

Composition & Variations in the Abundance of Zooplankton of Backwaters from Cochin to Alleppey

M. MADHUPRATAP & P. HARIDAS

Indian Ocean Biological Centre, National Institute of Oceanography, Cochin 682018

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Zooplankton abundance from Cochin to Alleppey was studied during 1972. Spatial and seasonal variations in the mean abundance of different groups and species of zooplankton organisms were very much related to salinity fluctuations occurring in backwaters. Most of the groups showed higher abundance during high saline premonsoon from January to April. During monsoonal efflux most of the high salinity organisms were wiped out and only low salinity species were able to thrive in the middle and upper reaches of the estuary. Process of repopulation of backwaters which begins during postmonsoon is discussed.

ZOOPLANKTON of Cochin backwaters has been studied by several authors¹⁻¹². In the present study, a total picture of spatial as well as seasonal variations in the occurrence and the abundance of different groups and species of zooplankton of Cochin backwaters are presented. The data are based on a year-round collection from the lower to the upper reaches of the estuary. Hydrography of backwaters surveyed along with this study has been reported¹³.

Materials and Methods

Zooplankton samples were taken once in every month during 1972 from 7 fixed stations¹³ during day-time covering the backwaters from Cochin to Alleppey (09°30'-09°58'N; 76°15'-76°25'E). Samples were collected using a HT net (mesh width 300 μ m) with a flow meter attached. The hauls were oblique taken from bottom to the surface. Depth of the water column at different stations varied and at each station the net was drawn gradually to reach the surface in 5 min. Salinity and temperature for each metre depth were recorded with a salinity-temperature bridge. A single series of sampling was conducted at night at these stations in March.

Plankton samples were filtered, drained of excess water on absorbent paper and added to a known volume of water to find out the displacement volume. Depending on the size of the sample, subsamples were taken. The organisms in each of the subsample were counted to species level wherever possible. Often, when the sample was small, the whole sample was taken.

Statistical analysis of data was done using analysis of variance technique to find if there were significant groupwise and specieswise variations in abundance between months and between stations. Analysis of variance was performed by converting the abundance figures to their corresponding logarithmic values after adding one to each of the observation. Using the formula

$$\sqrt{\left(\frac{1}{r_1} + \frac{1}{r_2}\right)} V_E \times t(0.05)$$

for critical difference or least significant difference, significantly higher and lower mean abundance in different months and stations were separated. In the formula, r_1 and r_2 are the number of replications for the 2 treatments, V_E is the error mean square and $t(0.05)$ is the 5% Student's t table value.

Salinity range for different species was evaluated from the salinity values at different depths at each station. Some of the species which were abundant only during the premonsoon period occasionally appeared at stations near the mouth of the estuary during the monsoon period. Distinct stratification in the salinity distribution was evident at these stations during this period due to the intrusion of high saline sea water into the estuary along the bottom¹³. For evaluating the salinity range tolerated by these species it was assumed that their distribution is confined to the higher saline bottom layers since the salinity at the upper layers was always nearly zero during this season. The opposite of this assumption was applied to those species which were abundant only during the low salinity regime and were present near the mouth of the estuary during the monsoon period. Backwaters were inhabited by immigrants from the sea and fresh water either at alternate times or at different water depths.

Results

Total Zooplankton

Total numbers of zooplankton organisms and their displacement volume/m³ are listed in Table 1. Both were higher during the high saline premonsoonal period and reached their peak in March-April. Total counts of zooplankton attained a maximum of 4633.7/m³ at station 4 in April. Displacement volumes were especially high at those stations where swarms of hydromedusae and ctenophores occurred. Highest displacement volumes, observed at station 3 in April and station 1 in June, corresponded to the maximum numbers of hydromedusae observed during the year. With the onset of the south-west monsoon in May, average total numbers of zooplankton

TABLE 1 -DISPLACEMENT VOLUME AND TOTAL NUMBER OF ZOOPLANKTON (JANUARY TO DECEMBER 1972)

