of common species of copepods in time (1972) and space (Cochin to Alleppey)

Table 2—Maximum Salinity (‰) Range and Optimum Salinity for Major Copepod Species

Species	Maximum	Optimum
<i>Paracalanus aculeatus</i>	13.5-34.5	25.5-34.5
<i>P. crassirostris</i>	14 -34.7	28 -34.7
<i>Acrocalanus similis</i>	2 -35.6	25.5-33.5
<i>Centropages alcocki</i>	14 -35.5	29 -35.5
<i>Heliodiaptomus cinctus</i>	0 -11.5	0 - 1.5
<i>Allodiaptomus mirabilipes</i>	0 -11.5	0 - 1.5
<i>Pseudodiaptomus annandalei</i>	0 -35.2	5 -31
<i>P. binghami malayalus</i>	0 -10	0 - 2
<i>P. jonesi</i>	18.5-35.2	25.5-34
<i>P. serricaudatus</i>	13.4-35.5	25.5-34
<i>Labidocera pectinata</i>	2 -35.5	29 -35.5
<i>Acartia centrura</i>	5.8-35.2	26.5-33.5
<i>A. bowmani</i>	9.5-35.2	27.5-32
<i>A. spinicauda</i>	5.8-35.2	29 -33
<i>A. plumosa</i>	0 -28	15 -25
<i>A. southwelli</i>	17 -35.5	30 -35
<i>A. pacifica</i>	12.6-35.5	30 -35.5
<i>A. bilobata</i>	8.6-35.5	26 -34
<i>Acartiella keralensis</i>	0 -29.7	18 -26
<i>A. gravelyi</i>	0 -12	0 - 3

Pseudodiaptomus serricaudatus, *P. jonesi*, *Acartia pacifica* and *A. southwelli*. They also occurred in the estuary by postmonsoon. They had sudden peaks in abundance in certain months, but unlike in the previous group were not consistently abundant throughout the saline season. Variations existed in the distribution of species within this group. *Paracalanus crassirostris*, *Acartia pacifica* and *A. southwelli* were restricted to the mouth region during post-monsoon. Among the 2 species of *Acartia*, *A. southwelli* showed more restricted distribution and was not found beyond middle reaches unlike *A. pacifica*. *Pseudodiaptomus serricaudatus* and *P. jonesi* exhibited more or less similar pattern of distribution and *Paracalanus aculeatus* had more restricted occurrences. This species may be even grouped with the next category.

The 2 euryhaline marine species *Centropages alcocki* and *Labidocera pectinata* were common, but occurred in still lesser numbers. Except for these 2 species which propagated in the estuary, other species recorded from these 2 genera were only stragglers into the backwaters. Among the two, *C. alcocki* showed less tolerance to

lower salinities (Table 2) and was restricted to the lower reaches of the backwaters.

Acartia plumosa and *Acartiella keralensis* preferred medium salinities. Although the 2 species were more abundant in the estuary during premonsoon they were absent at the mouth region during this season (Fig. 2). They were present at Aroor and middle reaches where salinity was not high during early premonsoon. When salinity registered higher values at these regions they shifted further up the estuary. The locality of their abundances oscillated with salinity vacillations. When monsoons started and upper reaches became fresh water, these species were observed at the mouth region. But later during the monsoon (August) they were absent at the mouth also.

Pseudodiaptomus annandalei exhibited a peculiar distribution. It had a wide range of salinity tolerance (0-35‰) and occurred in large numbers in various salinities. It occurred throughout the year, but in low numbers during the peak salinity months of March and April. It dominated some samples taken during monsoon period at the lower reaches. In spite of its wide range of salinity tolerance this species did not occur at the upper reaches at any time during the year (Fig. 3). This species seems to prefer stratified waters of early premonsoon, monsoon and post-monsoon seasons present at the lower reaches⁸. Its salinity tolerance is probably used as an adaptation to survive in such conditions and to escape competition. But this species could not survive in total freshwater for long as they were always absent at the upper reaches which are shallow and remains fresh water from top to bottom for most part of the year. Salinity penetration reaches the upper reaches only by late premonsoon, but vertically homogenous conditions exist throughout the system during this period¹³. This explains its occurrence in low numbers during this period and exclusion from the upper reaches throughout the year.

