STUDIES ON THE ECOLOGY OF ZOOPLANKTON OF COCHIN BACKWATERS
(A TROPICAL ESTUARY)

THESIS SUBMITTED AT THE COCHIN UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

BY

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This is to certify that this thesis is an authentic record of the work carried out by Mr. M. Madhupratap, M.Sc., under my supervision at the Indian Ocean Biological Centre, Regional Centre of National Institute of Oceanography (C.S.I.R.), Cochin and that no part thereof has been presented before for any other degree in any University.

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A C K N O W L E D G E M E N T S

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P R E F A C E

"Ecology is the study of systems at a level in which individuals or whole organisms may be considered elements of interaction, either among themselves, or with a loosely organised environmental matrix. Systems at this level are named ecosystems, and ecology, of course, is the biology of ecosystems" (Margalef, 1968).

This thesis includes principally, a study on the ecology of zooplankton of the Cochin backwaters conducted during the years 1971-72. This monsoonal estuarine system is particularly interesting, since it exhibits a wide range of variations in its environmental conditions which is naturally reflected in the fauna also. Several publications on various aspects of its hydrobiology have come out in the recent past. But studies on the zooplankton of the estuary have mostly been discontinuous either in space or time or restricted to its groups. Also, apart from general distribution and taxonomy, studies on

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C H A P T E R 1

INTRODUCTION

1. INTRODUCTION

Estuaries form a unique and fascinating environment, being dynamic and constantly changing through the interaction of fresh water with seawater. They are important areas of human use in fisheries, transport, food production and recreational pursuits. Besides, they form the receptacle for industrial effluents and other human wastes. Studying their physico-chemical aspects and the ecology of organisms inhabiting them are necessary for realistic and essential management of them (Lauff, 1967).

1.1. Definitions and Classification of Estuaries.

Historically, the term estuary has been applied primarily to the lower tidal reaches of a river (Pritchard, 1967). They have been defined variously over the years. Ketchum (1951) defined an estuary "as a body of water in which the river water mixes with and measurably dilutes sea water". Emery and Stevenson (1957) described it as the mouth of a river or an arm of the sea where the tides meet the river currents. They differentiated two types based on salinity and tidal characteristics. 1. 'Normal' type where due to river discharge salinities are reduced as one goes upstream. 2. 'Hypersaline' or 'negative' estuary where exchange is poor and salinities are much higher than neighbouring sea. Various classifications also have been put forward by Day (1951) and Rochford (1951).

Pritchard (1952) defined estuaries as a semienclosed coastal body of water having a free connection with the open sea and containing a measurable quantity of sea salt. He classified the estuaries in terms of freshwater inflow and evaporation into 1. 'Positive' estuaries, where there is a measurable dilution of sea water by land drainage, 2. 'Inverse' estuaries where evaporation exceeds precipitation and 3. 'Neutral' estuaries where neither freshwater inflow nor the evaporation dominates. But Pritchard (1967) modified his original definition as "an estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and with in which sea water is measurably diluted with freshwater derived from land drainage". He prefers to reserve the term 'estuary' without any qualifying adjective to those bodies which he previously called 'positive estuaries'. This is probably the most recent and commonly recognised definition for estuaries.

From a geomorphological stand point Pritchard recognises four sub-divisions. 1. Drowned river valleys or coastal plain estuaries which have been formed by drowning of former river valleys either from a subsidence of land or

from a rise in sea level. They are usually an elongated indenture of the coastline with the river flowing into the upper end. 2. Fjords: They are generally 'U' shaped in cross section, most of them having a river entering at the head and exhibiting estuarine features in the upper layers. 3. Bar built estuaries: They result from the development of an offshore bar on the shoreline and have a relatively small channel connecting the estuary with the ocean. They are shallow within, and run parallel to the coastline with frequently more than one river entering the estuary.
4. Estuaries produced by tectonic processes: They are coastal indentures formed by faulting or by local subsidence having an excess supply of fresh water.

The original definition of Pritchard is further refined by Caspers (1967) who feels that it would include both estuaries and lagoons. He differentiates them by considering the ~~former~~ latter having a stable body of brackish water whereas in estuaries the mixing of fresh and marine waters is not stable but shows periodic changes.

1.2. <u>Review of earlier work</u>.

The importance of having detailed understanding of the intricate processes happening in an estuary such as its dynamics and ecology has been recognised over recent years.

Considerable amount of work on them have come out especially in the latter half of this century. The following account is being limited to include only the more important contributions pertinent to this study.

The South African estuaries has been studied by Day (1951, 1967), Day et al. (1952, 1954, 1956), Australian estuaries by Rochford (1951) and Chepsapeake Bay by Pritchard (1952 a,b, 1954, 1956). Contributions on the studies on estuarine hydrography, circulation, fauna and their ecology have come from Bowden (1960, 1963), Emery and Stevenson (1957), Hedgepeth (1957), Jeffries (1962, a,b,c,d) Ketchum (1951, 1954) and Odum (1971). A treatise on various aspects of estuarine research and management by most of these and other outstanding authors is available in 'Estuaries' (Ed. by Lauff, 1967).

Pioneering studies on the estuaries in India date back to the beginning of this century. The fauna of Ganges delta was described by Annandale (1907), Alcock (1911) and Kemp (1917). Excellent studies have come from the Chilka Lake (Annandale and Kemp, 1915; Sewell, 1924). Some interesting work was carried out on the brackish water fauna of Madras area by Panikkar and Aiyar (1937) and Panikkar (1951) reviewed the physiological adaptations of animals in an estuary. Godavary estuary has been studied (I.C.A.R. report, 1964) and by Chandramohan (1963) and Chandramohan and Rao (1972).

Various publications have come from the Vellar estuary of Portonovo (Seshaiya, 1959; Rangarajan, 1959; Krishnamurthy, 1961; Ramamurthy et al. 1965; Subbarajan and Krishnamurthy, 1972; Krishnamurthy and Sunderraj, 1973; Devendran et al. 1974 etc.) and the Mandovi-Zuari estuarine system of Goa (Das et al. 1972; Singbal, 1973; Parulekar et al. 1973; Cheriyan et al. 1974; 1975; Bhargava and Dwivedi, 1974; Goswami and Singbal, 1974; Rao, 1974; Varma et al. 1975).

Cochin backwater system forms one of the better studied estuaries in India. General hydrography of the estuary has been studied by Ramamirtham and Jayaraman (1963), Darbyshire (1967), Wellershaus (1972), Haridas et al. (1973) and Shynamma and Balakrishnan (1973). The tidal fluctuations have been covered by George and Krishna Kartha (1963) and Qasim and Gopinathan (1969); solar radiation by Qasim et al. (1968); nutrient distribution by Sankaranarayanan and Qasim (1969); Joseph (1974) and Manikoth and Salih (1974); silting by Gopinathan and Qasim (1971); sediments by Murthy and Veerayya (1972 a,b) and Veerayya and Murthy (1974); phosphate regeneration by Reddy and Sankaranarayanan (1972) and nannoplankton by Qasim et al. (1974). The organic production, phytoplankton ecology and related aspects have been studied by Qasim and Reddy (1967), Qasim et al. (1969), Qasim (1970), and Devassy and Bhattathiri (1974). Some work on the pollution problems in the estuary has been initiated by Unnithan et al. (1975).

The general composition of the zooplankton of Cochin backwaters was published first by George (1958). Some aspects of seasonal changes in zooplankton has been studied by Nair and Tranter (1971) and Wellershaus (1974) and biomass by Menon et al. (1971). Distribution and ecology of some of the groups of zooplankton has been studied by various authors such as hydromedusae by Vannucci et al. (1970) and Santhakumari and Vannucci (1971); chaetognaths by Vijayalakshmi Nair (1971, 1973) and Sreenivasan (1971); copepods by Pillai (1971); Pillai and Pillai (1973), Pillai et al. (1973), and species of the family Acartiidae by Tranter and Abraham (1971). An account of the taxonomy of copepods in the estuary is given by Wellershaus (1969, 1970), the species composition and their fluctuations in the estuary by Madhupratap and Haridas (1975) and Rao et. al. (in press).

1.3. The environment.

The backwaters of Kerala consist of shallow, semi-enclosed and extensive body of brackish water running parallel to the coastline located in the tropical zone. The portion between Alleppey and Azhikode (09°30' - 10°10'N, 76°15' - 76°25'E) is the biggest of its segments, which with its labyrinth of canals and waterways forms a large basin into which several rivers empty themselves. It covers an area of about 512 square kilometres. At Cochin it has a permanent connection to the Arabian Sea on the western side, (Fig. 1) about 450 m wide which forms the entrance to the Cochin harbour. At the northern extrimity(Azhikode) it has another connection with the sea and at the southern side it terminates into a large body of freshwater - the Vembanad lake. Some of its areas, especially around the harbour and the Kalamassery Industrial Complex, are intensely polluted.

The coastline is of an emergent type formed of a number of long narrow sand bars running parallel to the coastline, often in several rows (Darbyshire, 1967). The sand bar and the harbour channel at Cochin are periodically dredged to accommodate the traffic of the port. The channel area around the mouth is about 15 m deep. Otherwise, the system is shallow, the area south of the channel gradually inclines upward from a depth of 7 m at Aroor to about 2 m at Alleppey. The area north of barmouth, Cochin to Azhikode is uniformly shallow, the depth being about 2 - 4 m. The bottom of the estuary is muddy. Physically it can be classified as a bar-built estuary.

Two large rivers, Periyar and Pamba open into the backwaters at the northern and southern extrimities respectively. Besides, Muvattupuzha and Meenachil rivers and several other canals join it at various places. These, during the SW and NE monsoons disgorge large quantities of freshwater into the backwaters.

Tides in the estuary are of a mixed, semidiurnal type the amplitude of which is about 1 m in the harbour area, decreasing towards the upper reaches. Incursion of seawater to the upper reaches of the estuary oscillates depending on the freshwater efflux (Haridas et al., 1973).

Monsoons form the predominant factor controlling the hydrographical and biological features of the estuary. This annual catastrophe of 'flushing out' of the estuary during the height of the monsoons and the 'recoupment' when the effect of the monsoons subsides render the system interesting both in its hydrography and ecology. The pre-monsoonal, monsoonal and post-monsoonal seasons telescope into each other to be performed over each year.

C H A P T E R 2

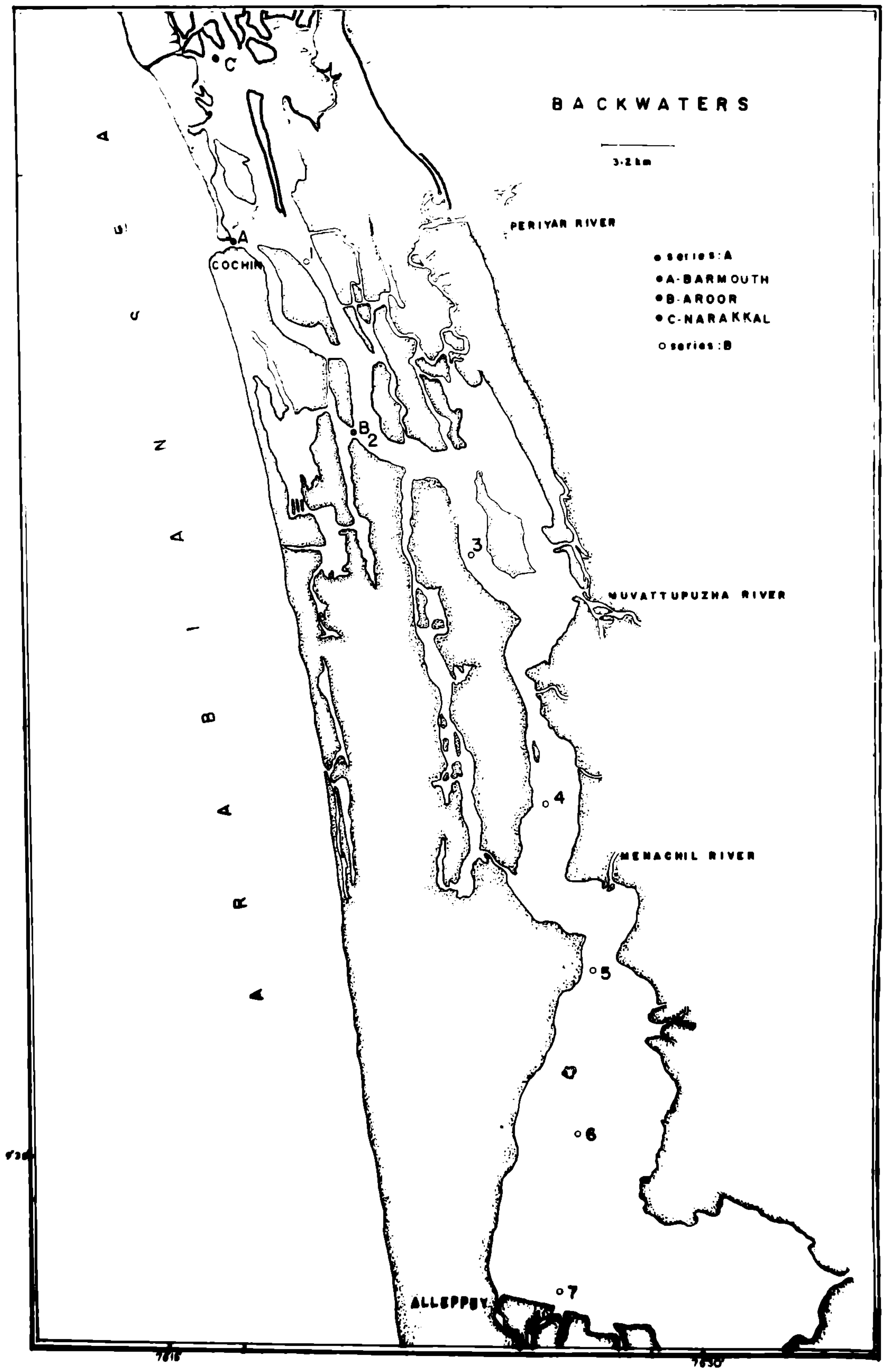
MATERIALS AND METHODS

2. MATERIALS AND METHODS

Zooplankton sampling and hydrographic observations were simultaneously made from stations fixed in the estuary. Results from two series of studies are incorporated in this thesis.

Series A: BARMOUTH, Cochin, where the exchange with sea water takes place was chosen as the primary station (Fig. 1). Collections were made once in a month from November 1971 to October 1972 covering the four tides (2 high and 2 low) of a day. Salinity and temperature were recorded for each metre depth using a salinity temperature bridge (Type MC.5 by Electronic Swichgear (London) Ltd.). Surface and bottom water samples were collected (latter with a Nansen bottle) and analysed for estimating the oxygen content using Winkler's technique. Zooplankton samples were collected using a HT net (Heron-Tranter net, mouth area - 0.25 m^2, length - 3 m, mesh size 300 μ) with flowmetre (TSK 2440) attached. The hauls were oblique and the net was gradually drawn from bottom to reach the surface in 5 minutes. Horizontal tows were also made using a Clark-Bumpus sampler (mesh 300 μ) from surface and bottom and also depending on the stratification of the water column whenever present. The duration of the hauls were 15 minutes. The zooplankton was preserved in 5 % formalin using water collected in situ.

FIGURE 1   Locality ~~of~~ Map of Backwaters showing sampling stations.


BACKWATERS
3·2 km
PERIYAR RIVER
series: A
A-BARMOUTH
B-AROOR
C-NARAKKAL
series: B
MUVATTUPUZHA RIVER
MENACHIL RIVER
COCHIN
ALLEPPEY
ARABIAN SEA
A
B
C
2
3
4
5
6
7

Samplings were done at AROOR about 14 km south (depth of water column about 7 m) and at NARAKKAL (depth of water column 3 m) 10 km north of barmouth. These stations represent relatively more stable areas subject to lesser amount of turbulance than at barmouth. At these two stations one day collection and one night collection was made each month. These samplings were conducted on days subsequent to the collection at barmouth. The procedure adopted for sampling was the same as that at barmouth.

Series B: The focus in this series of collections was on the changes in the hydrobiology of the whole estuarine system. Backwaters from Cochin to Alleppey was covered once in every month of the year 1972. Seven stations were fixed (Fig. 1) representing various stages of seawater - freshwater interaction in the estuary. Station 1 was about a kilometre away from mouth and station 7 at the head of the estuary. Zooplankton samples were taken with a HT net (mesh 300 μ) in oblique hauls lasting 5 minutes. Salinity and temperature of the water column and surface oxygen were measured as mentioned earlier.

These observations and collections were made to study the spatial and temporal changes in composition and distribution, diurnal changes, tidal variations, vertical segregations and migrations, effects of hydrographical changes on these aspects and various other ecological relations among groups and species of zooplankton.

Plankton samples were filtered, drained of excess water on absorbent paper and added to a known volume of water to find out displacement volume. Depending on the size of the sample sub-samples were taken using a Folsom plankton splitter. Larger organisms like medusae, ctenophores and chaetognaths were removed and counted for the whole sample. The rest of the organisms in each subsample were spread on a counting tray and counted to species level* where-ever possible. Often, when the sample was small, the whole sample was analysed. The counts were transformed into counts per unit volume of water filtered using the flowmetre data.