Month	Stations							Average	
	1	2	3	4	5	6	7		
	DISPLACEMENT			VOLUME (ml/m ³)					
Premonsoon^a									
Jan.	0.0709	0.1320	0.7184	0.2923	0.0970	0.9576	0.0789	0.3353	
Feb.	0.2347	0.2975	0.406 1	0.3949	0.2575	0.0165	0.0089	0.2309	
March	0.0302	0.3520	0.3300	0.2689	0.3242	0.2263	0.0251	0.2224	
April	0.3106	0.4108	2.0888	0.6844	0.2005	0.4196	0.1131	0.6013	
Monsoon^b									
May	0.0220	0.0560	0.0082	0.0577	0.0055	0.0481	0.0456	0.0347	
June	2.3580	0.9058	0.4359	0.0158	0.3766	0.1790	0.1400	0.6302	
July	0.0299	0.0069	0.0048	0.0052	0.0063	0.0023	0.0021	0.0082	
Aug.	0.0735	0.0140	0.0085	0.0095	0.0130	0.0095	0.0031	0.0187	
Sept.	0.0054	0.0034	0.0042	0.0039	0.0033	0.0022	0.0020	0.0035	
Oct.	0.0012	0.0010	0.0093	0.0085	0.0043	0.001 9	0.0011	0.0039	
Postmonsoon^c									
Nov.	0.0500	0.0641	0.0471	0.0292	0.0030	0.0011	0.0010	0.0279	
Dec.	0.0384	0.0369	0.0307	0.0316	0.0100	0.0099	0.0125	0.0217	
	TOTAL			NUMBERS /m ³					
Premonsoon^d									
Jan.	409.2	573.4	481.6	336.2	227.7	94.8	2.1	303.6	
Feb.	678.7	845.7	272.5	380.6	197.4	86.5	50.1	358.8	
March	308.4	503.7	1023.0	1307.2	994.6	762.4	168.1	723.9	
April	4031.4	1206.6	1396.3	4633.7	516.1	165.9	531.6	1783.1	
Monsoon^e									
May	194.9	368.0	6.8	80.3	5.1	59.2	40.2	107.8	
June	270.7	237.8	422.4	36.9	211.0	106.0	14.8	185.7	
July	2.2	2.1	0.7	0.4	1.8	0.4	0.1	1.1	
Aug.	435.2	17.4	2.2	15.7	11.6	3.0	0.2	69.3	
Sept.	5.0	10.7	3.1	3.5	1.6	0.8	0.5	3.6	
Oct.	13.5	5.3	8.2	6.8	3.5	0.4	0.1	5.4	
Postmonsoon^f									
Nov.	175.4	94.2	27.6	16.4	0.9	0.1	0.9	45.1	
Dec.	420.5	345.1	106.6	57.7	5.1	2.4	4.9	134.6	
Seasonal average: a, 0.3475; b, 0.1165; c, 0.0275; d, 792.4; e, 62.2; and f, 89.9									

decreased from 1783.1/m³ in April to 107.8/m³ in May and to 1.1/m³ at the peak of the monsoon in July. A general increase in the zooplankton abundance occurred in June following a break in the monsoon and a consequent increase in salinity. During the postmonsoon season of November-December the zooplankton increased along with trends of salinity recovery.

Composition of Zooplankton

Relative abundance of various groups of zooplankton in the estuary fluctuated with seasonal salinity variations. Table 2 lists the numbers and relative percentages, by count, of the numerically abundant groups of organisms. Almost all the major groups flourished in the backwaters during the high saline period from December to April. Many groups such as hydromedusae, ctenophores, chaetognaths and lucifers were either absent or poorly represented during the low salinity regime. Copepods

were present at all the stations throughout the year. Apart from these many other organisms such as siphonophores, invertebrate eggs, a variety of invertebrate larvae, fish eggs and larvae, copelates, amphipods, isopods, cladocerans and other Crustacea constituted the total zooplankton. Table 3 lists the period, stations of occurrence, peak density of population and salinity range observed for different species.

Analysis of variance showed that the mean abundance of some of the groups and species of zooplankton varied over months and stations highly ($P \leq 0.01$) while some others were just significant ($P \leq 0.05$). significant difference in abundance was not observed for those groups and species whose distribution was more or less uniform or when they were represented only occasionally and in small numbers in the collections. Results of analysis of variance and the months and stations of peak abundance for various groups and species are given

TABLE 2 — TOTAL NUMBER/m³ AND RELATIVE PERCENTAGES OF MAJOR GROUPS OF ZOOPLANKTON

Month	Hydromedusae		Ctenophora		Chaetognatha		Copepoda		Lucifer		Decapod larvae		Fish eggs		Fish larvae	
	No./m ³	%	No./m ³	%	No./m ³	%	No./m ³	%	No./m ³	%	No./m ³	%	No./m ³	%	No./m ³	%
Jan.	32.3	1.5	—	—	15.7	0.6	623.0	29.3	45.4	2.1	1284.7	60.5	81.0	3.8	35.2	1.6
Feb.	4.8	0.2	29.0	1.2	8.1	0.3	1195.6	47.6	12.1	0.5	1373.1	54.7	276.4	1.1	11.3	0.5
March	49.9	1.0	66.4	1.1	50.6	1.0	2715.8	53.6	151.5	2.9	1944.0	38.4	10.1	0.2	19.4	0.4
April	189.8	1.5	333.7	2.7	164.0	1.3	2348.5	18.8	75.1	0.6	9318.1	74.6	29.2	0.2	7.0	0.01
May	—	—	0.04	0.01	0.05	0.01	48.5	6.4	15.5	2.1	593.8	78.7	0.03	0.04	96.8	12.8
June	142.2	10.9	15.0	1.2	5.8	0.4	804.7	61.9	59.2	4.5	99.3	7.63	—	—	14.0	1.1
July	—	—	—	—	—	—	3.4	44.1	—	—	2.1	27.7	—	—	0.2	2.7
Aug.	—	—	—	—	3.7	0.8	44.8	9.2	0.4	0.1	23.0	4.	—	—	0.2	5.7
Sept.	—	—	—	—	—	—	7.5	29.7	—	—	4.2	16.7	25.8	5.3	25.7	2.7
Oct.	—	—	—	—	0.03	0.1	13.9	36.7	2.5	9.9	13.1	34.7	4.1	10.8	13.0	51.2
Nov.	—	—	0.2	0.06	4.2	1.3	192.6	61.0	18.3	5.8	66.5	21.1	7.0	2.2	4.2	11.1
Dec.	0.3	0.03	0.7	0.1	5.6	0.6	71.6	7.6	93.7	9.9	727.8	77.2	31.2	3.3	10.5	3.3
Annual	34.9	1.3	37.1	0.5	21.5	0.5	672.5	33.8	39.5	3.2	1270.8	41.4	38.7	2.2	20.1	7.6
Annual mean	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Annual % to total	—	1.5	—	1.7	—	1.0	—	30.9	—	1.8	—	57.6	—	1.7	—	0.9

