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STUDIES ON THE ECOLOGY OF ZOOPLANKTON OF COCHIN BACKWATERS

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ABSTRACT

Zooplankton abundance and its variation based on year round collections from the lower reaches of Cochin backwaters is reported. Homogeneous conditions in vertical distribution of salinity, temperature and oxygen occurred during the premonsoon period and changes from tidal influence were minimal during this season. But sharp vertical gradients developed during monsoons at the mouth when the upper strata of water column was occupied by freshwater. Higher numerical counts and biomass of zooplankton occurred during high saline premonsoon period. They fell sharply with the onset of monsoons. Tidal variations were not apparent in the distribution. Diel variations were also not significant except at Narakkal, a shallow station, where higher abundance was observed during night. Principal component analysis indicated salinity to be the key factor associated with the changes in zooplankton abundance. General composition of zooplankton, their seasonal variations and ecological implications are discussed and compared with estuaries elsewhere.

INTRODUCTION

Varying physical and chemical forces have caused estuaries to become specialised environments. Its inhabitants have to be tremendously accommodative to put up with the stress imposed upon by the fluctuations. Thus estuarine organisms form a class by themselves and the zooplankton occurring in the estuaries consist largely of true estuarine forms apart from the more common euryhaline marine forms and to a lesser extent stenohaline forms and freshwater organisms which frequent these waters.

Several studies have been conducted on the zooplankton of Cochin backwaters and have been listed in an earlier communication (Madhupratap and Haridas, 1975). The general aspects of zooplankton ecology in the Cochin backwaters, based on year round collections made at its lower reaches, are presented in this paper. The ecological aspects of various groups and species in detail will be treated separately.

MATERIAL AND METHODS

Zooplankton samplings were made once in a month from November, 1971 to October, 1972 covering four tides (two high and two low) of a day at barmouth, Cochin (depth about 12 m). Samplings were done at Aroor, about 14 km south (depth of water column about 7 m) and at Narakkal (depth–3 m) 10 km north of barmouth (Fig. 1). These two stations represent relatively more stable areas subject to lesser amount of turbulence than barmouth. At these two stations one day and one night collections were made each month on days subsequent to the collection at the barmouth. The zooplankton were collected using a HT net (mouth area 0·25 m², mesh size–300 μ) in oblique hauls from bottom to surface lasting 5 min with a flow meter attached. Salinity and temperature for each metre depth, and surface and bottom oxygen were also recorded.

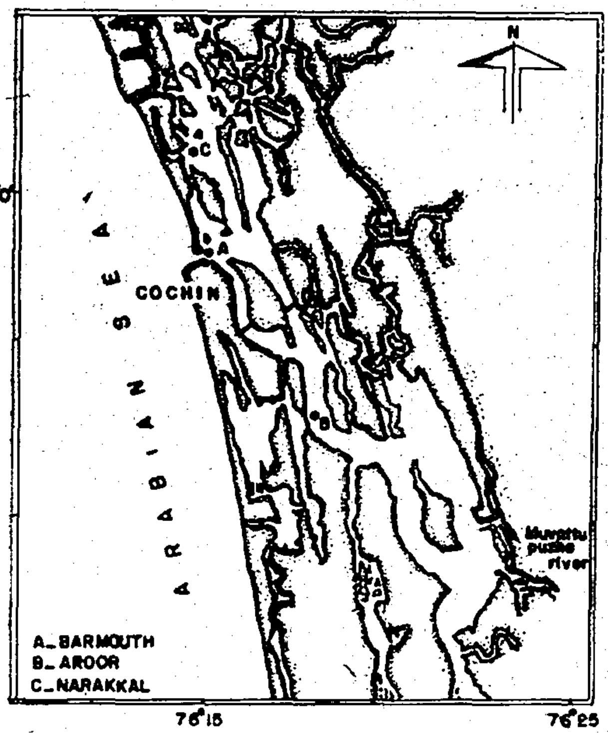

Fig. 1. Location map showing stations of observations.