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* The zooplankton were identified with the help of various publications from Cochin backwaters, adjoining inshore waters and elsewhere and also with the help of experts on various groups at the Indian Ocean Biological Centre, Cochin whose help is gratefully acknowledged.

C H A P T E R 3

HYDROGRAPHY

3. HYDROGRAPHY

Assessment of environmental features and its changes is essential for understanding the ecology and interrelations of the organisms inhabiting an area. Several earlier studies (mentioned earlier, 1.2) have contributed to the general understanding of the hydrological aspects of the Cochin backwater system. The year can be broadly divided into the pre-monsoon (January-April), monsoon (May-October) and post-monsoon (November-December) periods. The precise division into the month in which a season begins or ends is arbitrary as it is dependent largely on the time of the onset and duration of the monsoons. The divisions given here are based on the rainfall of the year 1971-1972. These seasons telesco into each other to complete the annual cycle.

3.1. Salinity.

Salinity is perhaps the most important key to the various physical processes, especially in a tropical estua It provides the clue to the circulation and mixing pattern the extent of tidal influence and the rate and effects of freshwater efflux.

Pre-monsoon:

Even by the beginning of pre-monsoon period (January), a vertically homogeneous pattern in salinity distribution was observed at the mouth. Salinity values had recovered ($>$ 30 ‰) and no appreciable differences occurred between high tides and low tides during the pre-monsoon period (Fig. 2). 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 (Figs. 4 and 5 A). The major difference was only spatial, the gradient being horizontal. This was so even during the peak salinity period (April) when the salinity values came up to 32.8 ‰ at Aroor and 31.5 ‰ at Narakkal. This horizontal gradient in salinity distribution was present up to the head of the estuary. The recovery was gradual and the values at the head increased from 3.9 ‰ in January to 13.0 ‰ by April. Some amount of stratification occurred at the middle reaches (Fig. 6) during early pre-monsoon (January-February). But later, a well mixed condition was observed at these regions also.

Monsoon:

Abrupt changes were brought about in the environment with the onset of the monsoons. Large quantities of fresh water discharged into the backwaters through the rivers and land runoff during the SW and NE monsoons resulted in a total transformation of the hydrobiology of the estuary. The surface salinity variations at the three stations could be closely associated with the rainfall during the period (Fig.5 B). In 1972 the monsoon started in May and the rains lasted up to October with intermittent breaks.

At the mouth the surface salinity fell to 3.4 ‰ during low tide in May. The water column became stratified showing a two layered flow. Bottom salinity varied from 21.0 ‰ in low tide to 33.8 ‰ during high tide. In June a break in the monsoon resulted in a temporary recovery of salinity. Bottom salinity reached 35.5 ‰, the highest encountered in the estuary. The presence of this high saline water in the bottom layers was probably due to intrusion of upwelled Arabian Sea water found to enter the channel during this period (see 3.2 and 3.3). July represented the zenith of the monsoon when the force of the freshwater efflux restricted the salinity to near zero values through out the water column during low tide and the upper layers during high tide (Fig. 3 A). Salinity showed an increasing trend in August and September due to a reduction in the force of the monsoon. It went down again in October, especially in the surface layers, when the rainfall showed another increase.

The picture of salinity distribution at the other stations were also corresponding. The fluctuations in salinity intrusion at the mouth were reflected at Aroor and Narakkal also. But the intrusion of salinity when the rainfall decreased was limited to the lower reaches of the estuary during this season. The upper reaches remained fresh throughout the monsoon (Fig. 7).

Post-monsoon:

Post-monsoon season represented the period of salinity recovery after the monsoons subsided. It was rapid at the mouth and gradual towards the upper reaches.

By November surface salinity started to show an increase. But the water column was stratified during high tide as the freshwater efflux had not ceased completely. Marine water started to dominate by December, stratification being less apparent at the mouth, the season merging into the homogenous conditions of the premonsoon.

At the other stations also salinity recovery began in post-monsoon season. Stratification was present at these stations in December also since the salinity incursion was along the bottom layers and the tidal influence was not strong enough to completely mask the effect of fresh water flow. Salinity incursion gradually but steadily began to happen in the upper reaches also (Fig. 7).

3.2. Temperature.

Being a tropical estuary, the fluctuations in temperature were not as pronounced or drastic as that of salinity. However, the seasonal variations reflected on the temperature structure also.

Pre-monsoon:

Temperature was naturally higher during the dry pre-monsoon period. In January, the surface temperature was around 27.5 to 28.0 °C. There was a gradual increase in the season progressed and by April the surface temperature reached 31.6 °C. No appreciable diel or tidal variations were observed during this season (Fig. 8). 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 homogenous conditions prevailing in the water column during this period.

Monsoon:

A sudden fall in temperature was observed with the onset of monsoons. In May surface temperature at the mouth came down to around 26 °C, a difference of about 5°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 of 3.5°C to 6.7°C from June onwards.

Study of the bottom temperature at the mouth during the monsoon was particularly interesting. During the monsoon the continental shelf is pervaded by cold, dense waters upwelled from the sub-surface levels of Arabian Sea (Banse, 1959; Ramamirtham and Jayaraman, 1960, 1963). In May, the bottom layer showed higher temperature than that at the surface showing that the freshwater at the top was colder than the intruding sea water. But in later months, particularly in July and August, the thermal gradient was quite sharp, water at the bottom being colder (Fig. 9) and more saline. The origin of this water could be ascribed to be from the upwelled Arabian Sea water. Also, during June-October, temperature was generally lower during high tide than at low tide showing the characteristic of the seawater entering the channel.

At Aroor and Narakkal, (Fig. 10) where the freshwater element dominated, the thermal gradient was not as a steep as at the mouth. This was particularly true at Narakkal which is a shallow station. But in general, low temperature conditions prevailed over the entire estuary when compared with pre-monsoon season.

Post-monsoon:

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 had more or less reestablished.

3.3. Oxygen

Diurnal and tidal differences in oxygen content were not appreciably significant or uniform. During pre-monsoon, pattern of oxygen distribution also fell in tune with that of salinity or temperature. There was no much difference between surface and bottom oxygen values, the water column being well mixed. In general the range in oxygen values were between 2.5 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. But the bottom values fell during this season (Figs. 11, 3 B). This must be because of the high turbidity during this period (Qasim et al., 1968) limiting primary production in the bottom layers. Similar conditions could be observed at Aroor also. The very low oxygen content of 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 post-monsoon months, oxygen content at the bottom became more or less same as that of surface values. This sharp increase of bottom values after the monsoon was especially noticeable at Aroor. The surface oxygen content was less than that during the monsoonal period.

3.4. Tidal variations

The exchange of marine and fresh water elements and the circulation and mixing in an estuary is primarily induced by the tides. In the Cochin backwaters the tides are of a mixed, semidiurnal type, the maximum range being about 1 m. With the increase in distance towards the upper reaches of the estuary, the magnitude of its influence progressively decreases as the time lag in the tidal height increases and the tidal range decreases (Qasim and Gopinathan, 1969).

During the pre-monsoon, when the freshwater flow into the backwaters was minimal, the sea water ingradient dominated the estuary. The tides and associated currents help in the mixing of the water column and there was no significant difference in hydrography between spring and ebb tides at any depth.

But conditions were different during the monsoons. The force of the freshwater efflux restricted the influence of the tides to the lower reaches of the estuary. The extent of penetration of tidal forces oscillated depending on the strength of the freshwater flow and force of the tidal influx. Fresh water dominated the upper strata of the water column and the penetration of high saline sea water along the bottom resulted in stratification. At the peak of the monsoon in July, the entire water column at the mouth has dominated by fresh water during low tide. While the surface salinity remained the same (less than 2.0 ‰), bottom salinity rose up to 35.0 ‰ during high tide. Appreciable increases in surface salinity was noticed during the monsoon months only in June and August when there was an ebb in the strength of the rainfall. Tidal differences in thermal gradient was also visible during this season, the bottom temperature being usually lesser during high tide due to the influence of cold upwelled Arabian Sea water.

The extent of influence of tides including the depth at which stratification occurred was dependent on the tidal height and hence the strength of the tide. During post-monsoon, influx of sea water started to dominate the environment and by December more or less homogeneous conditions were restored in the water column at the mouth.

3.5. Circulation.

The main physical problems to be investigated in an estuary are the water movements, the mixing processes and the distribution of salinity resulting from their combined action (Bowden, 1967). Some information on the pattern of circulation and mixing in the estuary could be gathered from the distribution of salinity at stations 1 and 2 (Series:B). Salinity profiles and isohalines at these two stations for representative months are given in Fig. 12. As these two stations remained the same (less than 2.0 ‰), bottom salinity rose up to 35.0 ‰ during high tide. Appreciable increases in surface salinity was noticed during the monsoon months only in June and August when there was an ebb in the strength of the rainfall. Tidal differences in thermal gradient was also visible during this season, the bottom temperature being usually lesser during high tide due to the influence of cold upwelled Arabian Sea water.

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Based on the pattern of circulation Bowden (1967) classifies estuaries into four chief categories: 1) Salt wedge estuary. Here salt water extends as a wedge into the estuary and the interface slopes slightly downward in the upstream direction. 2) Two layered flow with entrainment. When the velocity of freshwater flow increases salt water moves upward without a corresponding downward movement of freshwater. But often there is a certain amount of mixing with a small portion of low salinity water from upper layer entering the layer below. The interface is then replaced by an intermediate layer of steep salinity gradient known as halocline. 3) Two layer flow with vertical mixing. In comparatively shallow estuaries, tidal currents cause a mixing of freshwater downward and saline water upward. There is no marked interface, but salinity profile shows a continuous increase from surface to bottom, the maximum gradient occurring near the level of no net motion. 4) Vertically homogeneous estuaries. If the tidal currents are very strong, the vertical mixing becomes so intense that there is no measurable variation in salinity from surface to bottom. There is only the horizontal gradient in salinity increasing from head to mouth.

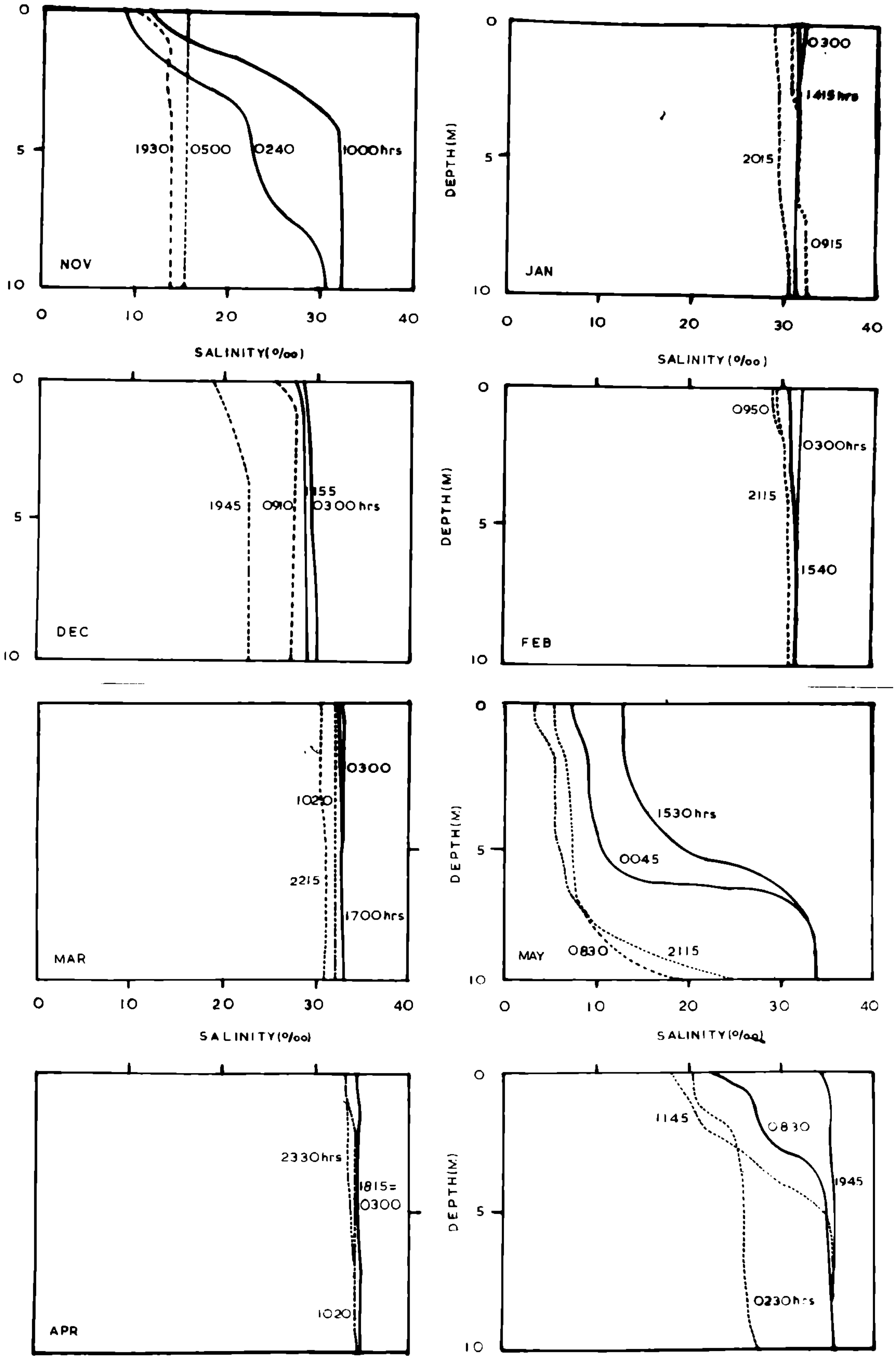
It seems that the circulation in Cochin backwaters cannot be rigorously classified into any of these. But it showed a mixed pattern, varying with the force of freshwater inflow into it.

By late pre-monsoon (March, Fig. 12), the estuary is 'dry' and the effect of freshwater flow is negligible. The circulation was dominated by tidal currents, flow was practically onesided, towards the head, at all depths. In April, the conditions more or less approached that of a vertically homogeneous estuary, the gradient being chiefly horizontal (Fig. 6).

But during monsoons and post-monsoon the two layered flow, the upper water flowing towards the sea and the bottom saline water penetrating up the estuary, was maintained. During these seasons the pattern of flow and mixing was essentially controlled by the strength of freshwater efflux.

In May, June and October, the typical saltwedge along the bottom with interface sloping towards upstream was met with. The stratification was abrupt, the depth of the interface where mixing occurred varied depending on the strength of freshwater efflux. But in July, when the freshwater flow attained its maximum, the isohalines showing the penetration of salt water was restricted to the mouth region, the mixing pattern nearing that of a two layered flow with entrainment. Some amount of mixing could be recognised, the interface with isohaline showing 3.5 ‰ (Fig. 12) could be recognised as a halocline. By late pre-monsoon (December) salt water domination was seen again, the salinity distribution in this month and early pre-monsoon period resembled that of a two layer flow with vertical mixing with regard to individual stations.