in Table 4. The period and stations of maximum abundance are indices to the preferences of environmental conditions for various species.

Amphipoda and copelata did not show any significant variations over months. Variations between stations were significant for Chaetognatha, Copepoda, *Lucifer*, decapod larvae, invertebrate eggs, fish eggs, fish larvae and Copelata. Mean number of different species of hydromedusae and *Pleurobrachia* sp. varied significantly over months. But most of them did not show significant abundance over stations except *Euceilota menoni* and *Eutima commensalis*. All the species of chaetognaths exhibited significant variations over months and stations except *Sagitta Oceania*. Among the common copepods of the estuary all the species except *Centropages tenuiremis*, *C. trispinosus*, *Pseudodiaptomus annandalei*, *P. binghami malayalus* and *Acartia erythraea* showed significant variations in abundance over months. Among cladocerans between months, variation of the species *Penilia avirostris* was significant. Abundance of the two species of *Lucifer* varied significantly over months and stations. Species showing greater variability occurred in larger numbers during their peak seasons.

Spatial and seasonal variations of most groups of zooplankton and the species within these groups showed higher mean abundance during the pre-monsoon period. Among these, only those species which were able to withstand lower salinity conditions could establish in the middle or upper reaches of the estuary. Others showed maximum abundance at stations at the lower reaches. These species were absent in the estuary during the monsoon except for their occasional occurrences at the mouth. Only a few groups such as cladocera and fish larvae and species like *Heliodiaptomus cinctus*, *Allodiaptomus mirabilipes* and *Acartiella gravelyi* showed higher abundance during the monsoonal period.

Most species of hydromedusae, *Pleurobrachia* sp., *Sagitta oceania*, Paracalanus *crassirostris f. cochinensis*, *Heliodiaptomus cinctus*, *Allodiaptomus mirabilipes*, *Acartia plumosa*, *A. southwelli* and *Penilia avirostris*, did not exhibit significant variations between stations since their distribution over space was more or less uniform during the months of their occurrence. On the other hand, even though the distribution of *Pseudodiaptomus annandalei* was uniform over months it showed significant variations in abundance over stations. The other groups and species whose abundance did not vary significantly over months or stations were represented only occasionally in the collections.

Hydromedusae — Large numbers of hydromedusae occurred in backwaters during the high saline premonsoon period. In January and February they were absent at the lower reaches of the estuary. Hydromedusae were present throughout the backwaters in March and April and a maximum density of 133.4/m³ was observed at, station 3 in April. With the onset of monsoon they disappeared from May to November although they were collected in June at stations 1 to 3 following a break in the monsoon. *Blackfordia virginica*, *Eirene ceylonensis*

TABLE 3 — SPECIES OF ZOOPLANKTON, PERIOD AND STATIONS OF OCCURRENCE, MAXIMUM DENSITY OF POPULATION OBSERVED AND SALINITY RANGE (JANUARY TO DECEMBER 1972)