Biomass of the zooplankton samples was estimated as displacement volume and the total counts of zooplankton and counts for groups and species in each sample were made. Data for zooplankton were subjected to analysis of variance (Federer, 1967) to study significance in variations between months (seasons), tides and diel aspects. Numbers were converted to their log values for the analysis. Critical difference was used for separating significant effects. [To study the pattern of distribution of different groups and species in the selected regions, the mean and variance for each of them were calculated and the ratio of variance to mean was taken. All values were found to be significantly higher than 1 showing that the distribution was 'contageous' or 'negative binominal' Under log transformation a negative binominal is transferred to normal distribution (Cassie, 1962). This justified log transformation of figures for forming ANOVA]. Principal components analysis (Harman, 1960) was employed for separating first and second factor coefficients from the environment. Communalities were calculated using multiple regression analysis taking zooplankton abundance, salinity, temperature and oxygen as variables. The matrix of correlation was formed after converting the abundance figures to their logarithmic values.

RESULTS AND DISCUSSION

Physical characteristics

Based on the changes in the environment, the year coula be divided into premonsoon (January–April), monsoon (May–October) and post–monsoon (November–December) periods. The precise division into the month in which a season begins or ends in each year is arbitrary and depends largely on the time of the onset, intensity and duration of the monsoons.

Table I. Salinity, temperature and oxygen distribution at barmouth, Cochin at surface and bottom (in parenthesis) at high tide and low tide (averages of two high and two low tides) in 1971-72.

Months	Salinity ‰ HT	Salinity ‰ LT	Temperature (°C) HT	Temperature (°C) LT	Oxygen (ml/l) HT	Oxygen (ml/l) LT
Nov.	10·1 (32·1)	10·1 (13·5)	30·0 (27·4)	30·0 (27·9)	2·9 (2·4)	3·0 (2·8)
Dec.	29·8 (30·1)	25·2 (27·2)	28·4 (27·9)	28·1 (28·0)	2·0 (2·1)	2·2 (2·0)
Jan.	32·1 (32·2)	30·1 (30·2)	27·5 (27·9)	28·0 (27·9)	2·0 (2·0)	1·9 (1·7)
Feb.	32·2 (32·2)	31·0 (31·0)	30·0 (29·1)	29·7 (29·5)	3·0 (2·8)	2·6 (2·4)
March	33·3 (33·4)	32·0 (32·3)	30·0 (30·0)	30·1 (30·0)	3·0 (2·9)	3·5 (3·2)
April	34·8 (34·8)	33·0 (34·0)	31·6 (31·6)	30·3 (30·3)	2·1 (2·0)	1·8 (1·5)
May	9·9 (33·1)	3·5 (22·2)	26·0 (26·2)	25·0 (26·4)	3·9 (2·1)	2·5 (1·9)
June	23·5 (35·5)	19·2 (29·0)	29·8 (25·8)	30·0 (25·8)	2·9 (1·0)	4·0 (1·5)
July	0·5 (34·9)	0 (3·3)	27·9 (24·4)	27·2 (27·4)	4·0 (0·5)	4·0 (1·8)
Aug.	10·8 (34·5)	2·1 (20·0)	30·1 (25·0)	29·8 (29·7)	5·0 (0·4)	5·0 (0·5)
Sept.	20·8 (33·1)	14·0 (25·1)	28·0 (26·4)	30·0 (29·5)	3·9 (1·9)	4·2 (2·0)
Oct.	5·2 (30·0)	1·2 (24·0)	30·0 (27·6)	30·0 (29·1)	3·0 (2·8)	4·0 (2·2)

Table II. Salinity, temperature and oxygen distribution at Aroor and Narakkal in surface and bottom (in parenthesis) layers in 1971-72.