FIGURE 2 : Salinity profiles at barmouth, Cochin from November, 1971 to June, 1972 at high tide (continuous line) and low tide (broken line).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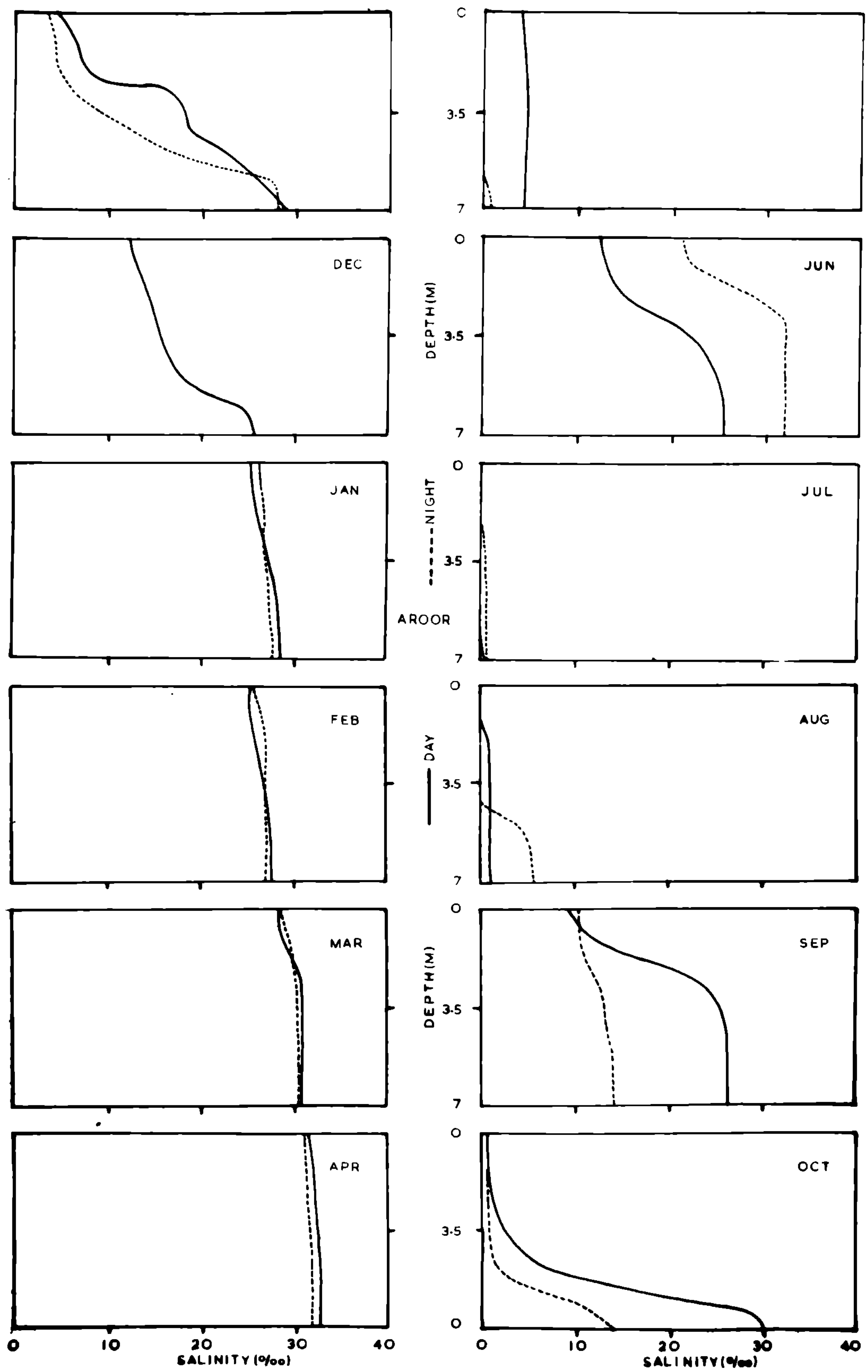
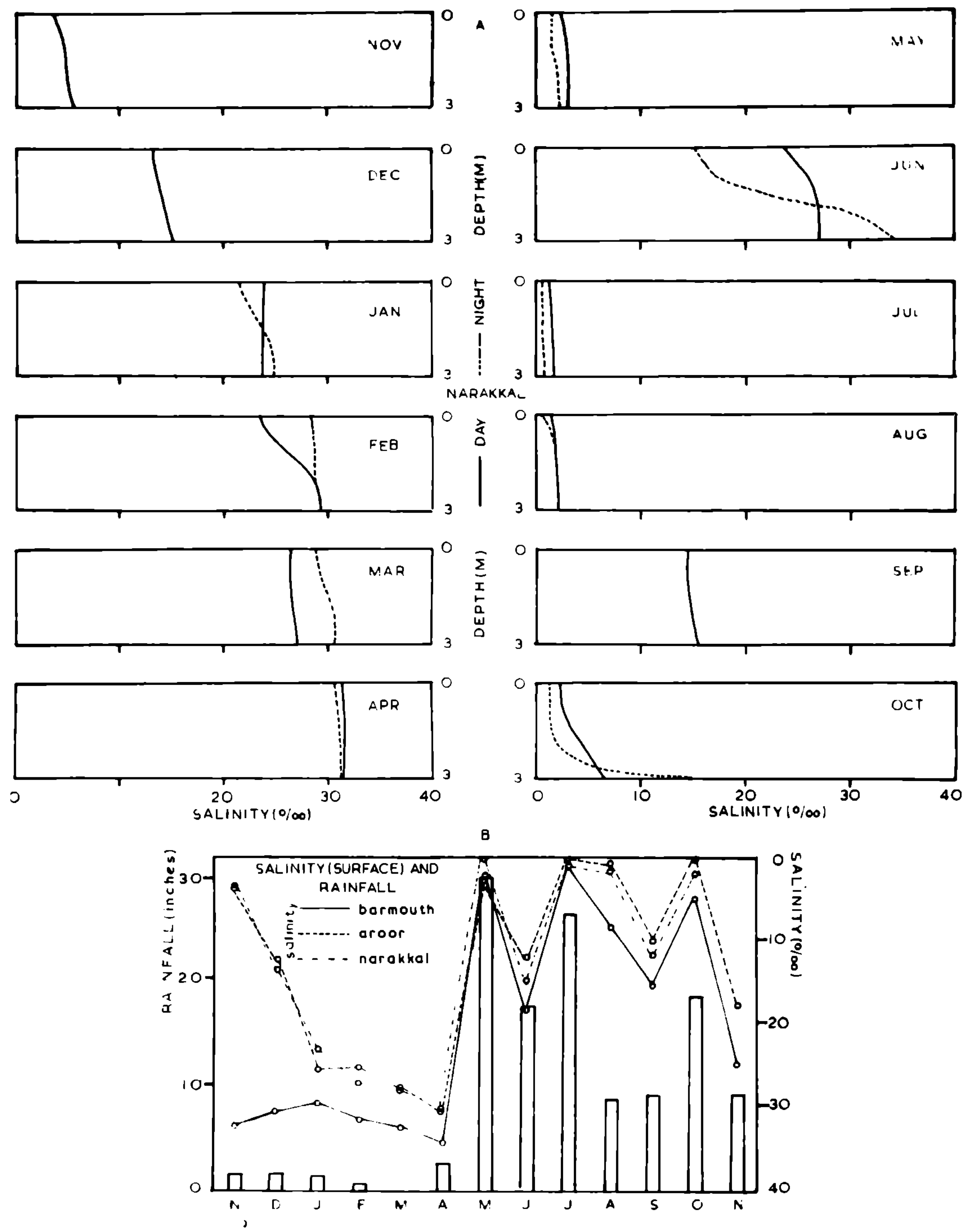

DEC
JAN
FEB
MAR
APR
JUN
JUL
AUG
SEP
OCT
DEPTH (M)
NIGHT
DAY
AROOR
SALINITY (‰)
0
3.5
7
10
20
30
40

FIGURE 5 : A. Salinity profiles at Narakkal from November, 1971 to October, 1972.

B. Rainfall and surface salinity distribution at barmouth, Cochin, Aroor and Narakkal in 1971-1972.



A
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
DEPTH (M)
NIGHT
DAY
NARAKKAL
SALINITY (0/00)
B
SALINITY (SURFACE) AND RAINFALL
salinity
barmouth
aroor
narakkal
RAINFALL (inches)
SALINITY (0/00)
N D J F M A M J J A S O N

FIGURE 6 : Salinity distribution from mouth to the head of the estuary (Series:B) from January to June, 1972.

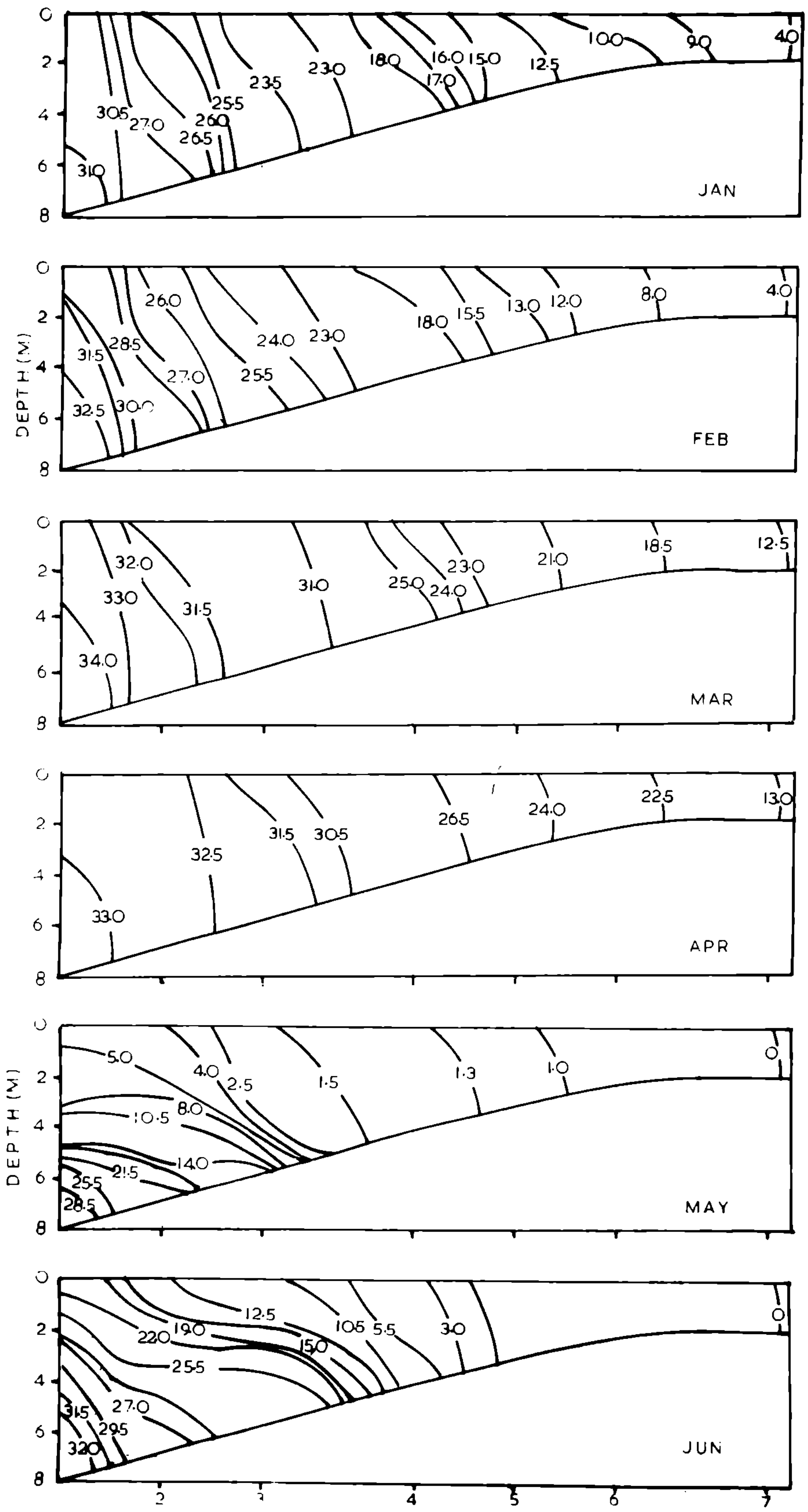
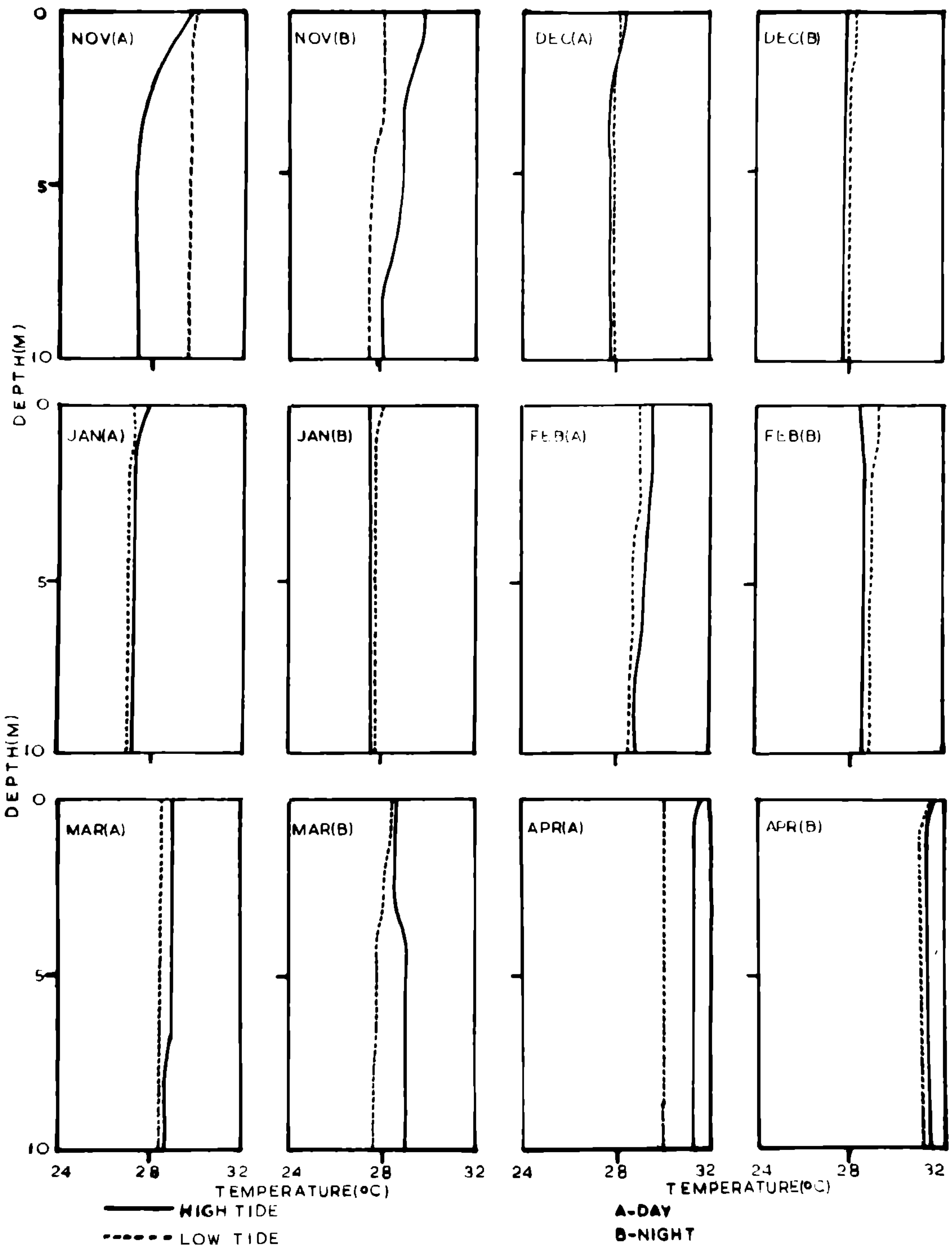

JAN
30.5
27.0
26.0
25.5
26.5
23.5
23.0
18.0
16.0
17.0
15.0
12.5
10.0
9.0
4.0
31.0
FEB
DEPTH (M)
26.0
31.5
28.5
27.0
25.5
24.0
23.0
18.0
15.5
13.0
12.0
8.0
4.0
32.5
MAR
32.0
33.0
31.5
31.0
25.0
24.0
23.0
21.0
18.5
12.5
34.0
APR
32.5
31.5
30.5
26.5
24.0
22.5
13.0
33.0
MAY
5.0
4.0
2.5
1.5
1.3
1.0
0
8.0
10.5
14.0
21.5
25.5
28.5
JUN
12.5
10.5
5.5
3.0
0
22.0
19.0
15.0
25.5
27.0
31.5
29.5
32.0
0
2
4
6
8
2
4
5
6
7

FIGURE 8 : Temperature profiles at barmouth, Cochin from November, 1971 to April, 1972 at high tide (continuous line) and low tide (broken line).



NOV(A)
NOV(B)
DEC(A)
DEC(B)
JAN(A)
JAN(B)
FEB(A)
FEB(B)
MAR(A)
MAR(B)
APR(A)
APR(B)
DEPTH(M)
0
5
10
24
28
32
TEMPERATURE(°C)
HIGH TIDE
LOW TIDE
A-DAY
B-NIGHT

FIGURE 9 : Temperature profiles at barmouth, Cochin from May, 1971 to October, 1972 at high tide (continuous line) and low tide (broken line).