Species	Period	Stations		Post- monsoon	Maximum density		Salinity range ‰
		Pre- monsoon	Mon- soon		No./m ³ *	Station	
Hydromedusae							
<i>Obelia</i> sp.	March, April	1-3	—	—	3	1.94 (0.09)	30.9-34.2
<i>Blackfordia virginica</i> Mayer	Jan.-April, June, Dec.	3-7	1-3	2	1	27.40 (0.05)	8.6-32.2
<i>Eucheilota menoni</i> Kramp	Feb.-April	1-3	—	—	1	32.00 (0.16)	29.5-34.2
<i>Eirene menoni</i> Kramp	Feb.-April, June	3-6	2-3	—	6	1.30 (0.19)	17.0-26.7
<i>E. cyclonensis</i> Browne	Jan.-April, June	2-7	1-3	—	1	61.70 (0.11)	8.6-32.2
<i>Eutima commensalis</i> Santhakumari	March-April, June	1-5	1-3	—	3	100.50 (0.09)	22.3-33.1
<i>E. neucaledonia</i> Uchida	Jan., March, April	1-4	—	—	3	12.10 (0.04)	23.8-33.1
Siphonophora							
<i>Diphyes chamissonis</i> Huxley	Aug., Dec.	—	1	1	1	14.60 (1.15)	—
<i>Lenisia</i> sp.	Dec.	—	—	1	1	0.40	—
Ctenophora							
<i>Pleurobrachia</i> sp.	Feb.- June, Nov., Dec.	1-7	1-3	3	4	218.30 (0.04)	8.6-34.2
<i>Beroe</i> sp.	June	—	1,2	—	2	0.30 (0.03)	—
Chaetognatha.							
<i>Sagitta bedoti</i> Béranec	Jan., Feb., June, Aug., Oct.-Dec.	1-3	1-3	1-4	3	740 (0.02)	8.5-34.7
<i>S. enflata</i> Grassi	Jan., Feb., Nov., Dec.	1-4	—	1-3	1	8.70 (0.01)	17.0-34.0
<i>S. Oceania</i> Gray	March-May	1-7	—	—	4	92.00 (0.09)	13.0-34.2
Copepoda							
<i>Eucalanus crassus</i> Giesbrecht	Oct., Dec.	—	1	1	1	0.30 (0.09)	—
<i>Calocalanus pavo</i> Dana	Nov.	—	—	1	1	0.05	—
<i>Paracalanus aculeatus</i> Giesbrecht j. major Sewell	Jan.-April, Dec.	1-6	—	1-3	1	84.30 (0.09)	18.7-34.2
<i>P. crassirostris</i> Dahl f. <i>cochinensis</i> Wellershaus	Jan.-April	1-5	—	—	3	1.30 (0.03)	21.4-32.5
<i>Acrocalanus similis</i> Sewell	Jan.-April, Sept.-Dec.	1-7	1,2	1-6	1	482.60 (0.03)	2.0-34.7
<i>A. monachus</i> Giesbrecht	March, April	1,2	—	—	1	3.20 (0.04)	31.2-34.2
<i>Centropages alcocki</i> Sewell	Jan.-April, June, Aug., Dec.	1-4	1,2	1-3	1	63.53 (0.02)	17.0-34.0
<i>C. furcatus</i> Dana	Jan., March, April, Nov., Dec.	1-3	—	1,2	1	0.97 (0.06)	30.5-34.7
<i>C. tenuiremis</i> Thompson & Scott	Jan., Feb., April, Aug.	1,2	1	—	1	22.90 (0.21)	26.432.5
<i>C. trispinosus</i> Sewell	Jan., Feb., Aug., Dec.	1-3	2	1-3	1	16.50 (0.10)	19.6-34.0
<i>Heliodiaptomus cinctus</i> Gurney	May, June, Sept., Oct., Dec.	—	1-7	2	2	1.00 (0.02)	0-11.5
<i>Allodiaptomus mirabilipes</i> Kiefer	May-July, Sept., Oct., Dec.	—	1-7	2	7	0.80 (0.04)	0-11.5

TABLE 3 — SPECIES OF ZOOPLANKTON, PERIOD AND STATIONS OF OCCURRENCE, MAXIMUM DENSITY OF POPULATION OBSERVED AND SALINITY RANGE (JANUARY TO DECEMBER 1972)