Months	Aroor Salinity (‰)	Aroor Temperature (°C)	Aroor Oxygen (ml/l)	Narakkal Salinity (‰)	Narakkal Temperature (°C)	Narakkal Oxygen (ml/l)
Nov.	6·0 (28·2)	30.6 (30·0)	2·0 (2·0)	3·2 (5.1)	30.5 (30·4)	1·3
Dec.	11·1 (27·1)	28·7 (28·0)	1·9 (1·7)	7·2 (15·1)	28·0 (27·9)	0.8
Jan.	26·3 (26·8)	28·0 (27.5)	2.6 (2·1)	24·2 (24.3)	27.5 (27·5)	3·0
Feb.	26·0 (27·0)	29·5 (29·3)	2.8 (2·5)	28·1 (28·2)	29·5 (29·4)	2·7
March	29·4 (30·1)	29·3 (29·3)	2.7 (2·5)	28·8 (30·1)	30·0 (30·0)	3.1
April	32·0 (33·1)	30·9 (30·3)	3·5 (3·0)	30·5 (30·6)	31·0 (31·0)	2·3
May	3·3 (5·1)	26.8 (26·7)	3·6 (1·9)	2·4 (2·5)	27·0 (26·5)	2.9
June	11·1 (26·8)	31.2 (29.5)	4.5 (1·6)	15·0 (25.3)	31·0 (29·8)	3·6
July	0 (0·3)	29.0 (28.8)	4·6 (1.0)	0·8 (1·0)	27·5 (27·5)	4·5
Aug.	0 (0·5)	30·1 (29·2)	4·8 (2·6)	0·2 (1·0)	30.5 (30.0)	5·0
Sept.	0 (8·5)	30·0 (28.7)	4·0 (3·1)	14.9 (15·0)	30·5 (30·0)	4·2
Oct.	2·1 (15·2)	29.9 (28·9)	4.1 (2·0)	1·4 (15·0)	30.0 (30·0)	3·7

Even by the beginning of premonsoon period (January), a vertically homogeneous pattern in salinity distribution was observed at the mouth. Salinity values were high (>30‰) and no appreciable differences occurred between high tides and low tides during the premonsoon period (Table I). Salinity steadily advanced and registered the maximum value for the season (34.8‰) in April. Distribution of salinity was more or less of a similar pattern at Aroor and Narakkal (Table II). The major difference was only spatial by having a horizontal gradient in values.

Abrupt changes were brought in the environment with the onset of the monsoons. In 1972, the monsoons started in May and rains lasted upto October with intermittent breaks. At the mouth the surface salinity fell to 3.4°/₀₀ during low tide in May. The water column became stratified showing a two layered flow. Bottom salinity varied from 21.0°/₀₀ in low tide to 33.8°/₀₀ during high tide. In June a break in the monsoon resulted in a temporary recovery of the salinty. Bottom salinity reached 35.5°/₀₀, the highest encountered in the estuary. The presence of this high saline water in the bottom layers was probably due to the intrusion of upwelled Arabian Sea water into the channel during this period. Salinity showed an increasing trend in August and September after being lowest in July due to a reduction in the force of the monsoon. It went down again in October, especially in the surface layers, when the rainfall increased. The fluctuations in salinity intrusion at the mouth were reflected at Aroor and Narakkal also.

By November surface salinity started to show an increase. But the water column was stratified during high tide as the fresh water efflux had not ceased completely. Sea water started to dominate by December, stratification being less apparent at the mouth, the season merging into the homogeneous conditions of the premonsoon. But stratification occurred in December in the stations away from the mouth since salinity incursion was not strong enough to completely mask the effect of freshwater flow.

Temperature was higher during the 'dry' premonsoon period. In January, the surface temperature was around 27.5 to 28.0°C. There was a gradual increase as the season progressed and by April the surface temperature reached 31.6°C. No appreciable diel or tidal variations were observed during this season. Vertical thermal gradient was also weak, the difference between surface and bottom layers usually did not exceed 0.5°C or was even less. This is further evidence to the well mixed homogeneous conditions prevailing in the water column during this period.

A sudden fall in temperature was observed with the onset of monsoons. In May, surface temperature at the mouth came down to around 26.0°C, a difference of about 5.0°C from that in April. Surface temperature generally varied between this to 30.0°C during the monsoon season. Vertical thermal gradient associated with stratification was steep during monsoons. The difference between surface and bottom temperature fell within the range or 3.5°C to 6.7°C from June onwards.

During monsoon the continental shelf is pervaded by cold, dense waters upwelled from the subsurface levels of Arabian Sea (Banse, 1959; Ramamirtham and Jayaraman, 1963). In May, the bottom layer showed higher temperature than that at the surface showing that the freshwater at the top was colder than intruding sea water. But in later months, particularly in July and August, the thermal gradient was quite sharp, water at the bottom being colder (Table I) and more saline. The origin of this water could be ascribed to be the upwelled Arabian Sea water. Also, during June–October, temperature was generally lower during high tide than at low tide showing the characteristics of the sea water entering the channel. Similar changes in stratification and influence of upwelled waters in Cochin backwaters during monsoon have been observed by Sankaranarayanan and Qasim (1969). At Aroor and Narakkal where freshwater dominated, the thermal gradient was not as steep as at the mouth.