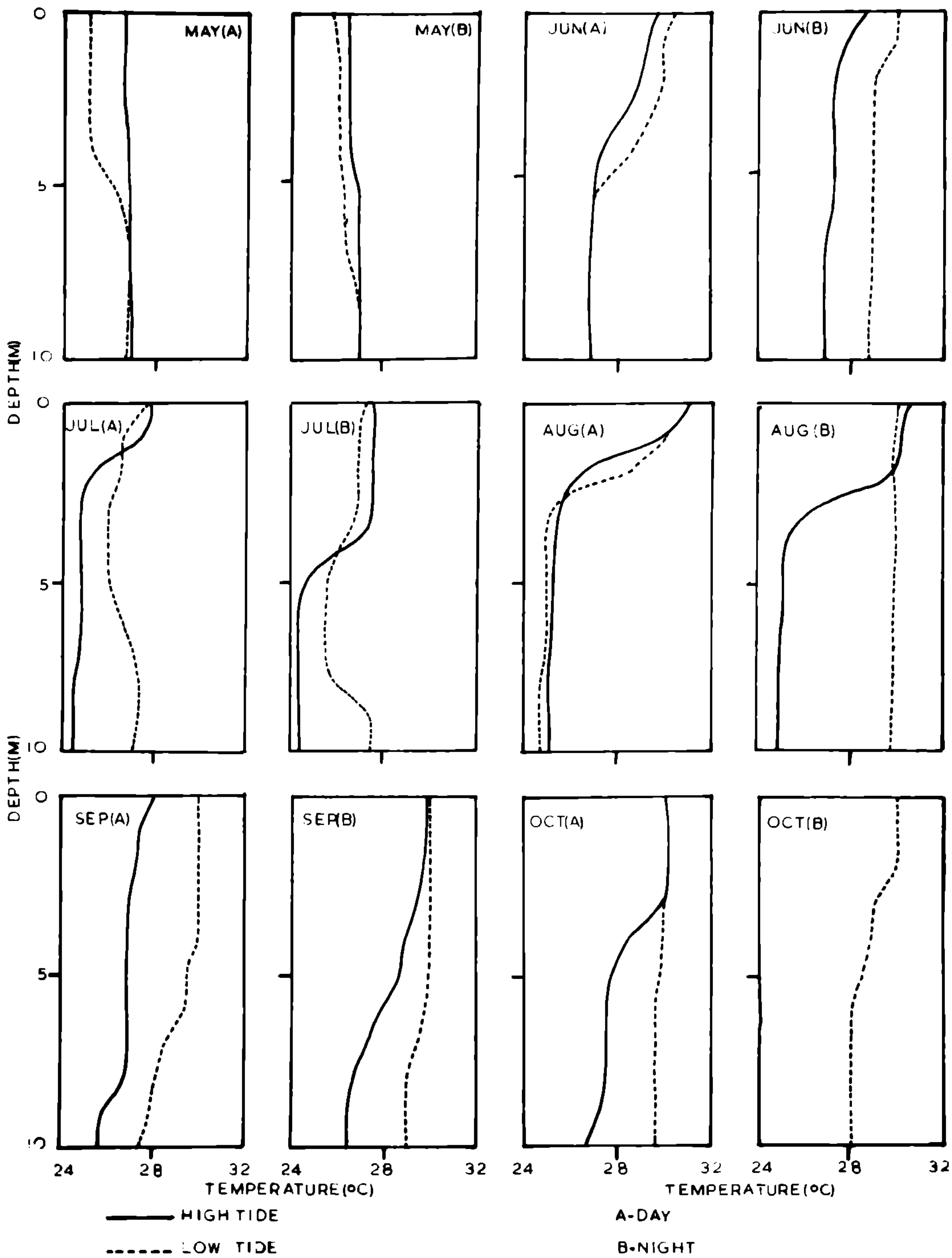
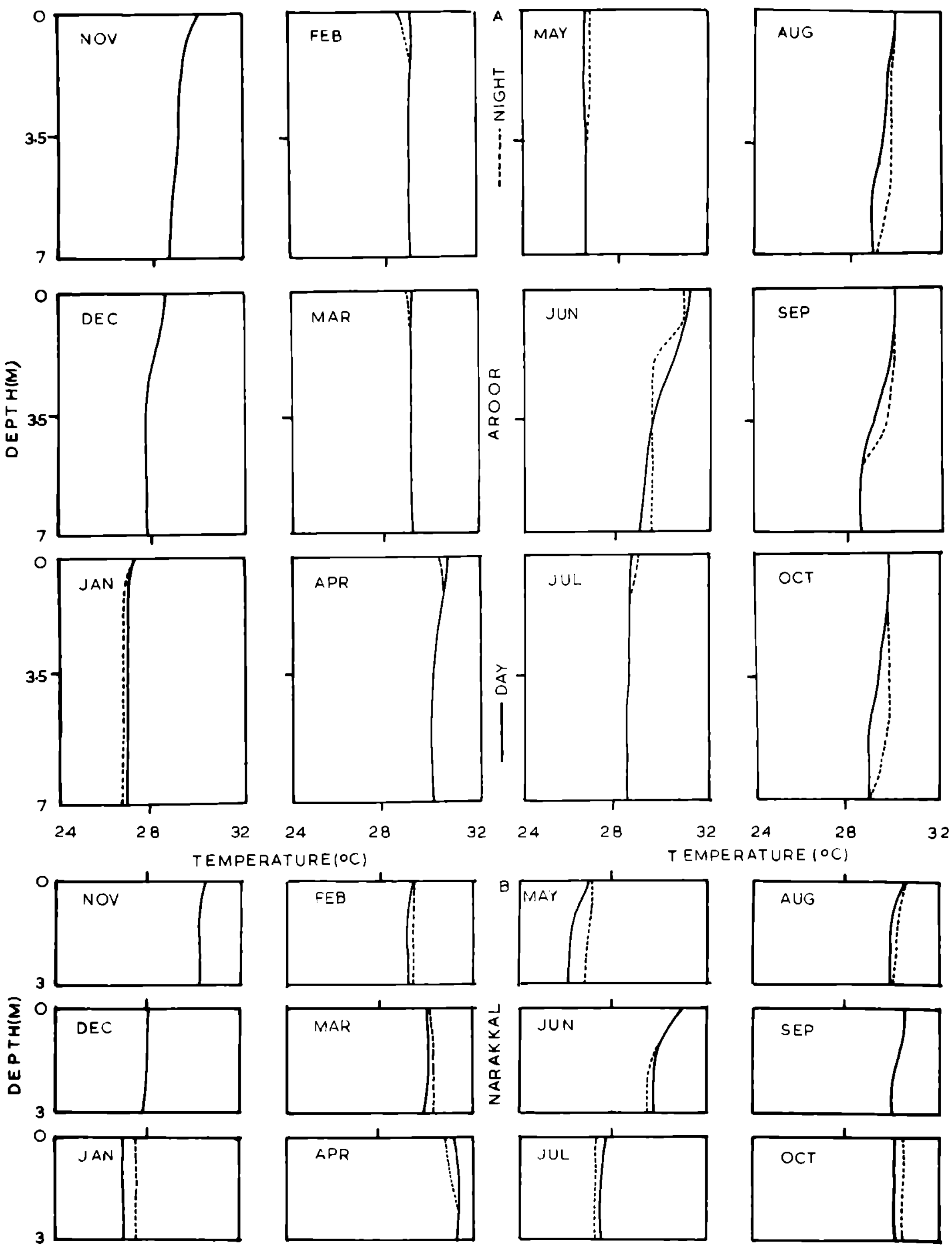

MAY(A)
MAY(B)
JUN(A)
JUN(B)
JUL(A)
JUL(B)
AUG(A)
AUG(B)
SEP(A)
SEP(B)
OCT(A)
OCT(B)
DEPTH(M)
TEMPERATURE(°C)
HIGH TIDE
LOW TIDE
A-DAY
B-NIGHT

FIGURE 10 : A. Temperature profiles at Aroor from November, 1971 to October, 1972 - day (continuous line) night (broken line).

B. Temperature profiles at Narakkal from November, 1971 to October, 1972 - day (continueus line) night (broken line).



A
NIGHT
AROOR
DAY
NOV
FEB
MAY
AUG
DEC
MAR
JUN
SEP
JAN
APR
JUL
OCT
DEPTH(M)
0
3.5
7
24
28
32
TEMPERATURE(°C)
B
NARAKKAL
3

FIGURE 11 : Distribution of Oxygen (ml/lt.) at barmouth, Cochin, from November, 1971 to October, 1972 at surface (continuous line) and bottom (broken line).

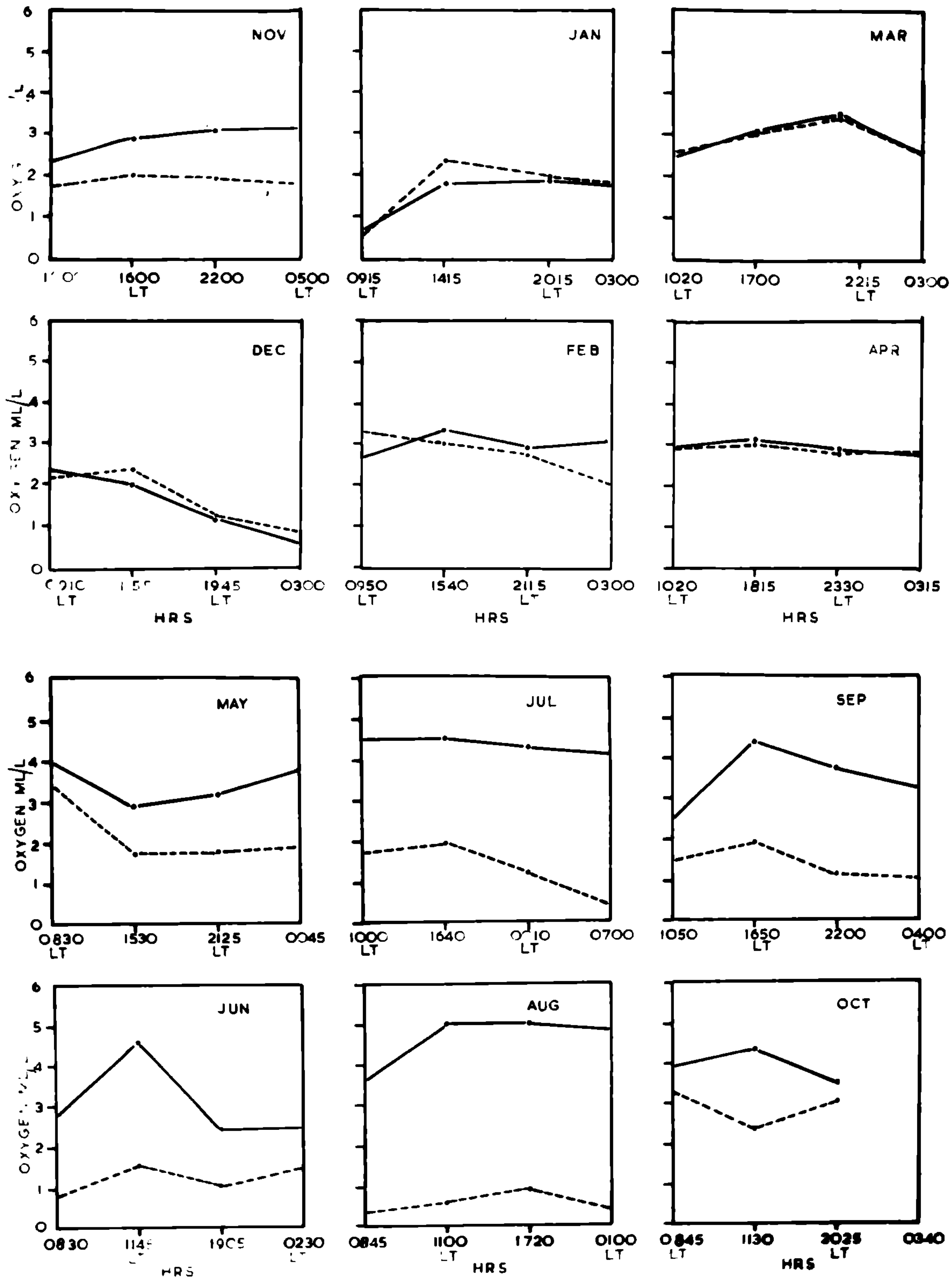
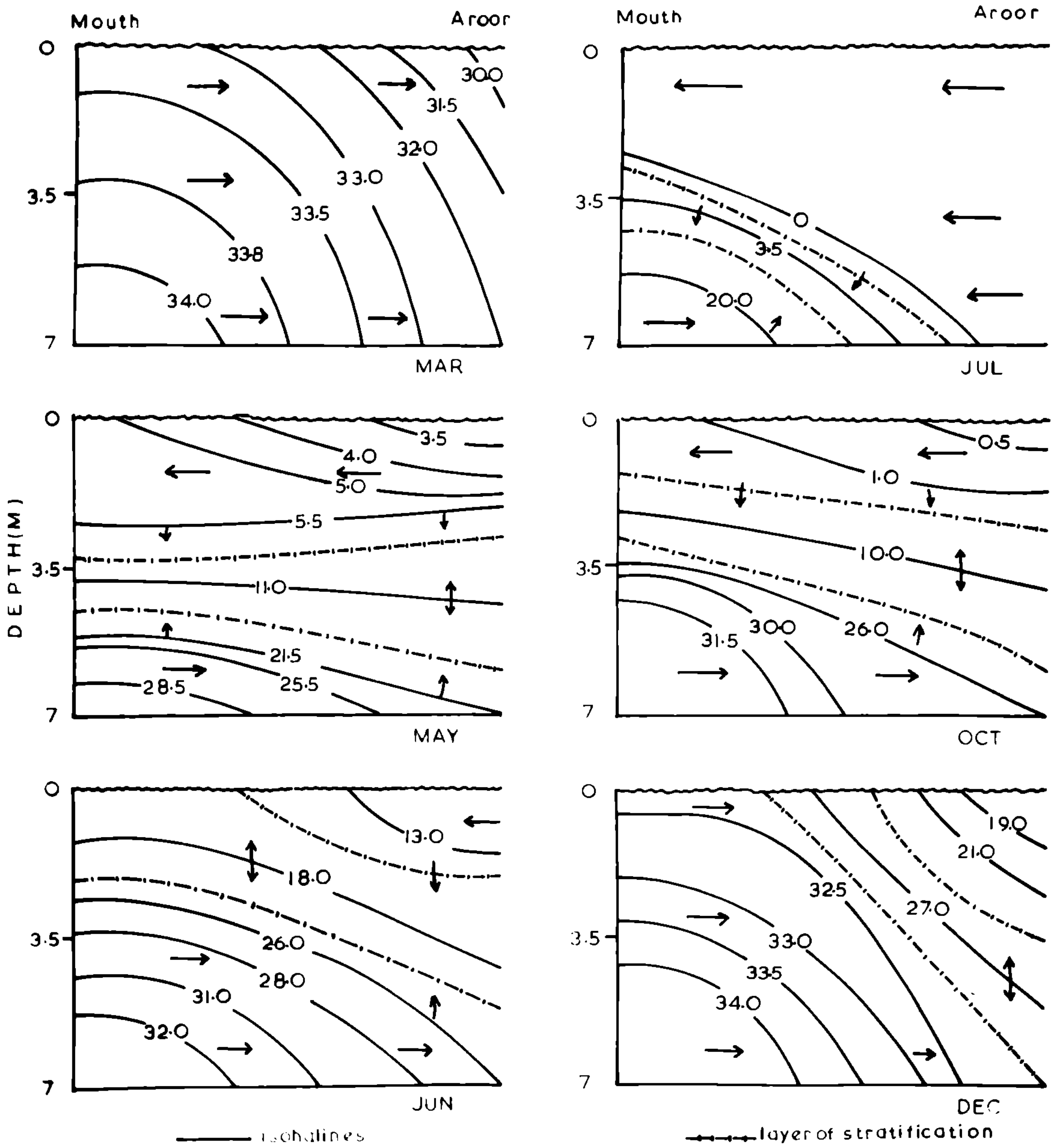

NOV
JAN
MAR
DEC
FEB
APR
MAY
JUL
SEP
JUN
AUG
OCT
OXYGEN ML/L
0
1
2
3
4
5
6
1600
2200
0500
0915
1415
2015
0300
1020
1700
2215
1945
0950
1540
2115
1815
2330
0315
0830
1530
2125
0045
1000
1640
0700
1050
1650
2200
0400
0230
0845
1100
1720
0100
1130
2025
0340
LT
HRS

FIGURE 12 : Schematic diagram of the pattern of ~~flow~~ circulation based on salinity distribution at station 1 and 2 in Series: B (1972).



Mouth
Aroor
O
3.5
7
30.0
31.5
32.0
33.0
33.5
33.8
34.0
MAR
Mouth
Aroor
O
3.5
7
O
3.5
20.0
JUL
DEPTH(M)
O
3.5
7
3.5
4.0
5.0
5.5
11.0
21.5
25.5
28.5
MAY
O
3.5
7
0.5
1.0
10.0
31.5
30.0
26.0
OCT
O
3.5
7
13.0
18.0
26.0
28.0
31.0
32.0
JUN
O
3.5
7
19.0
21.0
32.5
27.0
33.0
33.5
34.0
DEC
layer of stratification

C H A P T E R 4

ZOOPLANKTON

4. ZOOPLANKTON

Estuaries form the transition areas between the more stable conditions of the neighbouring sea and freshwaters, and exhibit increased gradients and fluctuations of abiotic and biotic factors (Kinne, 1967). Hence, like any other organisms inhabiting this peculiar biotope, estuarine zooplankton have to be tremendously accommodative to put up with the physiological stress imposed upon by the extreme variability of this environment. Thus, true estuarine organisms form a class by themselves apart from the more common euryhaline marine forms and to a lesser extent stenohaline forms and freshwater organisms which frequent these waters. Estuarine systems have developed their own ecology, the biocoenosis composed of 'characteristic' and 'accidental' species rendering their autecology, phenology and synecology interesting.

In addition to the zooplankton data given in figures, statistical analysis of the data was performed to study variations in abundance of total biomass, groups and species. Data were subjected to analysis of variance (ANOVA) (Federer, 1967; Fisher and Yates, 1938) to study the significance in variations between months (seasons), tides and diel aspects. Numbers were converted to their log values for the analysis.

Since the distribution was negative binomial (see 4.3) and zero values were present in the data, 1 was added to figures before conversion. The model for ANOVA at barmouth, Cochin was

$$Y_{ijk} = \alpha_i + \beta_j + r_k + \epsilon_{ijk}$$

and for Aroor and Narakkal was

$$Y_{ik} = \alpha_i + \beta_k + \epsilon_{ik}$$

where

α_i = effect of i^{th} season,

β_j = effect of j^{th} tide,

r_k = effect of k^{th} diel and

ϵ_{ijk} = random error.

Wherever the effects were found to be significant, critical difference or least significant difference (LSD) was formed by using the formula

$$\sqrt{\left(\frac{1}{r_1} + \frac{1}{r_2}\right) V_E} \quad t.05$$

where r_1 and r_2 are the number of replications, V_E is the error mean square and t (0.05) is the 5% Student's t table value. LSD was used for separating the significant effects.