Species	Period		Stations		Post-monsoon	Maximum density		Calinity range ‰
	Pre-monsoon	Monsoon	Monsoon	Post-monsoon		No./m ³ *	Station	
<i>Pseudodiaptomus amandalei</i> Sewell	1-6	1-7	Year-round except March and July	1-4	7.90 (0.02)	2	Aug	0-32.5
<i>P. binghami malayalis</i> Wellershaus	—	1-7	May, June, Oct.-Dec.	5,6	0.20 (0.02)	7	June	0-1.3
<i>P. jonesi</i> Pillai	1,2	—	April	—	0.20 (0.08)	1	April	32.5-33.1
<i>P. aurivillii</i> Cleve	1,2	2-7	June, Aug., Sept.	—	12.50 (0.06)	2	June	0-19.5
<i>P. mertoni</i> Fritchtl	1,2	1,2	April, June	—	44.43 (0.44)	1	do	26.3-33.1
<i>P. serricaudatus</i> T. Scott	1-6	1,2	Jan.-June, Oct.-Dec.	1-4	10.60 (0.02)	1	Feb.	13.4-34.7
<i>P. tollingarae</i> Sewell	—	2	July	—	0.05	2	July	—
<i>Temora styhifera</i> Dana	1	—	Jan.	—	1.70	1	Jan.	—
<i>T. turbinata</i> Dana	1	—	do	—	0.80	1	do	—
<i>Candacia bradyi</i> Scott	—	—	Oct., Nov.	1,2	0.30 (0.04)	1	Nov.	—
<i>Latidocera pectinata</i> Thompson & Scott	1-6	1,2	Jan.-April, June, Aug., Sept., Nov., Dec.	1-6	48.61 (0.02)	2	April	2.0-34.2
<i>L. acuta</i> Dana	1	—	Feb.	—	0.10	1	Feb.	—
<i>Acartia centura</i> Giesbrecht	1-7	1-4	Year-round except July	1-4	103.20 (0.02)	1	Nov.	5.8-34.7
<i>A. spinicauda</i> Giesbrecht	1-7	1-4	Jan.-April, June, Aug., Oct.-Dec.	1-4	40.70 (0.04)	1	June	5.8-34.7
<i>A. erythraea</i> Giesbrecht	2,3	—	April, Nov., Dec.	1	4.22 (0.49)	1	Dec.	30.9-34.7
<i>A. plumosa</i> T. Scott	3-7	1-7	Year-round except July	1-6	403.80 (0.04)	7	April	0-26.7
<i>A. southwelli</i> Sewell	1-5	—	Feb.-April, Dec.	1	24.50 (0.58)	3	March	17.0-34.0
<i>A. pacifica</i> Steur	1-7	1-3	March, April, June, Aug., Oct.-Dec.	1,2	31.00 (0.04)	1	April	12.6-34.7
<i>A. bilobata</i> Abraham	1-7	1,2	Jan.-June, Oct.-Dec.	1-3	156.00 (0.03)	1	do	8.6-34.2
<i>Acartiella kevalensis</i> Wellershaus	1-7	1-6	Jan.-June, Sept., Nov., Dec.	2-6	439.80 (0.09)	5	March	0-29.7
<i>A. graveyly</i> Sewell	—	1-7	May-Dec.	2-7	181.80 (0.02)	5	June	0-12.0
<i>Euterpina acutifrons</i> Dana	1,2	—	March, April	—	0.05 (0.03)	1	April	—
<i>Laophonta</i> sp.	—	2-5	May, June, Sept.	—	0.20 (0.03)	4	June	0.5-5.8
<i>Oithona hebbes</i> Giesbrecht	2-4	2,3	Jan., Feb., Sept., Nov.	3	0.40 (0.09)	2	Feb.	0.4-29.5
<i>O. brevicornis</i> Giesbrecht	1-3	3	Feb.-April, Sept.	—	0.30 (0.10)	2	March	0.4-34.2
<i>O. nana</i> Giesbrecht	2-6	—	Feb., March	—	1.30 (0.04)	4	Feb.	6.6-31.2
<i>O. rigida</i> Giesbrecht	1	—	Jan.	—	0.60	1	Jan.	—
<i>Mesocyclops</i> sp.	—	3-6	July	—	2.50 (1.06)	4	July	—
<i>Cyclopina</i> sp.	—	3-6	do	—	3.60 (0.13)	4	do	—
Cladocera								
<i>Pencilia airoides</i> Dana	—	1-7	May-Sept., Nov., Dec.	1-3	178.80 (0.02)	1	Aug.	0-31.6
<i>Evaadne tergestina</i> Claus	—	1-7	June, Aug., Nov.	1,2	170.10 (0.03)	1	do	0-30.5
Lucifer								
<i>Lucifer typus</i> H. M. Edm.	1-7	1-4	Jan.-April, June, Aug., Oct.-Dec.	1-5	41.70 (0.02)	5	March	3.8-34.7
<i>L. hanseni</i> Nobili	1-7	1-4	Year-round, except July, Sept.	1-6	37.00 (0.03)	5	do	2.0-34.0

*Numbers in parentheses denote minimum density of population observed

TABLE 4 — RESULTS OF ANALYSIS OF VARIANCE

Groups	Between months	Between stations	Maximum abundance	
			Month	Station
Hydromedusae	*	NS	March, April	—
Chaetognatha	*	*	do	1, 2
Copepoda	*	*	Jan.-April	1-3
Cladocera	†	NS	June, Aug., Nov.	—
Amphipoda	NS	NS	—	—
Lucifer	*	*	Jan.-April, Dec.	1-5
Polychaeta larvae	*	NS	April	—
Invertebrate eggs	*	*	Feb., April, Nov., Dec.	1
Decapod larvae	*	*	Jan.-May	1-4
Fish eggs	*	*	Jan.-April	1-3
Fish larvae	*	†	May, June, Aug., Sept.	1-4, 6
Copelata	NS	†	—	1-3
Species				
<i>Blackfordia virginica</i>	*	N S	Jan., June	—
<i>Eirene ceylonensis</i>	*	NS	Jan.-March, June	—
<i>E. menoni</i>	†	NS	March, June	—
<i>Eucheilota menoni</i>	*	†	March, April	1-3
<i>Eutima commensalis</i>	*	†	March, April, June	2, 3
<i>E. neuceledonia</i>	*	NS	April	—
<i>Ohelia</i> sp.	†	NS	March, April	—
<i>Pleurobrachia</i> sp.	*	NS	do	—
<i>Sagitta bedoti</i>	†	*	Jan., June, Dec.	1, 2
<i>S. enflata</i>	*	*	Jan.	1-3
<i>S. oceania</i>	*	NS	April	—
<i>Paracalanus aculeatus</i>	*	*	March	1-3
<i>f. major</i>				
<i>P. crassirostris f. cochinensis</i>	*	NS	April	—
<i>Acrocalanus monachus</i>	†	NS	do	—
<i>A. similis</i>	*	*	March, April	1-3
<i>Centropages alcocki</i>	†	*	Jan., Feb.	1, 2
<i>C. furcatus</i>	†	*	April	1
<i>C. tenuiremis</i>	NS	†	—	1
<i>C. trispinosus</i>	NS	NS	—	—
<i>Heliodiaptomus cinctus</i>	*	NS	May, June	—
<i>Allodiaptomus mirabilipes</i>	*	NS	May	—
<i>Pseudodiaptomus annandalei</i>	NS	*	—	2
<i>P. binghami malayalus</i>	NS	NS	—	—
<i>P. aurivilli</i>	*	†	June	2
<i>P. mertonii</i>	†	NS	do	—
<i>P. serricaudatus</i>	*	*	Feb.-April	1, 2
<i>Labidocera pectinata</i>	*	*	March	1-3
<i>Acartia centrura</i>	*	*	March, April	1, 2
<i>A. spinicauda</i>	*	*	do	1
<i>A. erythraea</i>	NS	NS	—	—
<i>A. plumosa</i>	*	NS	March, April, June	—
<i>A. southwelli</i>	*	NS	March, April	1, 2
<i>A. pacifica</i>	*	†	do	1, 2
<i>A. bilobata</i>	*	*	do	1-4
<i>Acartiella keralensis</i>	*	†	Jan.-May	3-7
<i>A. graveleyi</i>	*	*	May, Nov.	2-6
<i>Panilia avirostris</i>	†	NS	June, Aug.	—
<i>Evadne tergestina</i>	NS	NS	—	—
<i>Lucifer typus</i>	*	*	March, April	1-4
<i>L. hanseni</i>	*	*	Jan., March, April	1-4