In November, the vertical thermal stratification became less sharp and the absence of upwelled sea water was conspicuous at the bottom layer. By December homogenity in temperature distribution was more or less reestablished.

Diurnal and tidal differences in oxygen content were not appreciably significant or uniform. During premonsoon, pattern of oxygen distribution also fell in tune with that of salinity or temperature. There was little difference between surface and bottom oxygen values, the water column being well mixed. In general the range in oxygen values was between 1·5 to 3·5 ml/l.

During the monsoonal period a general increase in oxygen content of surface waters was observed. It increased to about 4·0 to 5·0 ml/l in July and August at the mouth. But the bottom values fell during this season (Table I). This must be because of the high turbidity during this period (Qasim, Bhattathiri and Abidi, 1968) limiting primary production to the surface layer. The very low oxygen content at the bottom layers at the mouth during July–August was further evidence to the presence of upwelled water of Arabian Sea in the channel. In the postmonsoon months, oxygen content at the bottom became more or less same as that of surface values.

Zooplankton

Spatial and temporal distribution of zooplankton showed definite seasonal trends associated with environmental fluctuations. The most striking feature in the zooplankton abundance in the Cochin backwater system was the contrast between premonsoon (January–April) and monsoon (May–October) periods. Averages of displacement volumes and total number of zooplankton at each station are listed in Table III. Seasonal differences were significant for both, biomass and total numbers at barmouth and Aroor. Maximum abundance was noticed in April at the mouth (1·2 ml/m^3 and 13464 Nos./m^3) and January to April at Aroor (maximum biomass 1·8 ml/m^3 and numbers 17842/m^3 in January). At Narakkal seasonal variations were not statistically significant. However higher abundance was observed during premonsoon and maximum density (7281/m^3) and biomass (1·6 ml /m^3) were observed in March.

Zooplankton abundance fell sharply during monsoons especially at Aroor and Narakkal. Seasonal averages showed that biomass fell to about 36·0% at barmouth, 4·3% at Aroor and 3·8% at Narakkal when compared to premonsoon values. Total numbers of zooplankton fell to 29%, 3·0% and 3·5% at the respective stations. During post-monsoon months (November–December), biomass and total counts

Table III. Displacement volume (ml/m^3) and total numbers/m^3 (in parenthesis) of zooplankton (day and night) at barmouth, Aroor and Narakkal.

Months	Barmouth		Aroor		Narakkal	
	Day	Night	Day	Night	Day	Night
Premonsoon[a]						
January	0·16 (965)	0·20 (1106)	1.87 (17842)	0·50 (4210)	0·41 (156)	0·70 (3529)
February	0·58 (3257)	0·75 (4891)	1·18 (16009)	0·87 (6775)	0·01 (3)	0·38 (3739)
March	0·41 (2892)	0·63 (4302)	0·36 (3861)	0·80 (4014)	0·01 (21)	1·60 (7281)
April	0·82 (7229)	1·22 (13464)	0·24 (1462)	1·03 (5435)	0·14 (76)	0·28 (2954)
Monsoon[b]						
May	0·70 (6123)	0·36 (1902)	0·01 (4)	0·12 (508)	0·01 (2)	— —
June	0·09 (405)	0·18 (682)	0·10 (16)	0·15 (451)	0·02 (79)	0·02 (79)
July	0·51 (3051)	0·30 (2436)	0·02 (81)	0·02 (73)	0·01 (12)	0·02 (207)
August	0·08 (9)	0·10 (815)	0·04 (163)	0·05 (100)	0·01 (2)	0·01 (3)
September	0·02 (24)	0·03 (61)	0·01 (37)	0·01 (1285)	0·01 (9)	— —
October	0·14 (548)	0·06 (589)	0·01 (21)	0·01 (12)	0·01 (7)	0·01 (348)
Postmonsoon[c]						
November	0·17 (755)	0·20 (845)	0·63 (638)	0·48 (1571)	0·01 (2)	— —
December	0·22 (1843)	0·30 (1435)	0·21 (910)	—	0·03 (30)	— —
Seasonal averages						
a —	0·59 (4763)		0·87 (7451)		0·44 (2219)	
b —	0·21 (1387)		0·05 (230)		0·01 (78)	
c —	0·22 (1219)		0·44 (1039)		0·02 (16)	
– no data						

Table IV. Numbers/m^3 of major groups of zooplankton (average of day and night collections at the 3 stations combined.