4.1. Total zooplankton

The most striking feature in the zooplankton abundance in the Cochin backwater system was the contrast between pre-monsoon and monsoon periods. Earlier studies (Madhupratap and Haridas, 1975; Madhupratap *et al.*, 1975) have shown that biomass, zooplankton numbers and species diversity are low in the entire estuary during monsoon season. Averages of displacement volumes and total numbers of zooplankton for series A are listed in Table 1. Seasonal differences were significant for both biomass and total numbers at barmouth and Aroor. Maximum abundance was noticed in April at the mouth (1.22 ml/m^3 and 13464 $nos./m^3$) and January to April at Aroor (maximum biomass 1.87 ml/m^3 in January and numbers 17841 $/m^3$ in February). At Narakkal seasonal variations were not significant. Maximum density (7281 $/m^3$) and biomass (1.60 ml/m^3) were observed in March. Diel variations were significantly higher during night at this station. Thus zooplankton abundance was higher during the pre-monsoon period from January to April.

It fell sharply during monsoons especially at Aroor and Narakkal and up the estuary. Seasonal averages showed that biomass fell to about 36.0 % at barmouth, 4.3 % at Aroor and 3.8 % at Narakkal, when compared with pre-monsoon values. Total numbers of zooplankton fell to 29.0 %, 3.0 % and 3.5 % at the respective stations. During the post-monsoon months, biomass and total counts remained more or less same at the mouth whereas they registered an increase by almost 1200 % and 450 % respectively at Aroor.

Principal components analysis (Harman, 1960) was employed for separating the first and second factor coefficients from the environment. Communalities were calculated using multiple regression analysis taking abundance, salinity, temperature and oxygen as variables. The matrix of correlation was formed after converting the abundance figures to their logarithmic values. The results for the three stations are presented in Table 3.

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 the changes in the environment were indicated to be more associated with salinity.

Distribution of biomass and counts at surface and bottom layers (Table 2) showed an aggregation of zooplankton at the bottom during day time. But maximum abundance was noticed at surface during night. There was no pronounced variation at the bottom layer during day or night.

Observations (Madhupratap, unpublished) have shown that the estuarine belt from barmouth to Azhikode is less productive at secondary level when compared to its southern counterpart.

larvae (0.41 %), hydromedusae (0.39 %), ctenophora (0.15 %), and chaetognatha (0.14 %). (Decapod larvae showed higher abundance in series:B, Madhupratap and Haridas, 1975). They with copepoda constituted about 92.1 % of the total annual counts (88.5% in series : B).

The species composition of zooplankton in the estuary comprised of estuarine, marine and low saline organisms, their propogation in the backwaters largely depended on environmental conditions. Seventy six species from various groups were identified in the present study (Table 5). Of these 49 specie belonged to copepoda. Groups cumacea, isopoda, amphipoda, copelata, some stray hydromedusae and low saline ostracods were not further identified to lower levels due to practical difficulties.

Systematic list of species identified from the estuary.

Phylum	Coelenterata
Class	Hydrozoa
Order	Hydroida
Family	Companulariidae
	Obelia sp.
	Blackfordia virginica Mayer
Family	Lovenellidae
	Eucheilota menoni Kramp

Family	Eirenidae
	Eirene menoni Kramp
	Eirene ceylonensis Browne
Family	Eutimidae
	Eutima commensalis Santhakumari
	Eutima neucalendonia Uchida
Order	Siphonophora
Family	Diphyidae
	Diphyes chamissonis Huxley
	Lensia subtiloides (Lens & Van Riemsdi
Phylum	Ctenophora
Class	Tentaculata
	Pleurobrachia sp.
Class	Nuda
	Beroe sp.
Phylum	Chaetognatha
	Sagitta bedoti Be'raneck
	Sagitta enflata Grassi
	Sagitta oceania Gray
	Sagitta robusta Doncaster
Phylum	Arthropoda
Class	Crustacea
Order	Cladocera
	Evadne tergestina Claus
	Penilia avirostris Dana

Order	Ostracoda
Family	Halocyprididae
	Euconchoecia aculeata Th. Scott
Family	Cypridinidae
	Cypridina dentata Muller
Order	Copepoda
Suborder	Calanoida
Family	Calanidae
	Canthocalanus pauper (Giesbrecht)
	Undinula vulgaris (Dana)
Family	Eucalanidae
	Eucalanus monachus Giesbrecht
	Eucalanus crassus Giesbrecht
	Eucalanus subcrassus Giesbrecht
Family	Pseudocalanidae
	Calocalanus pavo Dana
Family	Paracalanidae
	Paracalanus aculeatus Giesbrecht
	f. major Sewell
	Paracalanus crassirostris Dahl
	f. cochinensis Weller
	Acrocalanus similis Sewell

Family Centropagidae

Centropages alcocki Sewell

Centropages furcatus (Dana)

Centropages tenuiremis Thomps

Centropages trispinosus Sewel

Family Diaptomidae

Heliodiaptomus cinctus Gurney

Allodiaptomus mirabilipes Kie

Family Pseudodiaptomidae

Archidiaptomus aroorus Madhup
Harida

Pseudodiaptomus annandalei S

Pseudodiaptomus binghami
m *Malayalus* Wel

Pseudodiaptomus jonesi Pillai

Pseudodiaptomus aurivilli Cle

Pseudodiaptomus mertoni Früch

Pseudodiaptomus serricaudatus

Pseudodiaptomus tollingarae S

Family Temoridae

Temora turbinata (Dana)

Temora stylifera (Dana)

Family Candaciidae

Candacia bradyi A. Scott

Family Pontellidae

Calanopia elliptica (Dana)

Calanopia minor A. Scott

Labidocera acuta (Dana)

Labidocera pectinata Thompson & Sco

Labidocera kroyeri (Brady) *var.gall*
Thompson & Scott

Family Acartiidae

Acartia centrura Giesbrecht

Acartia bowmani Abraham

Acartia spinicauda Giesbrecht

Acartia erythraea Giesbrecht

Acartia plumosa T. Scott

Acartia southwelli Sewell

Acartia pacifica Steur

Acartia bilobata Abraham

Acartiella keralensis Wellershaus

Acartiella gravelyi Sewell

Suborder Harpacticoida

Family Tachidiidae

Euterpina acutifrons (Dana)

Family Canthocamptidae

Nitocra spinipes Boeck

Suborder	Cyclopoida
Family	Oithonidae
	Oithona hebes Giesbrecht
	Oithona brevicornis Giesbrecht
	Oithona nana Giesbrecht
	Oithona rigida Giesbrecht
Family	Corycaeidae
	Corycaeus sp.
Family	Sapphirinidae
	Sapphirina sp.
Order	Mysidacea
Family	Mysidae
	Rhopalopthalmus indicus Pillai
	Siriella gracilis Dana
	Mesopodopsis zeylanica Nouvel
Order	Decapoda
Family	Penaeidae
Subfamily	Sergestidae
	Acetes spp.
	Lucifer hanseni Nobili
	Lucifer typus H.M. Edw.
Phylum	Chordata
Subphylum	Urochordata
Class	Thaliacea

Family Salpidae

Thalia democratica Forskal

Family Doliolidae

Dolioletta gegenbauri Uljanin

TABLE 1 A: Displacement volume (ml.) of zooplankton (Day and Nig at Barmouth, Aroor and Narakkal (HT net hauls).

Months	Barmouth		Aroor		Narakkal	
	Day	Night	Day	Night	Day	Night
Premonsoon[a]						
Jan.	0.160	0.200	1.870	0.500	0.410	0.700
Feb.	0.580	0.750	1.180	0.870	0.009	0.380
Mar.	0.410	0.630	0.360	0.800	0.008	1.600
Apr.	0.820	1.220	0.240	1.030	0.140	0.280
Monsoon[b]						
May	0.700	0.360	0.007	0.120	0.004	-
Jun.	0.090	0.180	0.010	0.150	0.020	0.020
Jul.	0.510	0.300	0.020	0.020	0.005	0.040
Aug.	0.080	0.100	0.040	0.050	0.001	0.003
Sept.	0.020	0.030	0.010	0.010	0.001	-
Oct.	0.140	0.060	0.005	0.003	0.008	0.070
Postmonsoon[c]						
Nov.	0.170	0.200	0.630	0.480	0.001	-
Dec.	0.220	0.300	0.210	-	0.030	-

Seasonal average

	Barmouth	Aroor	Narakkal
a -	0.596	0.856	0.440
b -	0.214	0.037	0.017
c -	0.222	0.440	0.015

TABLE 1 B: Total numbers of zooplankton (Day and Night at Barmouth, Aroor and Narakkal (HT net hauls).

Months	Barmouth Day	Barmouth Night	Aroor Day	Aroor Night	Narakkal Day	Narakkal Night
Premonsoon[a]						
Jan.	964.9	1105.9	17841.5	4210.4	156.3	3529.0
Feb.	3256.7	4891.2	16009.1	6774.9	3.3	3739.0
Mar.	2891.9	4301.5	3860.8	4014.3	21.4	7281.0
Apr.	7229.3	13464.2	1462.3	5434.6	75.6	2953.9
Monsoon[b]						
May	6123.4	1902.4	3.5	507.6	1.1	-
Jun.	404.7	681.7	16.4	456.5	79.3	78.5
Jul.	3050.8	2435.9	80.8	72.5	12.0	206.7
Aug.	8.5	814.5	163.4	99.9	1.1	3.4
Sept.	23.6	60.9	37.2	1284.6	9.1	-
Oct.	547.8	588.9	20.8	11.9	6.6	348.1
Postmonsoon[c]						
Nov.	755.0	844.7	637.4	1570.5	1.7	-
Dec.	1842.9	1434.5	910.0	-	30.0	-

Seasonal average

	Barmouth	Aroor	Narakkal
a -	4763.2	7450.9	2219.9
b -	1386.9	229.5	77.7
c -	1219.2	1039.3	15.8

TABLE 2 A: Displacement volume of Zooplankton (Day and Night) at surface and bottom at barmouth, Cochin (Clark-Bumpus hauls).

Months	DAY				NIGHT			
	HT S	LT B	HT S	LT S	HT S	LT B	HT S	LT B
Jan.	0.400	0.060	0.006	0.540	0.320	0.190	0.210	0.320
Feb.	0.140	0.470	--	--	0.200	0.110	0.290	0.220
Mar.	0.180	0.650	0.330	0.660	--	--	--	--
Apr.	--	--	0.040	0.070	--	--	0.620	0.260
May	0.090	0.120	0.002	0.008	0.030	0.230	0.040	0.080
Jun.	0.001	0.020	0.020	0.010	--	--	0.040	0.020
Jul.	--	--	0.010	0.100	0.030	0.030	--	--
Aug.	0.001	0.010	0.006	0.020	0.001	0.001	--	--
Sept.	--	--	0.005	0.050	--	--	--	--
Oct.	0.100	0.040	0.003	0.050	--	--	--	--
Nov.	0.005	0.140	0.010	0.110	0.490	0.290	0.320	0.190
Dec.	0.050	0.210	0.240	0.110	0.120	0.150	0.180	0.130

Average : Day - S = 0.081; B = 0.172

Night- S = 0.206; B = 0.158

-- absence of data, HT = High tide,

LT = Low tide, S = Surface, B = Bottom.

TABLE 2 B: Total numbers of Zooplankton (Day and Night) at surface and bottom at barmouth, Cochin (Clark-Bumpus hauls).

Months	DAY				NIGHT			
	HT S	LT B	HT S	LT B	HT S	LT B	HT S	LT B
Jan.	1052.0	207.5	41.9	3442.4	1052.0	332.5	2207.3	1029.5
Feb.	442.9	2151.2	--	--	482.6	598.4	1865.5	1662.5
Mar.	138.9	1442.2	784.9	3420.6	--	--	--	--
Apr.	--	--	666.9	774.3	--	--	8460.3	2325.0
May	16.1	291.2	11.5	94.7	62.3	1827.8	35.3	192.6
Jun.	5.7	132.6	58.4	226.7	--	--	982.6	98.5
Jul.	--	--	6.2	216.1	13.1	15.9	--	--
Aug.	1.2	4.3	2.4	7.3	1.3	1.1	--	--
Sept.	--	--	4.3	109.4	--	--	--	--
Oct.	67.6	44.6	5.2	65.0	--	--	--	--
Nov.	126.3	370.3	876.8	293.7	501.0	374.0	734.6	87.8
Dec.	501.4	1815.0	4472.5	899.7	1389.1	2549.1	319.9	172.4

Average : Day - S = 464.1; B = 800.4

Night - S =1293.3; B = 804.7

TABLE 3: Principal Factor Pattern

Variable	Common Factor		Communality
	I Factor	II Factor	
A. BARMOUTH			
1. Abundance	0.754	-0.132	0.65
2. Salinity	0.877	0.149	0.76
3. Temperature	0.072	0.858	0.71
4. Oxygen	-0.373	0.249	0.02
B. AROOR			
1. Abundance	0.962	-0.065	0.92
2. Salinity	0.775	0.475	0.81
3. Temperature	0.041	0.510	0.25
4. Oxygen	-0.838	0.392	0.86
C. NARAKKAL			
1. Abundance	0.761	-0.238	0.59
2. Salinity	0.862	-0.017	0.73
3. Temperature	0.387	0.449	0.36
4. Oxygen	-0.057	0.617	0.38

TABLE 4: Distribution of Major Groups, their Numbers/m^3 and relative percentages at Barmouth, Aroor and Narakkal in 1971-72.

A - HYDROMEDUSAE

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	-	-	-	-	-	-
Dec.	2	0.1	1	0.1	-	-
Jan.	1	0.1	3	0.02	1	0.05
Feb.	-	-	3	0.02	1	0.05
Mar.	6	0.1	55	1.39	6	0.15
Apr.	6	0.05	52	1.5	22	1.2
May	34	0.8	15	5.0	-	-
Jun.	43	8.0	40	8.4	2	2.53
Jul.	-	-	-	-	-	-
Aug.	-	-	-	-	-	-
Sept.	-	-	-	-	-	-
Oct.	-	-	1	6.2	-	-
Annual Mean	7.70	0.76	14.20	1.89	2.67	0.33
% to Annual Total		0.30		0.50		0.30

B - CTENOPHORA

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	-	-	-	-	-	-
Dec.	-	-	-	-	-	-
Jan.	-	-	1	0	-	-
Feb.	7	0.1	2	0.01	1	0.05
Mar.	14	0.3	26	0.6	12	0.3
Apr.	18	0.1	5	0.1	15	0.8
May	2	0.04	-	-	-	-
Jun.	4	0.7	2	0.4	-	-
Jul.	-	-	-	-	-	-
Aug.	-	-	-	-	-	-
Sept.	-	-	-	-	-	-
Oct.	-	-	-	-	-	-
Annual Mean	3.75	0.12	3.00	0.09	2.33	0.11
% to Annual Total		0.10		0.10		0.20

C - CHAETOGNATHA

Months	Barmouth		Aroor		Narakkal	
	No./m³	%	No./m³	%	No./m³	%
Nov.	2	0.2	-	-	-	-
Dec.	7	0.4	3	0.3	1	3.3
Jan.	2	0.1	13	0.1	1	0.05
Feb.	4	0.1	9	0.1	4	0.2
Mar.	8	0.2	5	0.1	4	0.1
Apr.	15	0.1	48	1.3	1	0.05
May	20	0.4	-	-	-	-
Jun.	45	8.0	5	1.0	1	1.3
Jul.	-	-	-	-	-	-
Aug.	-	-	-	-	-	-
Sept.	-	-	5	0.7	-	-
Oct.	2	0.3	-	-	1	0.6
Annual Mean	8.80	0.82	7.30	0.22	1.08	0.50
% to Annual Total		0.30		0.26		0.10

D - COPEPODA

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	245	30.5	489	44.3	2	100.0
Dec.	979	59.7	607	66.7	12	40.0
Jan.	688	66.4	9109	81.6	974	52.8
Feb.	3300	81.0	10775	94.5	1147	61.3
Mar.	3531	96.5	3460	87.8	2148	58.8
Apr.	9890	95.5	2669	77.4	858	46.3
May	3590	89.0	176	58.6	8	53.3
Jun.	523	96.0	267	56.5	45	56.9
Jul.	2436	88.5	390	51.3	26	23.8
Aug.	3	0.5	74	56.4	1	50.0
Sept.	6	14.0	270	40.9	1	11.1
Oct.	285	50.5	10	62.5	86	48.5
Annual Mean	2123.00	64.00	2328.80	64.90	442.30	50.23
% to Annual Total		85.40		83.00		55.10

E - CLADOCERA

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	342	42.8	12	1.0	-	-
Dec.	2	0.1	-	-	-	-
Jan.	-	-	-	-	-	-
Feb.	-	-	-	-	-	-
Mar.	-	-	-	-	-	-
Apr.	-	-	-	-	-	-
May	-	-	-	-	1	50.0
Jun.	7	1.0	29	6.1	20	25.3
Jul.	7	0.2	-	-	-	-
Aug.	-	-	--	-	-	-
Sept.	2	4.5	174	26.3	3	33.3
Oct.	6	1.0	-	-	-	-
Annual Mean	30.50	4.10	17.91	2.78	2.00	9.05
% to Annual Total		1.20		0.60		0.20