Heliodyptomus cinctus, *Allodyptomus mirabilipes*, *Archidyptomus aroorus*, *Pseudodyptomus binghami malayalus*, *P. tollingarae* and *Acartiella gravelyi* were the low saline calanoid copepods present in the estuary. Of them *A. gravelyi* was the only species that successfully flourished during the monsoons. It was present at the mouth only during the peak of the monsoon (July) when salinity was low. It dominated the copepod counts during low salinity regime. Other low saline species occurred only in small numbers.

Among the cyclopoids, *Oithona* spp were common in the estuary. *O. rigida* was frequent during high saline period. *O. brevicornis*, *O. hebes* and *O. nana* were more tolerant to lower salinities, the last two more so than *O. brevicornis*.

Family Acartiidae contributed to the majority of copepod counts in the estuary (Fig. 4). Ten species

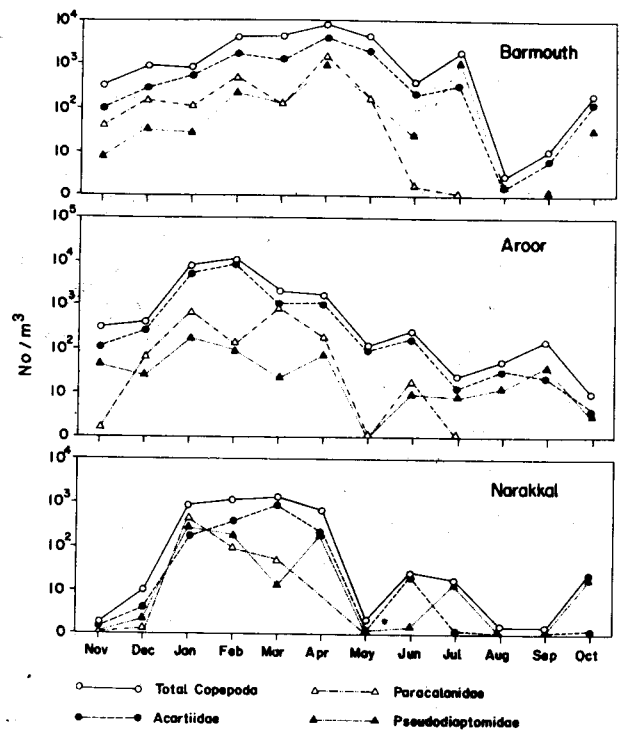


Fig. 4—Distribution of the major families of copepods at barmouth, Aroor and Narakkal (1971-72)

were recorded from the backwaters, the diversity of the family is higher than that found in any other area in the world. Family Pseudodiaptomidae ranked next by having 8 species. But next to Acartiidae family Paracalanidae dominated the copepod counts during premonsoon. Whereas families Acartiidae and Pseudodiaptomidae had low saline species to replace the high saline ones during monsoonal period, the abundance of species of the family Paracalanidae dwindled during this span.

Species of the family Acartiidae are well adapted to estuarine conditions and are found in the estuaries throughout the world. Experimental studies have shown that *Acartia tonsa*, *A. bifilosa* and *A. discaudata* are able to withstand considerable salinity variations¹⁴. *Acartia* probably attains dominance in brackish waters because low salinity excludes the more metabolically efficient oceanic species¹⁵. *Acartia* is the most common calanoid copepod of Southampton waters¹⁶. *A. clausi* and *A. tonsa* dominate the zooplankton of New England estuaries¹⁷. Species of *Acartia* and *Pseudodyptomus* have been reported to constitute the majority of zooplankton in Richards Bay, South Africa¹¹. In the east coast of India *Acartia* spp are common in the Godavari estuarine system¹⁸. But *Oithona* have been reported as the dominant copepod in the Vellar-Coleroon estuarine system although some 7 species of Acartiidae have been recorded from this area¹⁰.

The common copepod species of the Cochin backwaters exhibit a wide range of salinity tolerance ($> 34\text{‰}$). Of them only *Centropages alcocki*, *Labidocera pectinata* and *Paracalanus* and *Acrocalanus* spp are common in the coastal waters. Other common high saline species of the estuary belonging to families Acartiidae and Pseudodiaptomidae except *Pseudodiaptomus serricaudatus* are rare in the coastal waters of Cochin area¹⁹. The species which were only stragglers into the estuary are common in the inshore waters. Grindley and Wooldridge¹¹ have found that the salinity tolerance of Pseudodiaptomid species of Richards Bay ranged from nearly freshwater to 60‰ and peak survival at approximately 35‰ salinity and that these species do not occur in normal sea water. They believe that it is not salinity but competition from marine organisms that prevent them from surviving in the sea, whereas their adaptation for surviving extreme environmental fluctuations allow them to flourish in the estuary. This seems to be applicable here also. Similarly competition must be the factor which prevents survival of the numerous coastal water species in the estuary although salinity is comparably high at the lower reaches during premonsoon.