Months	Hydro-medusae	Ctenophora	Chaeto-gnatha	Copepoda	Cladocera	Decapod larvae	Amphi-poda	Serges-tidae	Copelata	Fish eggs	Fish larvae
Jan.	2·0	0·3	5·3	3590·4	—	1001·0	69·0	14·1	15·8	5·1	13·0
Feb	1·3	3·3	5·6	5074·0	—	529·3	16·0	14·1	86·1	38·1	15·3
Mar.	22·3	14·0	5·6	3046·0	—	599·0	5·0	12·2	13·2	33·9	9·1
Apr.	26·6	12·6	21·3	4472·0	—	450·0	7·2	12·7	11·2	8·2	4·1
May	16·3	0·7	7·0	1258·3	0·3	126·2	3·2	9·0	—	2·2	3·0
June	28·3	2·0	17·0	278·7	19·0	14·1	2·1	1·0	1·0	7·1	3·1
July	—	—	—	950·0	2·0	16·1	49·7	61·3	—	—	29·8
Aug.	—	—	—	26·3	—	5·0	10·8	—	—	—	11·7
Sept.	—	—	1·6	92·5	59·6	16·2	2·0	6·3	2·1	18·7	2·3
Oct.	—	—	1·0	127·4	2·0	69·7	31·0	1·9	—	8·8	6·1
Nov.	—	—	0·7	245·2	118·0	140·0	4·3	—	10·2	14·3	2·0
Dec.	1·0	—	4·0	533·2	1·0	253·1	1·1	1·0	29·3	8·2	4·0

Table V. Principal factor pattern.

Variable	Common Factor		Communality
	I Factor	II Factor	
Barmouth			
Abundance	0·75	−0·13	0·65
Salinity	0·88	0·15	0·76
Temperature	0·07	0·86	0·71
Oxygen	−0.37	0·25	0·02
Aroor			
Abundance	0·96	−0·07	0.92
Salinity	0·78	0·48	0.81
Temperature	0.04	0.51	0·25
Oxygen	−0·84	0.39	0·86
Narakkal			
Abundance	0·76	−0·24	0·59
Salinity	0·86	−0·02	0·73
Temperature	0·39	0·45	0·36
Oxygen	−0.06	0·62	0·38

remained more or less same at the mouth whereas they registered an increase by almost 780% and 350% respectively at Aroor. Tidal or diurnal variations for biomass and total numbers were not significant except at Narakkal where higher abundance of zooplankton was observed during night.

Various groups of organisms collectively contributed to the composition of zooplankton in the estuary. The relative abundance of various groups fluctuated with physical parameters in different seasons. The groups of zooplankton that occurred in the estuary were Hydromedusae, Siphonophora, Ctenopora, Chaetognatha, Copepoda, Ostracoda, Cladocera, Cumacea, Isopoda, Amphipoda, Mysidacea, Sergestidae, invertebrate eggs and larvae, fish eggs and larvae, Copclata and Thaliacea. The averages of abundance of various major groups at the three stations are given in table IV. Very few species flourished in the estuary during low saline period. Crustacea and among them Copepoda dominated the composition (Fig. 2) Average percentages of numerical counts at the three stations showed that Copepoda constituted about 79·3% of total annual counts. 49 of the 76 species identified in the present study belonged to Copepoda. Decapod larvae were next in the order (12·9%) followed by Cladocera (0·81%), Amphipoda (0·80%), Copelata (0·67%), fish eggs (0·57%), Sergestidae (0·53%), fish larvae (0·41%), Hydromedusae (0·39%), Ctenophora (0·15%) and Chaetognatha (0·14%). Other groups mentioned earlier are of relatively lesser importance in the ecology of the estuary at secondary level.

Factor analysis (Table V) showed that the coefficients of the first factor were large and positive for salinity and abundance and small for temperature and oxygen at all the three stations. Among the second factors, temperature was found to be highest at barmouth and Aroor and oxygen at Narakkal. Thus changes in the zooplankton abundance were indicated to be more associated with salinity.