F - DECAPOD LARVAE

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	97	12.0	325	29.4	-	-
Dec.	444	27.0	301	33.0	15	50.0
Jan.	295	28.5	2105	19.0	604	32.8
Feb.	383	9.0	500	4.3	705	37.7
Mar.	75	2.0	282	7.1	1440	39.4
Apr.	335	3.0	462	13.3	552	29.7
May	346	8.0	32	10.6	-	-
Jun.	16	3.0	23	4.8	2	2.5
Jul.	44	1.5	2	2.6	3	2.7
Aug.	11	2.5	5	3.8	-	-
Sept.	4	9.5	32	4.8	3	33.3
Oct.	198	35.0	4	25.0	4	2.25
Annual Mean	187.30	11.70	339.40	13.14	277.30	19.21
% to Annual Total		7.50		12.00		34.50

G - AMPHIPODA

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	13	1.6	-	-	-	-
Dec.	1	0.01	-	-	2	6.6
Jan.	4	0.4	4	0.02	200	10.8
Feb.	24	0.6	24	0.2	1	0.05
Mar.	3	0.08	3	0.07	10	0.3
Apr.	8	0.07	11	0.3	2	0.1
May	6	0.1	1	0.3	1	50.0
Jun.	4	0.7	1	0.2	-	-
Jul.	56	2.0	29	38.2	61	56.0
Aug.	2	0.5	27	20.6	1	50.0
Sept.	1	2.4	3	0.5	1	11.1
Oct.	9	1.6	2	12.5	83	46.9
Annual Mean	10.92	0.84	8.75	6.07	30.17	19.32
% to Annual Total		0.43		0.30		3.75

H - LUCIFER

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	-	-	-	-	-	-
Dec.	2	0.1	-	-	-	-
Jan.	1	0.1	39	0.3	3	0.2
Feb.	5	0.1	34	0.2	5	0.3
Mar.	7	0.1	21	0.5	9	0.3
Apr.	28	0.2	7	0.2	3	0.5
May	26	0.6	-	-	-	-
Jun.	2	0,3	1	0.2	-	-
Jul.	183	6.5	-	-	-	-
Aug.	-	-	-	-	-	-
Sept.	1	2.0	16	2.4	-	-
Oct.	2	0.3	-	-	-	-
Annual Mean	21.40	0.86	9.83	0.32	1.67	0.6
% to Annual Total		0.80		0.35		0.20

I - COPELATA

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	31	3.8	-	-	-	-
Dec.	61	3.7	27	2.9	-	-
Jan.	23	2.2	21	0.1	-	-
Feb.	241	5.9	8	0.07	11	0.6
Mar.	4	0.1	34	0.8	-	-
Apr.	-	-	33	0.9	-	-
May	1	0.02	-	-	-	-
Jun.	1	0.2	1	0.2	-	-
Jul.	-	-	-	-	-	-
Aug.	-	-	-	-	-	-
Sept.	2	4.7	3	0.4	-	-
Oct.	-	-	-	-	---	-
Annual Mean	30.30	1.70	10.58	0.45	0.92	0.05
% to Annual Total		1.22		0.30		0.11

J - FISH EGGS

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	42	5.0	-	-	-	-
Dec.	23	1.0	-	-	-	-
Jan.	3	0.2	12	0.1	-	-
Feb.	39	1.0	73	0.6	1	0.05
Mar.	8	0.2	88	2.2	2	0.1
Apr.	22	0.2	2	0.65	-	-
May	6	0.1	-	-	-	-
Jun.	15	2.5	5	1.0	-	-
Jul.	-	-	-	-	-	-
Aug.	-	-	-	-	-	-
Sept.	5	12.0	50	7.5	-	-
Oct.	24	4.0	-	-	-	-
Annual Mean	15.60	2.18	19.17	0.95	0.25	0.01
% to Annual Total		0.60		0.68		0.03

K - FISH LARVAE

Months	Barmouth		Aroor		Narakkal	
	No./m^3	%	No./m^3	%	No./m^3	%
Nov.	1	0.1	5	0.4	-	-
Dec.	10	0.6	1	0.1	-	-
Jan.	10	1.0	25	0.2	4	0.2
Feb.	9	0.2	37	0.3	1	0.1
Mar.	11	0.3	11	0.2	5	0.1
Apr.	9	0.1	1	0.2	2	0.1
May	4	0.1	6	2.0	-	-
Jun.	7	1.0	2	0.4	1	1.3
Jul.	82	3.0	3	3.9	1	0.9
Aug.	5	1.0	28	2.13	-	-
Sept.	1	2.0	5	0.7	-	-
Oct.	15	2.5	1	6.2	1	0.6
Annual Mean	13.67	0.99	10.41	1.38	1.30	0.27
% to Annual Total		0.50		0.30		0.15

TABLE 5: Species of zooplankton, period of occurrence, maximum density of population observed (in paranthesis) with month (underlined) at Barmouth, Aroor and Narakkal and salinity range* (Maximum and optimum).

Species	Period of occurrence and maximum density with month			Maximum salinity range	Optimum salinity range
	Barmouth	Aroor	Narakkal		
1	2	3	4	5	6
Hydromedusae					
Obelia sp.	Mar.,Apr.(1.2)	Feb-Apr.(2.1)	Mar.(11.3)	> 25.5	-
Blackfordia virginica	Apr-Jun. (11.8)	Jan.,Mar.,Apr., Jun. (127.9)	Jan.,Mar.,Apr., Jun. (13.4)	8.6 - 35.5	> 25.0
Eucheilota menoni	Jan.,Mar.,Apr., Jun.,Dec.(12.9)	Mar. (1.2)	Mar. (0.2)	> 28.0	-
Eirene menoni	Apr-Jun.(2.3)	Jun. (0.7)	Jun. (0.4)	> 22.0	-
E. ceylonensis	Apr.,May,Jun. (30.4)	Dec-Apr.,Jun. Sep. (64.0)	Feb-Apr.,Jun. (4.1)	8.6 - 35.5	> 29.0
Eutima commensalis	Mar.,Apr.,May, Jun. (27.4)	Dec-Mar.,Apr., Jun. (50.0)	Jan-Mar.,Apr. (29.1)	18.4 - 35.5	> 29.5
E. neucaledonia	Feb-Apr.(1.2)	Apr. (0.8)	-	> 23.8	-
Siphonophora					
Diphyes chamissonis	Dec. (1.9)	-	-	> 30.0	-
Lensia subteloides	Nov. (0.9)	-	Jun. (4.3)	> 30.5	-

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TABLE 5 (Contd.)

1	2	3	4	5	6
Ctenophora					
Pleurobrachia sp.	Feb–Jun.,Dec. Dec. (20.1)	Jan–Mar., Apr., Jun.,Sept.(31.2)	Jan–Mar.,Apr., Jun. (19.0)	8.6 - 35.5	> 29.0
Beroe sp.	Mar., Apr.(0.7)	Apr. (0.2)	-	> 32.0	-
Chaetognatha					
Sagitta bedoti	Jan–May,Jun.,July, Sep.,Oct. (46.5)	Jan–Apr.,Jun., Sep.,Dec.(11.2)	Feb–Apr.,Jun. (5.3)	8.5 - 35.2	> 27.5
S. enflata	Jan.,Feb.,Jun., Sep.,Dec.(11.8)	Jan.,Feb.,Jun., Sep.,Dec. (4.7)	Feb,Jun.(0.4)	17.0 - 34.0	> 30.0
S. oceania	Mar.,Apr.,May(35.6)	Feb–Apr. (70.7)	Mar. (4.9)	13.0 - 34.7	> 31.5
S. robusta	Dec., Jun. (70.6)	Feb. (1.2)	-	> 30.5	-
Cladocera					
Penilia avirostris	Jun.,Jul.,Octo, Nov. (75.4)	Jun. (31.2)	Jun.,Jul. (11.6)	0 - 35.5	6.5 - 23.5
Evadne tergestina	Jun.,Sep.–Nov. Dec. (555.7)	Jun.,Sep.,Nov. (344.6)	May,Jun.,Sep., Oct. (27.2)	0 - 35.5	10.3 - 23.0
Ostracoda					
Euconchoecia aculeata	Apr. (0.4)	-	-	> 34.0	-
Cypridina dentata	Apr. (0.8)	-	-	> 34.0	-

TABLE 5 (Contd.)

1	2	3	4	5	6
Copepoda					
Canthocalanus pauper	Feb.,Mar. (12.6)	-	-	> 32.2	-
Undinula vulgaris	Jan.,Nov. (1.4)	Feb.(1.2)	-	> 31.5	-
Eucalanus monachus	Jan.,Dec. (4.0)	Jun.(3.7)	-	> 31.5	-
E. crassus	Jan.,Dec. (2.3)	-	-	> 31.5	-
E. subcrassus	Jan.,Dec. (4.0)	-	-	> 32.1	-
Calocalanus pavo	Nov. (0.9)	-	-	> 32.4	-
Paracalanus aculeatus f. major	Jan.,Feb.,May,Dec. (612.0)	Jan.,Mar,Apr.,Dec. (72.1)	Mar.,Dec. (1.8)	13.5 - 34.5	25.5 - 31.5
P. crassirostris f. cochinensis	Feb.-Apr.,Oct.,Nov. (2306.2)	Jan.,Mar., Apr. Jun. (947.10)	Jan,Mar.(55.6)	14.0 - 34.7	28.0 - 35.0
Acrocalanus similis	Jan-Apr.-Jun., Oct-Dec.(3136.0)	Jan-Mar-Jun. Oct.,Nov.(1109)	Jan-Jun.,Dec. (1377.1)	2.0 - 35.6	25.5 - 33.5
Centrapages alcocki	Jan-Jun.,Nov. (169.1)	Mar.,Apr., Jun. Nov. (15.2)	Jan.,Feb. (63.0)	14.0 - 35.5	29.0 - 34.5
C. furcatus	Jan.,Dec.(1.5)	-	Jun.(0.04)	> 30.0	-

TABLE 5 (Contd.)

1	2	3	4	5	6
C. tenuiremis	Mar.,Sep. (108.7)	Jun. (0.2)	Feb.(26.2)	> 29.0	-
C. trispinosus	Jan.,Dec.(28.7)	-	Feb.(21.9)	> 30.0	-
Heliodiaptomus cinctus	Jul.,Aug.(114.0)	May,Jul.-Oct. (10.3)	May (0.2)	0 - 11.5	0 - 1.5
Allodiaptomus mirabilipes	Jul. (18.3)	May,Jul.-Oct. (5.8)	May (0.05)	0 - 11.5	0 - 1.5
Archidiaptomus aroorus	-	Oct.(2.2)	-	< 1.0	-
Pseudodiaptomus annandalei	Jan.-Mar.,May-Jul. Aug.-Dec. (2985.0)	Jan.-Mar.,Jun.- Nov. (713.2)	Jan-Apr.,Jun.- Oct.,Dec.(705.1)	0 - 35.2	5.0 - 31.0
P. binghami malayalus	Aug. (0.2)	Jul.,Aug.-Oct. (31.3)	Jul.-Oct.(12.0)	0 - 10.0	0 - 2.0
P. jonesi	Jan.-Apr.-Jun., Dec. (1402.1)	Jan.,Feb.-Apr., Jun. (139.1)	Jan-Apr.,Jun. (429.0)	18.5- 35.2	25.5 - 34.0
P. aurivilli	May (8.7)	Jun.(0.2)	Jun.(0.2)	0 - 19.5	-
P. mertoni	Jun.(8.4)	Jun.(1.2)	Jun.(0.6)	> 25.0	-
P. serricaudatus	Jan-Apr.,Jun., Oct.,Nov.(2693.0)	Jan.,Mar.,Apr., Nov.,Dec.(340.7)	Jan,Feb-Apr,Jun. Dec.(294.4)	13.4 -35.5	25.5 - 32.0
P. tollingarae	Sep. (0.3)	Jul. (0.1)	-	0 - 9.5	-

TABLE 5 (Contd.)

1	2	3	4	5	6
Temora stylifera	Jan. (12.7)	-	-	> 30.4	-
T. turbinata	Jan,Nov.(15.8)	Mar.,Jun.(1.3)	-	> 32.1	-
Candacia bradyi	Nov. (0.03)	-	-	> 32.4	-
Calanopia elliptica	Jan,Feb,Mar.(8.8)	Mar. (0.8)	-	> 31.0	-
C. minor	Jan.(1.8)	-	-	> 31.0	-
Labidocera pectinata	Jan-Apr.-Jun. (1042.0)	Jan-Mar,Apr., Jun. (40.6)	Jan,Feb,Mar. (47.3)	2.0 - 35.2	29.0 - 31.5
L. acuta	May (7.8)	-	-	> 33.1	-
L. kroyeri var. gallensis	Apr.,Jun.	-	-	> 32.7	-
Acartia centrura	Jan,Feb-Jun., Sep.-Dec.(2517.1)	Jan-Apr,Jun., Sep. (1317.7)	Feb-Apr.,Jun., Sep. (105.3)	5.8 - 35.2	26.5 - 33.5
A. bowmani	Jan-Apr.-Jun., Oct.,Nov.(4244.0)	Jan-Apr,Jun. Oct-Dec.(1533.3)	Mar,Apr,Jun,Dec. (226.7)	9.5 - 35.2	27.5 - 32.0
A. spinicauda	Jan-Apr-Jun. Sep,-Dec.(3212.6)	Mar,Apr, Jun., Nov,Dec.(465.4)	Apr.,Jun.(24.7)	5.8 - 35.2	29.0 - 33.0
A. erythraea	Dec. (66.7)	Apr. (1.3)	-	> 30.0	-
A. plumosa	May,Jul-Oct. (724.1)	Jan,Mar,May,Jun., Nov. (596.3)	Jun.,Oct-Dec. (21.4)	0 - 28.0	15.0 - 25.0

TABLE 5 (Contd.)

1	2	3	4	5	6
A. southwelli	Jan-Apr,Jun (1108.2)	Feb,Mar,Apr. (397.9)	Mar,Apr,Jun. (180.0)	17.0 - 35.5	30.0 - 35.0
A.pacifica	Jan-Apr-Jun, Sep,-Dec.(369.8)	Mar,Apr,Jun., Sep. (242.3)	Jun.(2.0)	12.6 - 35.5	30.0 - 35.5
A. bilobata	Jan-Mar-Jun, Sep-Dec.(1454.2)	Jan-Feb-Apr,Jun, Oct-Dec.(14917.0)	Jan-Mar,Apr,Jun, Dec. (1275.8)	8.6 - 35.5	26.0 - 34.5
Acartiella keralensis	May,Jul,Aug, Sep. (1038.2)	Jan,Feb,Mar, May,Jun,Aug,Oct,, Nov. (243.5)	Jan,May (58.8)	0 - 29.7	18.0 - 26.0
A. gravelyi	Jul.,Sept.(86.3)	May-Aug,-Oct. (107.7)	Jul.,Aug,Oct. (1.2)	0 - 12.0	0 - 3.0
Euterpina acutifrons	May (7.6)	-	-	>33.1	-
Nitochra spinipes	Jun.(0.4)	Jan,Feb,May(9.3)	May,Jun.(4.2)	2.0 - 30.0	10.0 - 25.0
Oithona hebes	Jun.-Sep,Nov. (114.1)	Jan-Mar,Jun-Sep,Nov.(242.9)	Feb,Mar,Sep., Oct. (9.1)	0 - 30.2	10.6 - 25.0
O. nana	Feb. (1.9)	Feb.,Mar.(2.1)	-	6.5 - 31.5	10.0 - 30.0
O. rigida	Jan,Feb-Apr. Jun.(117.8)	Feb,Apr.(60.0)	Feb,Apr.(71.8)	28.6 - 34.1	30.0 - 33.0
O. brevicornis	Jan,Feb,Jun. Dec.(57.9)	Jan-Apr,Jun, Sep-Dec.(71.8)	Feb,Apr.,Sep., Oct. (11.1)	6.5 - 30.8	22.0 - 30.5

TABLE 5 (Contd.)

1	2	3	4	5	6
Corycaeus sp.	Jan, Feb. (12.7)	-	-	> 31.5	-
Sapphirina sp.	-	Jun. (0.7)	-	> 30.5	-
Mysidacea					
Rhopalopthalmus indicus	Jan-May, Dec. (2.1)	Jan-Mar, Apr., Jun. (47.6)	Mar, Apr. (20.6)	27.4 - 34.7	30.0 - 34.7
Siriella gracilis	Jan-Jun. (0.9)	Jan, Feb, Mar. (1.1)	-	> 30.0	-
Mesopodopsis zeylanica	Mar. (0.02)	-	-	> 33.0	-
Sergestidae					
Acetes spp.	Apr-Jun, Jul., Oct. (3.0)	Jan, Feb, Apr., May-Jul., Oct. (3.3)	Apr-Jun, Jul. (2.2)	-	-
Lucifer typus	Mar-Jul., Oct. (71.2)	Jan-Apr, Jun. (8.8)	Jan-Feb. (0.2)	3.8 - 35.6	29.0 - 34.7
L. hanseni	Jan-Jul., Sep-Dec. (458.9)	Jan-Apr, Sep. (60.4)	Jan-Apr. (16.9)	2.0 - 35.6	25.0 - 31.0

TABLE 5 (Contd.)

1	2	3	4	5	6
Thaliacea					
Thalia democratica	_Jun_. (0.2)	-	-	> 35.0	-
Dolioletta gegenbauri	_Jun_. (2.1)	-	-	> 35.0	-

* Salinity range calculated from occurrence of individual species over the entire estuary.