Diversity—Diversity indices at the 3 stations were calculated using the formula of Fisher *et al.*²⁰ and are given in Fig. 5. The variations occurring in diversity could be explained to some extent based on salinity fluctuations. Although subject to constant changes owing to tidal mixings, some semblance of stability in the estuary is developed during the salinity regime and a higher diversity was maintained during this period. The increase shown at Narakkal in June and at the mouth in June and September corresponded with an increase in salinity during monsoonal period. At the mouth a higher diversity occurred from January to June but at the stations inside the estuary it gradually increased with increase of salinity and a drop was observed by May when the monsoons started.

It is generally accepted that stability increases diversity. Tropical estuaries have more of physically controlled than biologically accommodated communities²¹ and have less diverse communities than tropical marine environment. The total diversity of a community is a function of niche development and may therefore increase or decrease at various stages²². The premonsoon period although stabler is too short to develop high diversity comparable to the marine environment. Thus the species that operate in the estuary during this season have broad niches and utilizing their adaptability to adjust to the fluctuating environment extract the maximum from it within the available period. A progressive diminution of index values observed from mouth to head of the estuary⁶ indicates a less exploited biotope towards the upper

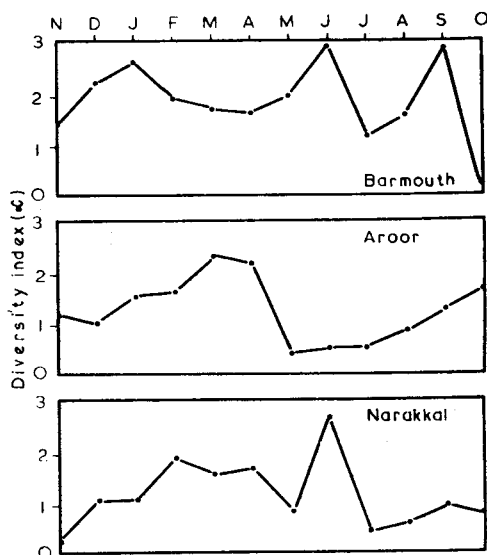


Fig. 5—Trends of diversity of copepods at barmouth, Aroor and Narakkal (1971-72)

reaches resulting from the delay or gradient developed in salinity incursion.

Various hypothesis and theories involving time, spatial heterogeneity, competition, predation, stability and productivity have been proposed to explain gradients in diversity. But pinpointing the reasons for the lack of diversity is difficult. "Niches can be defined only in retrospect, because the niche of any species has biotic dimensions determined by evolution"²³. Spatial heterogeneity is not wanting in the backwaters. Primary food is also available in plenty in the system²⁴. The cause for the absence of enough species to exploit different situations especially low saline period is to be looked elsewhere. Lack of stability, time to diversify and physiological stress imposed by the environment should be the main reasons.

Species succession—Depending on the environmental parameters various species occur and propagate in the estuary, attain ascendancy and disappear during unfavourable conditions. Species succession which begins in the postmonsoon months along with salinity recovery varies with space and time and can be gathered from the numerical dominance exerted by various species.

The conspicuous feature over space (Fig. 6 b) was the dominance of the 2 medium salinity species *Acartiella keralensis* and *Acartia plumosa* in the middle and upper reaches of the estuary during the saline period. Although species like *Acartia bowmani*, *A. centrura*, *A. bilobata* and *Acrocalanus similis* did penetrate up to the head along with salinity incursion and usually dominated the faunal component at the lower reaches, they could not dominate. Had the salinity in these areas increased further by some