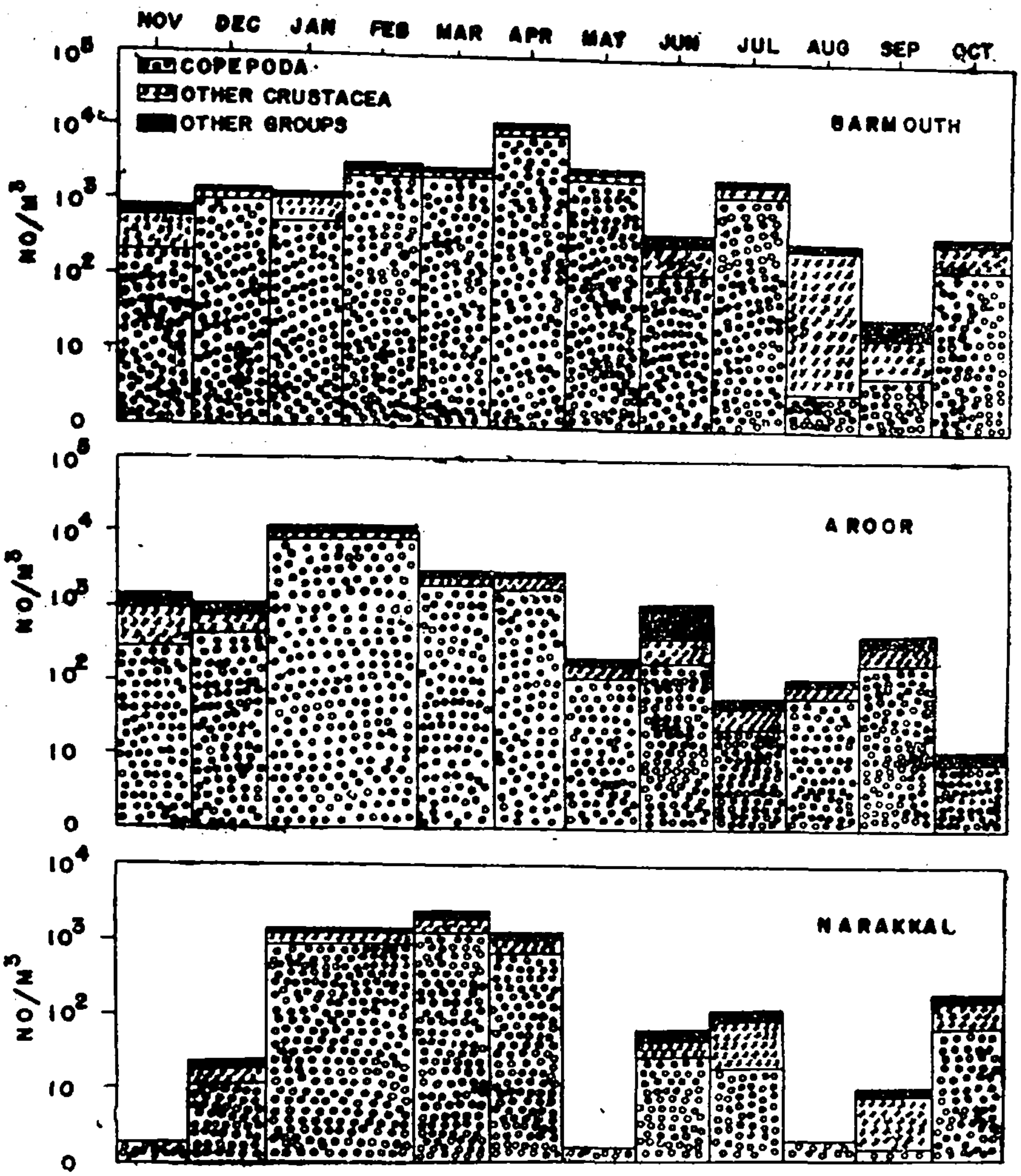

Fig. 2. Distribution of zooplankton at barmouth-Cochin, Aroor and Narakkal from November 1971 to October 1972.

Observations (Madhupratap, Rao and Haridas, 1976) have shown that the estuarine belt to the northern side of barmouth upto Azhikode is less productive at secondary level when compared to its southern counterpart. The shallowness of this area, the associated turbidity and possible differences in flow patterns perhaps render it so. Lower values encountered at Narakkal (a station situated in this segment), a lack of recoupment during the initial stages of succession (post-monsoon) and a more marked diel variation at this station could be possibly attributed to these factors.