TABLE 6: Nature of distribution - Values of variance/mean at Barmouth, Aroor and Narakkal for various groups and species.

Groups & Species	Barmouth	Aroor	Narakkal
Total number of Zooplankton	303469.8	268198.8	51363.6
Eutima commensalis	1892.7	4031.6	326.8
Eirene ceylonensis	2498.0	5514.7	140.8
Blackfordia virginica	1363.9	1995.2	22.9
Ctenophora	1062.0	2156.1	664.4
Sagitta enflata	137.7	62.3	40.3
S. bedoti	828.0	485.7	48.1
S. Oceania	400.6	1843.7	-
Invertebrate eggs	3535.1	3753.7	-
Polychaete larvae	1365.0	854.1	20.8
Cirripede larvae	7942.0	7591.6	4229.7
Zoea larvae	2323.0	44819.0	48221.5
Caridia larvae	2087.7	1248.0	3605.2
Total Copepoda	280405.4	286313.8	9293.0
Paracalanus crassirostris	25510.8	6443.6	1520.8
P. aculeatus	13123.5	1824.8	10.3
Acrocalanus similis	33530.7	59917.7	6483.2
Centropages alcocki	3853.4	405.0	16.0
Pseudodiaptomus annandalei	125469.4	53830.2	111.2
P. jonesi	8827.1	9066.0	770.0
P. serricaudatus	50146.5	4009.3	100.0
Labidocera pectinata	13848.6	2081.3	274.8

TABLE 6: Nature of distribution - Values of variance/mean at Barmouth, Aroor and Narakkal for various groups and species.

Groups & Species	Barmouth	Aroor	Narakkal
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Sagitta enflata	137.7	62.3	40.3
S. bedoti	828.0	485.7	48.1
S. Oceania	400.6	1843.7	-
Invertebrate eggs	3535.1	3753.7	-
Polychaete larvae	1365.0	854.1	20.8
Cirripede larvae	7942.0	7591.6	4229.7
Zoea larvae	2323.0	44819.0	48221.5
Caridia larvae	2087.7	1248.0	3605.2
Total Copepoda	280405.4	286313.8	9293.0
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Acrocalanus similis	33530.7	59917.7	6483.2
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Pseudodiaptomus annandalei	125469.4	53830.2	111.2
P. jonesi	8827.1	9066.0	770.0
P. serricaudatus	50146.5	4009.3	100.0
Labidocera pectinata	13848.6	2081.3	274.8

Gropps & Species	Barmouth	Aroor	Narakkal
Acartia bowmani	233675.8	79971.1	455.5
A. centrura	106634.5	101951.6	161.1
A. spinicauda	20855.3	34251.2	587.1
A. bilobata	40031.0	429061.9	36188.4
A. pacifica	15929.7	23566.0	200.8
A. southwelli	78882.8	26795.3	1451.9
A. plumosa	6544.3	16268.2	170.8
Acartiella keralensis	67210.8	18116.6	5.0
A. gravelyi	120.1	4471.4	56.1
Oithona rigida	11478.7	1201.8	1223.0
O. brevicornis	4200. 4	5311.7	92.9
O. hebes	1251.9	23669.7	907.4
Penilia avirostris	190.8	3120.3	1126.9
Evadne tergestina	33817.5	31878.2	2235.1
Lucifer hanseni	41958.1	1381.0	50.6
L. typus	6174.5	496.9	15.4
Amphipoda	8290.9	2781.2	601.4
Mysids	120.6	4136.7	1786.4
Copelata	42128.3	3186.5	8.0
Fish eggs	5228.8	8351.9	4.3
Fish larvae	1566.2	1149.3	53.6

4.3. Distribution of Zooplankton

Spatial and temporal distribution of groups and species of zooplankton showed definite trends associated with seasonal fluctuations and resultant environmental variations.

To study the pattern of distribution of different species in selected regions, the mean and variance for each species were calculated and the ratio of variance to mean was taken. Since all values were significantly higher than 1 (Table 6) it followed that distribution was 'contageous' or 'negative binomial'. Under log transformation ~~to~~ a negative binomial is transferred to normal distribution (Cassie, 1962). This justified log transformation of the figures for forming ANOVA.

The variations in abundance between months, diel and tides for groups and species of zooplankton are given in ANOVA tables (Table 7). Diagramatic representation of distribution of major groups and common species over the entire estuary (series:B) and at the three stations (series:A) are given in figures 14 to 18. The occurrence of other miscellaneous and less common organisms is listed under Tables 8.

HYDROMEDUSAE

Higher abundance of hydromedusae in the backwaters were during the peak salinity months of March and April. They were more or less uniformly distributed in the estuary during this period and they did not show significant variations in abundance over stations.

Nineteen species of hydromedusae have been recorded from this backwater system (Santhakumari and Vannucci, 1971). In the present study only the commoner species viz. Blackfordia virginica, Eutima commensalis, E. neucaledonia, Eirene ceylonensis, E. menoni and Eucheilota menoni were counted. Of these Blackfordia virginica, Eirne ceylonensis and Eutima commensalis are the most abundant species in the estuary (Vannucci et al., 1970; Madhupratap and Haridas, 1975) and constituted about 92% of the total hydromedusae in the present study. All the species were present in high saline conditions. The three common species showed significant seasonal variations except Blackfordia virginica at Narakkal. All of them showed higher abundance in May-June at the mouth. Eutima commensalis was more abundant in April at Aroor and Narakkal, Eirene ceylonensis, in March, April and June and Blackfordia virginica in April and June. Latter two were significantly more abundant in night at Aroor.

Hydromedusae were washed out of the estuary during the monsoons, when salinity values fell sharply in May. They were present only at the mouth during this month. In June following a break in the monsoon and a temporary salinity recovery at the lower reaches, they again penetrated these areas. Later, when the monsoons strengthened they were absent at the mouth also. They were probably absent in the inshore waters near the outlet during the peak of the monsoon due to the effect of freshwater outflow as they were not present at the mouth during post-monsoon except for the appearance of Eucheilota menoni in December. Monsoonal efflux from Cochin backwaters reduces the surface salinity of coastal waters considerably and the effect persists up to November (Darbyshire, 1967).

It has been observed (Santhakumari and Vannucci, 1971) that the species of hydromedusae that occurred in the backwaters during post-monsoon are endemic to this area. Vannucci et al. (1970) have suggested that hydroids develop resting stages during low saline period and become active again when salinity recovery reaches the lower threshold for active life of the species. Distribution pattern observed in the present study supports their view. Species like Eutima commensalis and Eirene ceylonensis do not seem to be recruited from coastal waters to repopulate the intermonsoon waters of the estuary. Their occurrence was noticed in September and December at stations away from the mouth. They first established themselves at Aroor and Narakkal and at the middle reaches during early pre-monsoon and spread to the mouth only by March-April. Recruitment of other species is probably from the marine water itself.

The distribution of hydromedusae agreed with the earlier findings of Vannucci et al. (1970) and Santhakumari and Vannucci (1971) except for their absence in post-monsoon period and peak densities recorded. Hydromedusae are exclusively carnivorous and they occurred in large numbers in the estuary during the saline period when there was a high standing stock of other zooplankton. Although their counts formed only 0.39 % (series:A) and 1.5 % (series:B) of total annual zooplankton numbers, the ecological dominance exerted by this highly predaceous group cannot be overlooked. Higher abundance of this group was generally inversely related to the abundance of copepods in a particular locality. Maximum density of hydromedusae recorded in series:B was 133 $/m^3$ at station 3 in April and corresponding copepod density was 268 $/m^3$. In the same month, maximum densityfor copepods for the whole series was recorded at station 1 as 874 $/m^3$ where the density of hydromedusae was only 35 $/m^3$. Observations (unpublished data, Estuarine Survey Project, Regional Centre of National Institute of Oceanography, 1975) from the middle reaches showed that copepod densities were drastically reduced when there was a teeming abundance of hydromedusae and ctenophores.

Copepod densities were 1.1 $/m^3$ and 38.1 $/m^3$ at two stations where that of hydromedusae were 193 $/m^3$ and 205 $/m^3$ respectively. The species composition of hydromedusae was constituted by the three common species mentioned earlier. In the same series, copepod density was 759.5 $/m^3$ at a station near the mouth where the density of hydromedusae population was 3.7 $/m^3$.

SIPHONOPHORA

Two species of siphonophores, Diphyes chamissonis and Lensia subteloides occurred in the estuary during post-monsoon season. Latter was observed at Narakkal in June also. These are common species occurring in the inshore waters (Daniel and Daniel, 1963; Rangarajan, 1973) and are evidently stragglers. They neither established themselves nor penetrated further up the estuary.

CTENOPHORA

Pleurobrachia sp. (globosa?) was the dominant ctenophore in the backwaters. Another carnivore, its general distribution was similar to that of hydromedusae (Fig. 17). It occurred from December to June at the mouth and during the premonsoon months and in June at other stations. Maximum abundance was during the peak saline months of March and April at Aroor and Narakkal and also in February at barmouth.

It showed higher abundance during night at Aroor and at high tide at the mouth. Beroe sp. was another 'accidental species' that occurred in the estuary in small numbers at the lower reaches during high saline months.

CHAETOGNATHA

The distribution and abundance of chaetognaths were indicators of the extent of intrusion of salinity in the estuary. Their numbers increased from January to April and again appeared in lesser numbers in June, November and December (Fig. 17). They were scarce at the upper reaches where the salinity intrusion did not reach its optimum ranges (Table 5). At the mouth they were present throughout the year except at the peak of the monsoon in July and August.

Four species of chaetognaths, Sagitta enflata, S. bedoti, S. oceania and S. robusta were observed in the estuary during the present study. Apart from these S. pulchra and Kronhitta pacifica have been recorded from the backwaters in earlier studies (Vijayalakshmi, 1971; Sreenivasan, 1971).

Chaetognaths are mainly oceanic forms and highly predacious. S. bedoti was the commonest species in the estuary. This species has been observed to breed in the estuary during high saline period (Vijayalakshmi, 1973). ANOVA tables (7 (7) - (9)) showed that the period of abundance of the three common species do not overlap. *S. enflata* appeared during post-monsoon period when the repopulation of the estuary had begun. Later in early pre-monsoon, *S. bedoti* became the dominant chaetognath. *S. oceania* abruptly appeared in the peak saline period of March-April, invaded the entire estuary and was washed out in the monsoonal efflux. During other months *S. bedoti* was the common species.

CLADOCERA

Penilia avirostris and *Evadne tergestina* were the two species of cladocerans that occurred in the estuary. These two species are common in the coastal and open waters of Indian Ocean (Della Croce and Venugopal, 1972). But curiously, they were absent in the estuary during the high saline pre-monsoon period except for a single occurrence of *E. tergestina* in small numbers (1.3 $/m^3$) at Narakkal in April. Although they occurred in the salinity range from 0 to 35.5 ‰ (Table 5), higher abundance was during monsoon and post-monsoon periods. They were present throughout the estuary during monsoon period, their distribution often discontinuous both in space and time. The two species usually occurred together and sometimes abruptly flowered into large swarms, their densities came up to 631.1 $/m^3$ in November at the mouth. Such sudden appearance of *Penilia avirostris* in the Indian Ocean has been recorded and their ability to reach peak numbers within a short time

OSTRACODA

Ostracods occurred in small numbers at the head of the estuary where salinity was low in May and June. Their presence in low saline waters was observed at the mouth also in various months. These fresh water ostracods were not identified. In April two marine species Euconchoecia aculeata and Cypridina dentata occurred in low numbers at the mouth. These two species are common in the neritic waters of South West Coast of India (Jacob George et al., 1975) and usually occur in salinities higher than 34.0 ‰ in the Indian Ocean (Jacob George, personal communication). Their occurrence at the mouth of the estuary seems to be purely accidental.

COPEPODA

Copepoda was the most dominant group in the estuary constituting 55.1 to 85.4 % of the total annual counts at the three stations (annual mean to total counts - 79.3 %). They formed the bulk of the zooplankton displacement volume except when hydromedusae and ctenophores were abundant.

Fortynine species of copepoda belonging to 22 genera were observed in the backwaters in the present study. Calanoid copepods comprising 41 species belonging to 11 families constituted the majority. Six species of cyclopoides belonging to 3 genera and 2 genera of harpacticoides each represented by a species constitued the remainder of the composition. About 50 % of the species occurred sporadically or in small numbers.

Peak abundance of copepoda was between February and April at the mouth and January to April and in November at Aroor. At Narakkal seasonal variations were not significant for total copepoda.

Density of copepod population varied highly. Minimum densities noticed were 3.0 $/m^3$, 10.0 $/m^3$ and 1.0 $/m^3$ at barmouth, Aroor and Narakkal respectively during monsoon season. Maximum densities went up to 18607 $/m^3$ (night, April) at barmouth, 15021 $/m^3$ (day, February) at Aroor and 4287 $/m^3$ (night, March) at Narakkal. But in series: B, maximum density of copepod population observed was only 873.9 $/m^3$ eventhough the period of sampling overlapped. This indicates the wide range of fluctuation of populations possible in a complex aquatic environment. Earlier observations of Tranter and Abraham (1971) also have shown wide variations in copepod population in this estuary. The highest copepod density observed by them was 55390 $/m^3$ at the middle reaches during post-monsoon whereas the minimum density observed in the same season at a nearby station was 2 $/m^3$. Subbaraju and Krishnamurthy (1972) have observed the average copepod population from Vellar estuary on the east coast during summer months to be more than 100,000 $/m^3$ with maximum density as 286,000 $/m^3$.

During the rest of the year also copepod densities are comparatively very high in this water ranging between 30,000 to 50,000 /m^3. Copepods constituted 90 % of the zooplankton population in Porto Novo waters. Grindley and Wooldridge (1974) have recorded density of a single estuarine copepod Pseudodiaptomus charteri from Richards Bay going as high as 42,700 /m^3. The average copepod counts from the three stations in series: A were 1631.3 /m^3 for the whole year, 4045.8 /m^3 for pre-monsoon, 435.8 /m^3 for monsoon and 390.6 /m^3 for post-monsoon. The apparant decrease during post-monsoon was due to the presence of higher densities of copepod population at the mouth during early monsoon period. The averages from two stations inside the estuary showed copepod densities to be 83.5 /m^3 for monsoon and 277.5 /m^3 during post-monsoon.

Distribution pattern of copepoda (Fig. 17) showed higher abundance during pre-monsoon. The increase and decrease in their munificence was closely associated with the salinity intrusion in the estuary. Their (total) distribution over space was more or less uniform occurring in large numbers throughout the estuary during high saline months. This was possible although a salinity gradient was present from mouth to head 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 three stations are given in figures 14 to 16 and 13 species of them over the whole estuary in figures 18. (Acartia bowmani was counted as Acartia centrura in series: B as the two species were separated only recently; Abraham, 1976).

Because of their abundance, copepods form the chief index of the utilization of the biotope at secondary level. Based on the distribution pattern, and variations in abundance of different species, it is possible to some extent to categorise them and evaluate the function of different groups among them in filling different biotopes.

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

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

P. jonesi, Acartia pacifica and A. southwelli. They were also present in the estuary by post-monsoon. They had sudden peaks in abundance in certain months, but unlike the previous group were not consistently abundant throughout the season. Variations did exist 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 two Acartia species A. southwelli showed a more restricted distribution as it was not found at all beyond the middle reaches. A. pacifica had an edge over A. southwelli in adapting itself more to the estuarine conditions. Pseudodiaptomus serricaudatus and P. jonesi exhibited more or less a similar pattern in distribution and Paracalanus aculeatus had more restricted occurrences. This species may even be grouped with the next category.

Two other euryhaline marine species Centropages alcocki and Labidocera pectinata were also common, but occurred in still lesser numbers. Except for these two species which propagated in the estuary, other species recorded from the two genera were only stragglers into the backwaters. Among the two C. alcocki showed less tolerance to lower salinities (Table 5) and was restricted to the lower reaches of the backwaters.