Significant at * 1% level; † 5% level; and NS, not significant.

and *Eutima commensalis* were the most frequent species that occurred in the estuary. Only the common species of hydromedusae occurring in backwaters could be identified. Others also were present in small numbers between January and April.

Siphonophora — Occurrence of *Diphyes chamissonis* was noticed in the estuary in August and December. *Lensia* sp. was also observed in December. Siphonophores were noticed only at station 1 and never occurred further up the estuary.

Ctenophora — Distribution of ctenophores in backwaters was similar to that of hydromedusae. They occurred throughout the estuary during the high saline months of February to April and up to station 3 in June. *Pleurobrachia* sp. was the dominant ctenophore. *Beroe* sp. occurred in small numbers at stations 1 and 2 in June.

Chaetognatha — Chaetognaths were numerically more abundant in the estuary during the premonsoon period. Different species dominated the chaetognath population in different months. *Sagitta enflata* was dominant in January whereas *S. Oceania* was abundant in March and April and accounted for the maximum density of chaetognath population (92.1/m³) observed at station 4 in April. During the other months occurrence of *S. bedoti* was comparatively more numerous.

Copepoda — Out of 18 genera and 41 species of copepods recorded from the backwaters during this study, 99.7% of the total annual count of copepods comprised calanoids represented by 13 genera and 33 species. The remaining 0.3% was constituted by 3 genera of cyclopoids representing 6 species and 2 genera of harpacticoids each represented by a species. About 50% of the species occurred sporadically or in small numbers. Copepods formed a major component of the zooplankton of the estuary constituting 30.9% of the total annual zooplankton count. Peak density (873.9/m³) of the population was observed at station 1 in April.

Copepod population of the estuary reached its maximum abundance and diversity during the high saline premonsoonal period. Many of the common species which were abundant in the estuary during this period such as *Paracalanus aculeatus*, *P. crassirostris*, *Acrocalanus similis*, species of the family Centropagidae, *Pseudodiaptomus serricaudatus*, *Labidocera pectinata*, *Acartia southwelli*, *A. pacifica* and *A. bilobata*, were absent during the low saline period except for occasional appearance at mouth of the estuary. Other species such as *Acartia centrura* and *A. spinicauda*, though tolerated a wider range of salinity fluctuations, were also restricted to the lower reaches of the estuary during the low salinity regime. *Heliodiaptomus cinctus*, *Allodiaptomus mirabilipes*, *Pseudodiaptomus binghami malayalus* and *Acartiella graveleyi* formed the common low saline copepod species in the backwater. Of these *A. graveleyi* dominated the copepod counts during this period.

Based on total number of copepods observed during the year the percentage composition of the major calanoid families was Paracalanidae 22.3%, Centropagidae 1.6%, Diaptomidae 0.8%, Pseudo-

diptomidae 1.7%, Pontellidae 2.6%, Acartiidae 70.6%. The species that were relatively numerous gave the following annual percentage values. *Acrocalanus similis* 19.6%, *Paracalanus aculeatus f. major* 2.6%, *Labidocera pectinata* 2.6%, *Acartia centrura* 6.8%, *A. spinicauda* 2.4%, *A. plumosa* 14.2%, *A. bilobata* 11.7%, *Acartiella keralensis* 28.3%, *A. gravelyi* 4.1%; these 9 species together accounting 92.3% of the total copepod population observed during the year.