Thus sharp contrast in abundance of zooplankton existed between high saline and low saline periods in the backwaters. Population was diverse and abundant while the salinity regime lasted ano consisted of estuarine, estuarine and marine and euryhaline marine forms in addition to adventitious immigrants. The various groups included species which were more or less uniformly abundant throughout this period and invaded the whole estuary with salinity incursion, species with more restricted distribution limited to the lower reaches, opportunist species which became abundant intermittantly when conditions became optimal and species which banked on their wide range of salinity tolerance to overcome the fluctuations in the estuary. The differences in their distribution were often subtle, but these subtle variations helped them in their niche selection and propagation.

Monsoon reversed the picture of abundance totally. Although most of the 'successful species' of the high saline period exhibited a wide range of salinity tolerance (Madhupratap and Haridas, 1975) they could not comply with the extreme nature of the environment during monsoon period when the salinity came down to near zero values. Surprisingly, the estuary does not possess an abundant low saline species as could naturally be expected to happen in the evolutionary sequence since the change from high saline period to low salinity and vice versa is recurring and hence rather 'predictable'. Slobodkin and Sanders (1969) contemplate that species poor environments fall under three categories, *viz*., new, unpredictable and severe. Perhaps, apart from salinity, strong currents downstream, turbidity or the nonavailability of 'right' food may be rendering the environment 'severe'.

Monsoonal flows exert profound influence on every aspect of estuarine hydrography and its ecology such as nutrients, salinity, temperature, oxygen (Sankaranarayanan and Qasim, 1969) and zooplankton. Although primary production in the estuary does not show marked variations with seasons (Qasim, Wellershaus, Bhattathiri and Abidi, 1969), the compositions of phytoplankton is different during the monsoon season (Devassy and Bhattathiri, 1971). Caspers (1967) analysing the classifications and definitions of estuaries considers that biological aspects also should be taken into account to define an estuary. Considering the importance of the effects of the monsoons in the system Cochin backwaters may rightly be called as a 'tropical monsoonal estuary'.

Wide variations, both spatial and temporal, in total zooplankton counts have been reported from estuaries elsewhere also. Zooplankton standing crop ranging from 180/m^3 to 3,00,000/m^3 have been observed in Victoria, Australia (Neale and Bayly, 1974). High abundance of fresh water zooplankton in the upper part of St. Lawrence estuary in low salinity ranges (1–10‰) have been reported by Bousfield, Filteau, O'Neill and Gentes (1975). In South Africa, Knysna estuary, where rainfall is more or less evenly distributed throughout the year has an abundant fauna compared to St. Lucia estuary where rains flood the system during part of the year (summer) and have little flow in winter (Day, 1967). Occurrence of only low numbers of zooplankton when there is a seasonal high flow of freshwater similar to Cochin backwater system have been observed in Werribee river, Victoria (Arnott and Hussainy, 1972).

Dominant component of zooplankton has also been reported to vary in different waters. Copepods predominate the zooplankton in Vellar estuary, Porto Novo (91%, Subbaraju and Krishnamurthy, 1972) and Australian estuaries (81%, Neale and Bayly, 1974). Cirripede naupliui dominate in Southampton waters (Raymont and Carrie, 1958) and York river, U. S. A. (Jeffries, 1964). Polychaete larvae are the major component in Raritan Bay and both polychaete and lamellibranch larvae dominate in Narrangansett Bay (Jeffries, 1964). In Cochin backwaters copepods dominated the total counts in the present study whereas decapod larvae, chiefly consisting of zoea larvae of Brachyura, showed higher abundance (58%) in an earlier survey (Madhupratap and Haridas, 1975).

Dominance expresses the magnitude of influence exerted by a species on its habitat and thus is not only dependent on the number of individuals but also their biomass (Debauche, 1962). Copepods, no doubt, showed highest numerical dominance and contributed to the bulk of the standing crop. But apart from the numerical dominance, the ecological dominance exerted by other groups, especially carnivores such as Hydromedusae, Ctenophora and Chaetognatha can not be overlooked. These being larger organisms formed a significant portion of the biomass even though occurring in smaller numbers. Their utility, whether positive or negative since they are carnivorous, in the energy transfer in the trophic system is also of considerable importance.

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