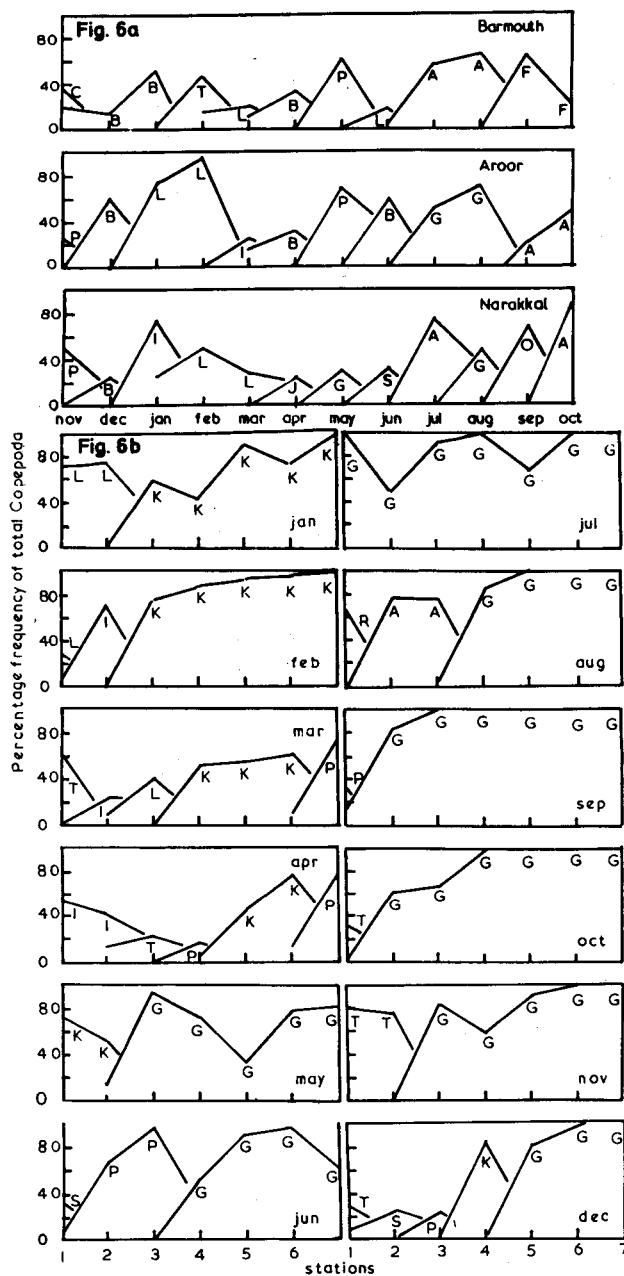


Fig. 6—(a) Succession of dominant copepod species at barmouth, Aroor and Narakkal [A—*Pseudodiaptomus annandalei*, B—*Acartia bowmani*, C—*Paracalanus crassirostris*, F—*Acartia pacifica*, G—*Acartiella gravelyi*, I—*Acrocalanus similis*, J—*Pseudodiaptomus jonesi*, L—*Acartia bilobata*, O—*Oithona previcornis*, P—*Acartia plumosa*, S—*Acartia spinicauda*, and T—*Acartia centrura*] (b) Succession of dominant copepod species from head to mouth of the estuary (series: B) from January to December 1972 [G—*Acartiella gravelyi*, I—*Acrocalanus similis*, K—*Acartiella keralensis*, L—*Acartia bilobata*, P—*Acartia plumosa*, S—*Acartia spinicauda*, R—*Centropages tenuiremis*, T—*Acartia centrura*]

mechanism (like a failure of monsoon) it is conceivable that they would have dominated in these regions also. But by April they could exert their dominance only up

to station 3 when monsoons inundated the estuary and the low saline species *Acartiella gravelyi* became the dominant copepod. In the postmonsoon months (November, December) the succession of high saline and medium saline species started from the lower reaches. Here (Fig. 6 a) high saline species dominated the counts during premonsoon and during the monsoon *Acartiella gravelyi* and *Pseudodiaptomus annandalei*, a copepod which prefers stratified water, usually dominated the zooplankton. It could be seen that the percentage of dominance attained by a species during salinity regime was not high unlike low saline period indicating that other species were also abundant in the composition.

Broadly, 3 seres could be recognised in the successional squence consisting of high saline, low saline and medium saline species. The redundance and dominance exerted by any sere at any time or place would depend on salinity incursion, fresh water efflux and resultant changes of salinity values. Most of the common species that occurred during high saline period were able to tolerate considerable range of salinity variations, but dominance seems to be achieved with optimum values. Among species with more or less same optimum salinity ranges, other factors such as metabolic requirements, competition, reproductive rate, etc. could be controlling factors.

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