Cladocera — This group was absent in the estuary from January to April and in October. Only two species, *Penilia avirostris* and *Evaadne tergestina*, occurred in the estuary. Usually they were present only in small numbers in the collections, but a sudden peak in their occurrence was observed at station 1 in August. Both the species occurred in large numbers and the population density was observed to be 348.9/m³.

Ostracoda — Ostracods were met with at stations towards the head of the estuary where the salinity was very low in May and June. Maximum density (0.2/m³) of population was observed at station 7 in June.

Cumacea — These animals also occurred at stations where the salinity was quite low in January and June. Maximum density observed was 0.3/m³ at station 7 in January.

Isopoda — *Sphaeroma* sp. was present at station 2 in May and July where low salinity condition prevailed (maximum density 0.5/m³ in May).

Amphipoda — Several species of gammarid amphipods were present at different stations in all months of the year except October. Maximum density of 1.8/m³ was observed at station 2 in January. No definite pattern in their distribution could be outlined since various species could not be identified.

Lucifer — Lucifers constituted an important group in the zooplankton of the estuary during the premonsoon and postmonsoon periods when they were distributed almost throughout the estuary.

Lucifer typus and *L. hanseni* occurred in backwaters. Their population attained a maximum density of 78.7/m³ at station 5 in March.

Invertebrate eggs — Eggs of invertebrates were present at several stations in January, February, April, August, November and December. Maximum number of eggs (307.5/m³) observed was at station 1 in February.

Invertebrate larvae — A few numbers of cyphonautes larvae of Bryozoa and actinotrocha larvae of alveolates, Phoronida were present in the collections at stations 1 and 2 in April. Cirripede nauplii were frequent in March, April and June at the lower reaches of the estuary. Larvae of polychaetes occurred sporadically in the backwater. April was the peak month and a maximum number of 2.4/m³ was noticed at station 4 during the month. The other months of their occurrence were June, August and December. Decapod larvae constituted the majority of the invertebrate larvae as well as that of the total annual zooplankton counts. They were present throughout the year but were more abundant during premonsoon period. Zoa larvae of *Brachiura* were

common and abundant in March and April. Maximum density of 3826.8/m³ was observed at station 1 in April. The other decapod larvae consisted mostly of protozoa stages, post-larvae of penaeids and caridean larvae which were abundant in January, February, and April to June.

Fish eggs — Peak abundance of fish eggs was registered during premonsoon period. A maximum density of 224.6/m³ was observed at station 1 in February.

Fish larvae — Fish larvae, observed in the estuary, mostly belonged to the groups Clupeoidei and Gobiidae. Larvae of Syngnathidae were observed at stations 1 and 2 in February. Peak abundance of fish larvae unlike fish eggs was noticed during monsoon. Maximum density of 42.3/m³ was observed at station 1 in May.

Copelata — Copelates occurred at lower reaches of the estuary in January, February, April, November and December. Stations 4 to 7 registered total absence of them. Peak density (3.6/m³) was observed at station 2 in February.

Apart from these arachnids and gastropods, bivalve shells were collected at several stations. Mysids were present in the night collections taken in March. They were present at all stations except 7. Their maximum density (76.9/m³) was at station 3. Total numbers of animals in almost all groups were higher in the night collections than that of the day collections taken during the month. The average increase observed was about 13 times for copepods, 7.2 times for hydromedusae, 6 times for fish larvae, 5 times for chaetognaths and 3.3 times for lucifers. Again, many groups such as isopods, amphipods, Cumacea, polychaete larvae, invertebrate eggs and copelates which were not represented in the day collections during the month were present in the night collections.

Discussion

The organisms inhabiting the estuary can be expected to react and adapt to the changes, physical, chemical or biological, in the environment. Studies on the hydrography of the estuary¹³ reveal that the temperature fluctuations are not very significant to influence the survival of zooplankton organisms. The range of thermal stratification varied in general over seasons between 1°C and 2.3°C. But drastic changes in the salinity conditions occurred in the estuary with seasons. During the premonsoon from January to April the salinity at station 1 was always higher than 30.9‰ and comparatively high saline conditions prevailed throughout the estuary. But during the monsoon from May to October, the salinity fell to near zero throughout the estuary except in the bottom layers at the mouth. In November-December the incursion of high salinity water began at the lower reaches of the estuary.

Fluctuations in the primary production does not appear to be a major factor controlling zooplankton abundance. Qasim¹⁴ has observed that the zooplankton grazing in this estuary is not sufficient enough when compared to the amount of primary production, thus leaving a larvae surplus of basic food unutilized. This view is further supported

by the observations of Pillai et al.⁸. Primary production in backwaters has been estimated to be relatively stable throughout the year, the changes in the production rates not exceeding 3-4 times with seasons¹⁵.

From the pattern of distribution of various groups and species of zooplankton it seems that salinity is the limiting factor controlling the abundance of most of them. A seasonal pattern in distribution reflecting the seasonal changes in salinity was exhibited by all groups of zooplankton.

Occurrence of hydromedusae at the lower reaches of the estuary in June after a total absence in May may be because they were present outside the mouth of the estuary during the period. But the absence of such an influx of hydromedusae during postmonsoon suggests that they might be absent even in this area due to the high quantum of fresh water efflux from the estuary during July to October. Monsoonal efflux from the outlet of Cochin backwaters reduces the surface salinity of coastal waters considerably and the effect could be traced, up to November¹⁶. The density of population of hydromedusae was observed to be very low by Santhakumari and Vannucci³ at the barmouth, Cochin, during postmonsoon when compared with that of the premonsoon. Even their occurrence in low densities might be due to the variations in the hydrology during the year.

Distribution pattern of chaetognaths in the estuary in essence is similar to the observations of Vijayalakshmi Nair¹⁷ except that during the peak salinity months of March and April *Sagitta oceanica* dominated throughout the estuary to the exclusion of other species of chaetognaths. General distribution pattern seems to confirm her view that the chaetognath fauna of the estuary is dependent on the faunal composition of the incoming waters.

Although carnivores such as hydromedusae, ctenophores and chaetognaths thrived in the estuary only during the high saline period when a higher standing stock of zooplankton was present, salinity rather than food seems to limit their presence during the monsoonal period.

Most of the copepods flourished in the backwaters during the high salinity regime. The presence of species of copepods which were abundant during the high saline period only at stations near the mouth during the monsoon strongly suggest that they might be present in the bottom layers only where the salinity was higher. In July, at the peak of the monsoon when the salinity incursion was very much limited, these species were absent at these stations also. Although more abundant during the high saline period, species such as *Acartia centrura*, *A. spinicauda* and *Labidocera pectinata* exhibited a wider range of salinity tolerance. *Acartia plumosa* and *Acartiella keralensis* were absent at stations 1 and 2 up to April and their populations showed peaks at the middle and upper reaches of the estuary where the salinity was between 27.0 and 11.0‰ during this period. Pillai et al.⁸ classify *Acartia southwelli* and *A. spinicauda* as species which occur in the backwaters during low saline conditions. Tranter and Abraham⁶ have observed *Acartia*

southwelli as high saline species which died out during the low salinity regime. The present study also registers *A. southwelli* as predominantly high saline. *A. spinicauda* also showed a primary preference to high saline conditions. Species belonging to the family Acartiidae dominated the copepod component of the estuary in numerical abundance in all seasons. Nine species belonging to this family were recorded from this estuary in this study.

Some of the organisms such as siphonophores, *Beroe* sp., *Eucalanus crassus*, *Calocalanus pavo*, *Acrocalanus monachus*, *Pseudodiaptomus mertonii*, *Temora stylifera*, *T. turbinata*, *Candacia bradyi*, *Labidocera acuta*, *Acartia erythraea* and *Euterpina acutifrons* appear to be stragglers into the estuary. They never penetrated deep or established in the estuary.

Abundance of decapod larvae and the occurrence of fish eggs and larvae almost throughout the year accentuates the importance of the estuary as the breeding and nursery ground for these groups.

Repopulation of backwaters after the monsoonal washout seems to be effected in 2 ways. The reappearance of most of these species occurring during the high saline premonsoon period such as *Sagitta bedoti*, *S. enflata*, *Acrocalanus similis*, *Centropages furcatus*, *Pseudodiaptomus serricaudatus*, *Labidocera pectinata*, *Acartia centrura*, *A. spinicauda*, *A. erythrasa*, *A. pacifica*, *A. bilobata*, *Lucifer typus* and *L. hansenii* by October-November at station 1 near the mouth of the estuary after being absent up to September during the low salinity regime, their occurrence further up the estuary by December, and the presence of similar species as *Centropages alcocki*, *C. trispinosus* and *Acartia southwelli* at station 1 in December suggest that these species after being flushed out of the estuary during the monsoonal peak penetrate into it from the coastal waters and establish themselves with the incursion of the salinity to breed and repopulate backwaters. Frequent occurrences of copepodites of *Acartia* and *Labidocera* and juveniles of *Lucifer* in the collections during November-December and the premonsoonal period support this view. Pillai⁷ also suggests that the breeding of the dominant calanoid copepod species of this backwater appears to be from November to March.

Species of hydromedusae such as *Eirene menoni*, *E. ceylonensis*, *Eutima commensalis* and *Blackfordia virginica* were present only towards the middle and upper reaches of the estuary in January and February. Hydromedusae were absent during the monsoonal period and in December, the reappearance of *Eutima commensalis* and *Blackfordia virginica* was noticed at station 2 while they were absent at the mouth of the estuary. This seems to confirm the view of Vannucci et al.² and Santhakumari and Vannucci³, that the hydroids develop some form of resting stage during the low saline period and become active again when the salinity condition reaches the appropriate level to bud off new medusae. It is highly possible that a similar resting stage or a diapause occur in the life cycle of species like *Heliodiaptomus cinctus*, *Allodiaptomus mirabilipes*, *Pseudodiaptomus binghami malayalus*, *Acartia*

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plumosa, *Acartiella keralensis* and *A. gravelyi* to tide over adverse environmental conditions.

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