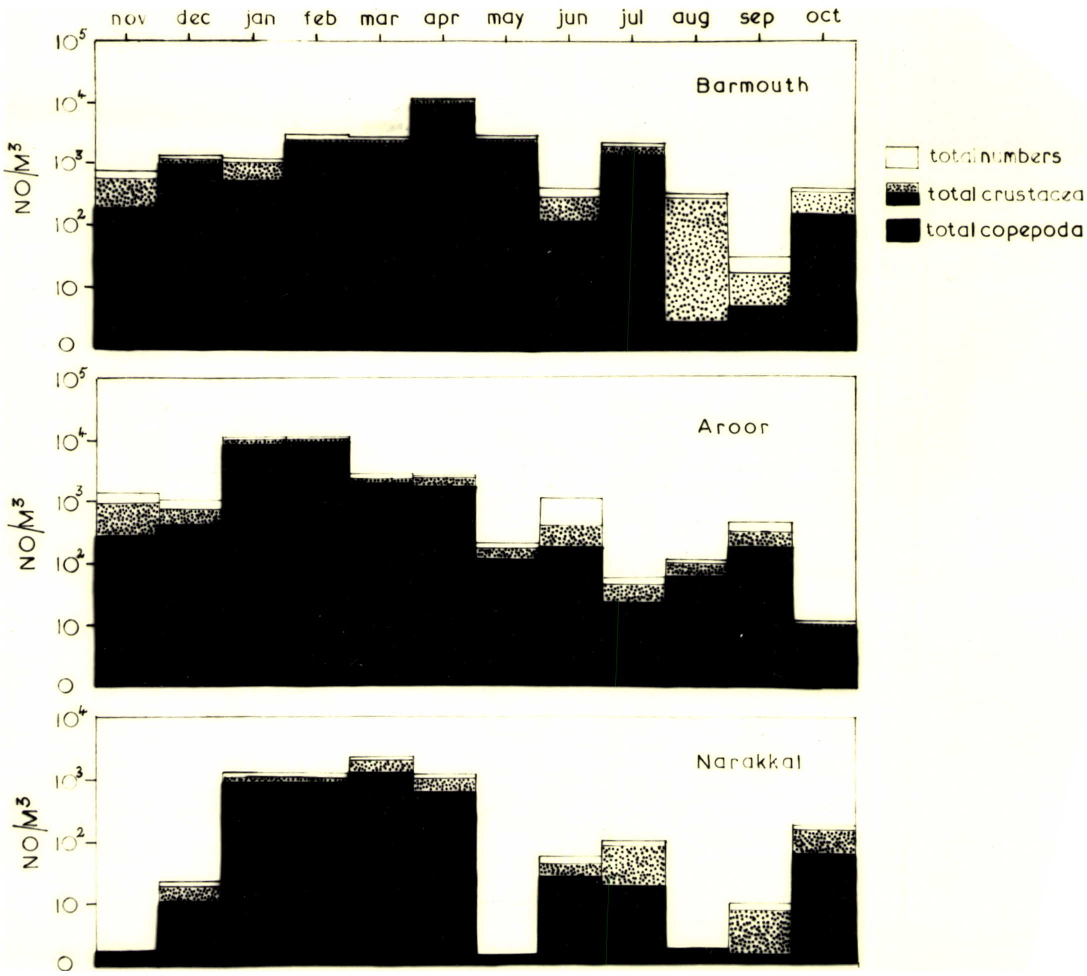
Acartia plumosa and Acartiella keralensis preferred medium salinities. Although the two species were more abundant in the estuary during pre-monsoon they were absent at the mouth during this season. They were present at Aroor and middle reaches where salinity was not very high during early pre-monsoon. When salinity registered higher values at these regions they shifted further up the estuary. The locality of their abundance oscillated with salinity vacillations. The two species together constituted 42.5 % of the total annual copepod counts in series:B. When monsoons started and upper reaches became freshwater, these species were observed at the mouth region. But later during the monsoon (August) they were absent at the mouth also. Their lack of adaptibility to high salinities is evident from their conspicuous absence at the three stations in June when salinity temporarily recovered during the monsoon period.

Pseudodiaptomus annandalei exhibited a peculiar distribution. It had a wide range of salinity tolerance (0-35 ‰) and occurred in large numbers in various salinities. They occurred throughout the year, but in low numbers during peak salinity months of March and April. It dominated some samples taken during monsoon period at the lower reaches. But strangel this species did not occur at the upper reaches at any time during the year (Fig. 18). This species seems to prefer stratified waters of early pre-monsoon, monsoon and post-monsoon seasons present at the lower reaches. Its salinity tolerance is probably used as an adaptation to survive in such conditions and to escape competition. But this species obviously cannot survive in total freshwater for long as they were always absent at the upper reaches which are shallow and remains freshwater from top to bottom for most of the year. It showed higher aggregation at the bottom layer during both day and night. Salinity penetration reaches the upper reaches only by late pre-monsoon, but vertically homogeneous conditions exist throughout the system during this period. This explains its occurrence in low numbers at the lower reaches during this period and its absence at the head of the estuary throughout the year.

Heliodiaptomus cinctus, Allodiaptomus mirabilipes, Archidiaptomus aroorus, Pseudodiaptomus 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 at the mouth. It dominated the copepod counts during the low salinity regime (Madhupratap et al., 1975). 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 salinity regime. O. brevicornis, O. hebes and O. nana were more tolerant to lower salinities, the last two more so than O. brevicornis.

FIGURE 13 : Composition of zooplankton (relative abundance of copepoda, total crustacea and non-crustacea) at barmouth, Cochin, Aroor and Narakkal from November, 1971 to October, 1972.



nov
dec
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
Barmouth
Aroor
Narakkal
NO/M³
total numbers
total crustacea
total copepoda

FIGURE 14 : Distribution of common species at barmouth, Cochin, Aroor and Narakkal from November, 1971 to October, 1972.

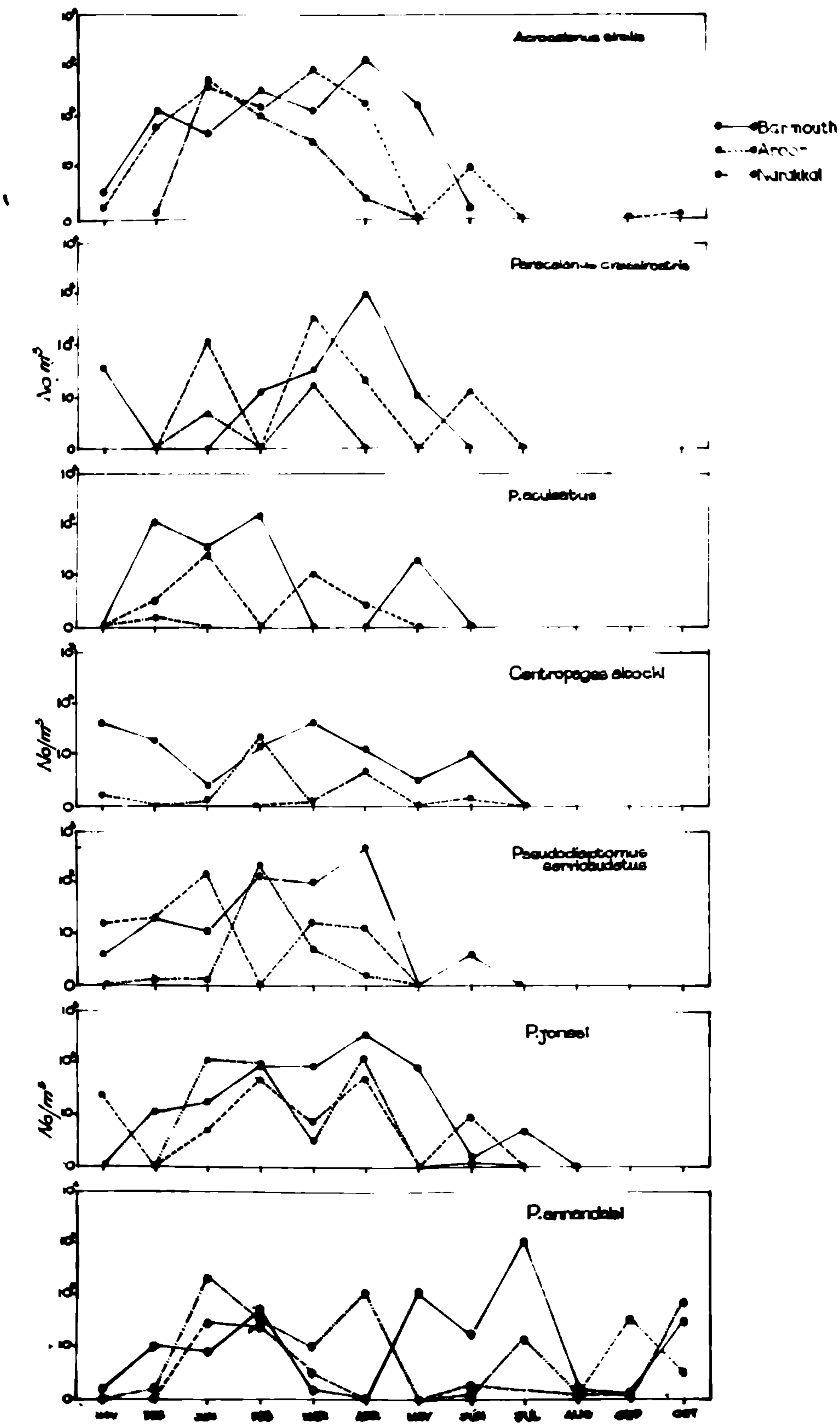

Acrocalanus similis
Paracalanus crassirostris
P. aculeatus
Centropages alcocki
Pseudodiaptomus serrulatus
P. jonesi
P. annandalei
Barmouth
Aroor
Nandikal
No/m³
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT

FIGURE 15 : Distribution of common species at barmouth, Cochin, Aroor and Narakkal from November, 1971 to October, 1972 (continued).

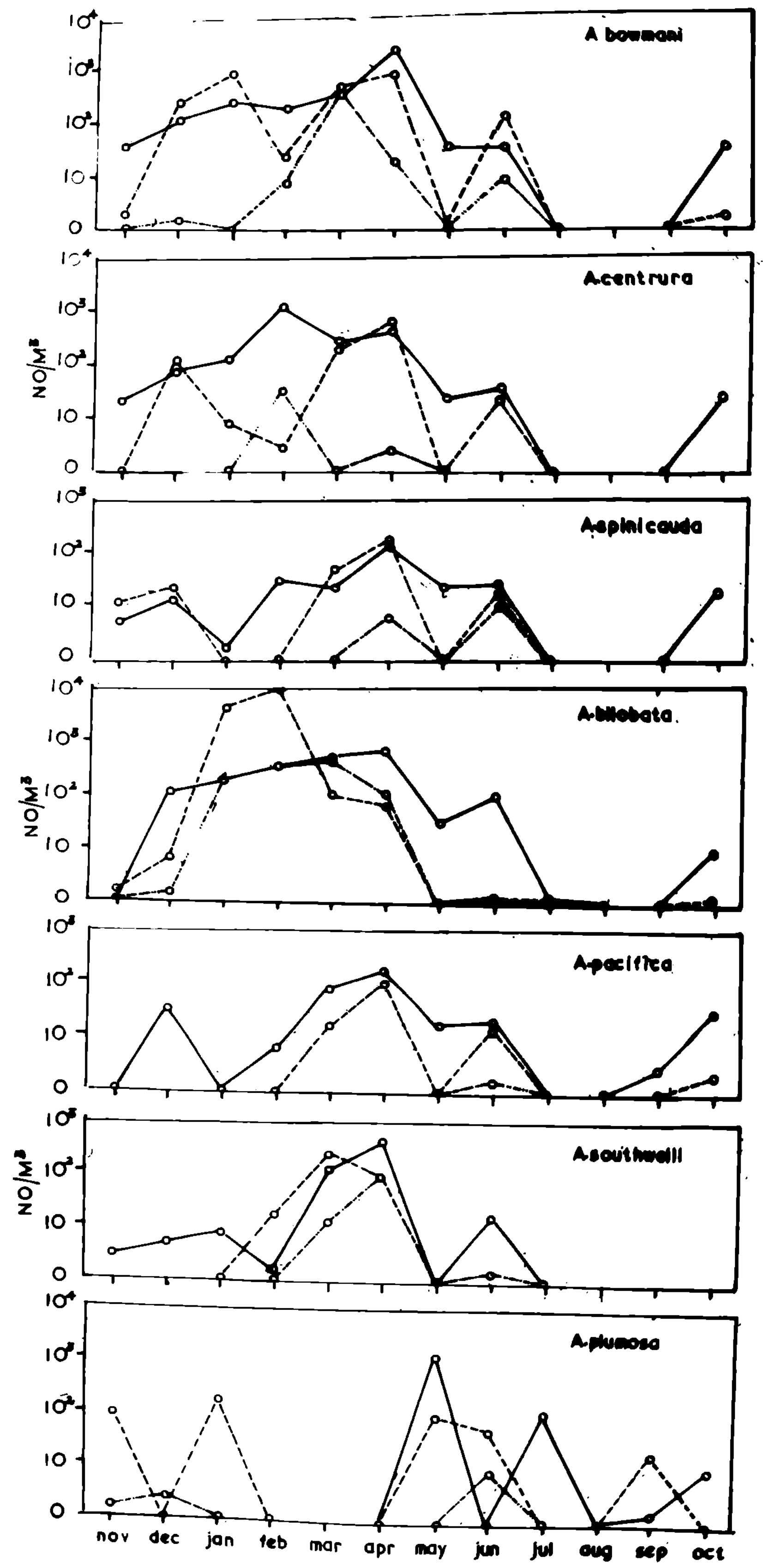

A bowmani
A.centrura
A.spinicauda
A.bilobata.
A.pacifica
A.southwelli
A.plumosa
NO/M³
nov
dec
jan
feb
mar
apr
may
jun
jul
aug
sep
oct

FIGURE 16 : (1) Distribution of common species at barmouth, Cochin, Aroor and Narakkal from November, 1971 to October, 1972 (continued).

(2) Distribution of total copepoda and major families among it (Paracalanidae, Pseudodiaptomidae and Acartiidae) at barmouth, Cochin, Aroor and Narakkal from November, 1971 to October, 1972.

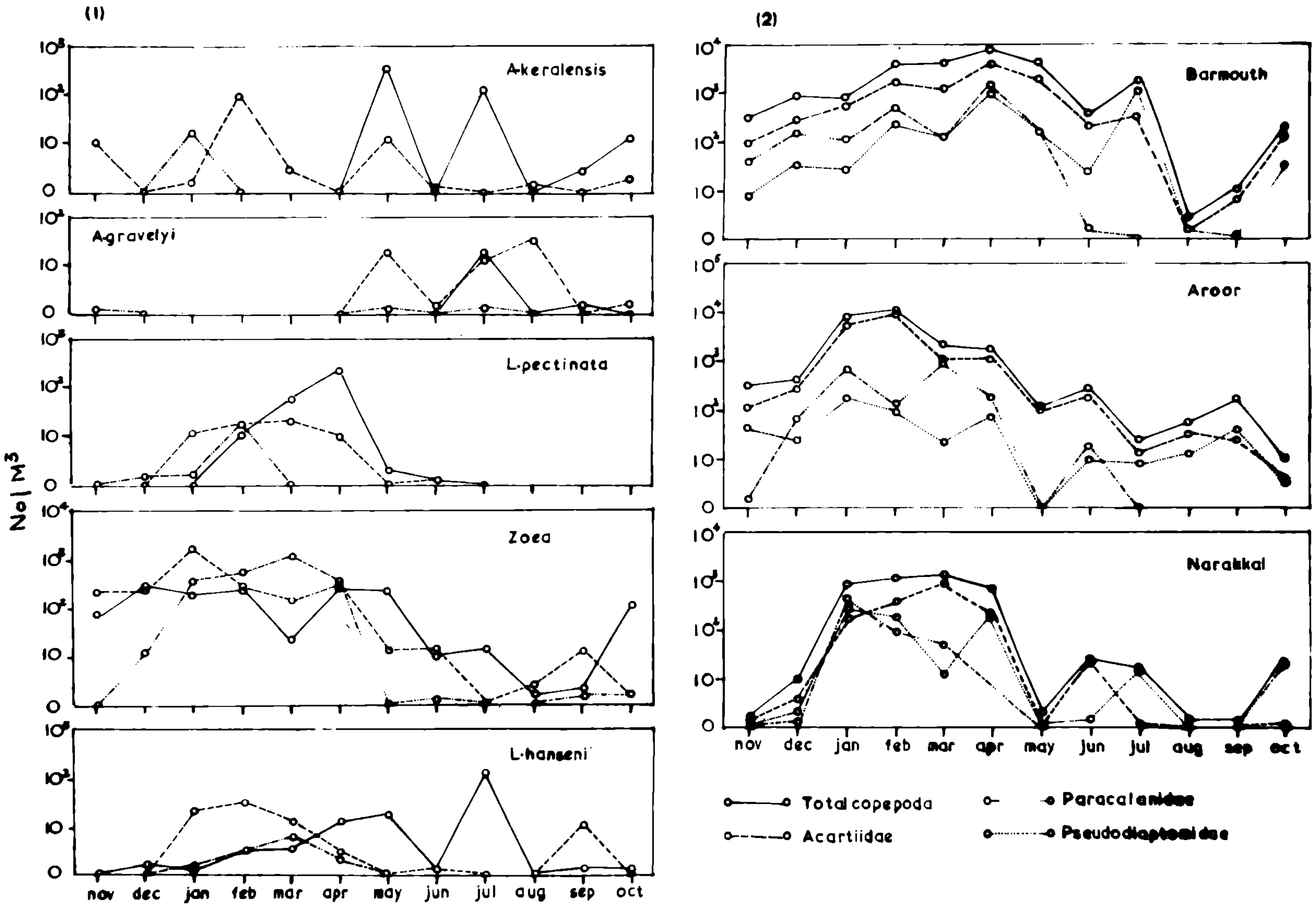

(1)
A.keralensis
A.gravelyi
L.pectinata
Zoea
L.hanseni
No/M3
nov dec jan feb mar apr may jun jul aug sep oct
(2)
Barmouth
Aroor
Narakkal
Total copepoda
Acartiidae
Paracalanidae
Pseudodiaptomidae

FIGURE 17 : Pattern of distribution of major groups of zooplankton in Series: B - over space (stations 1 to 7) and time (January to December, 1972).

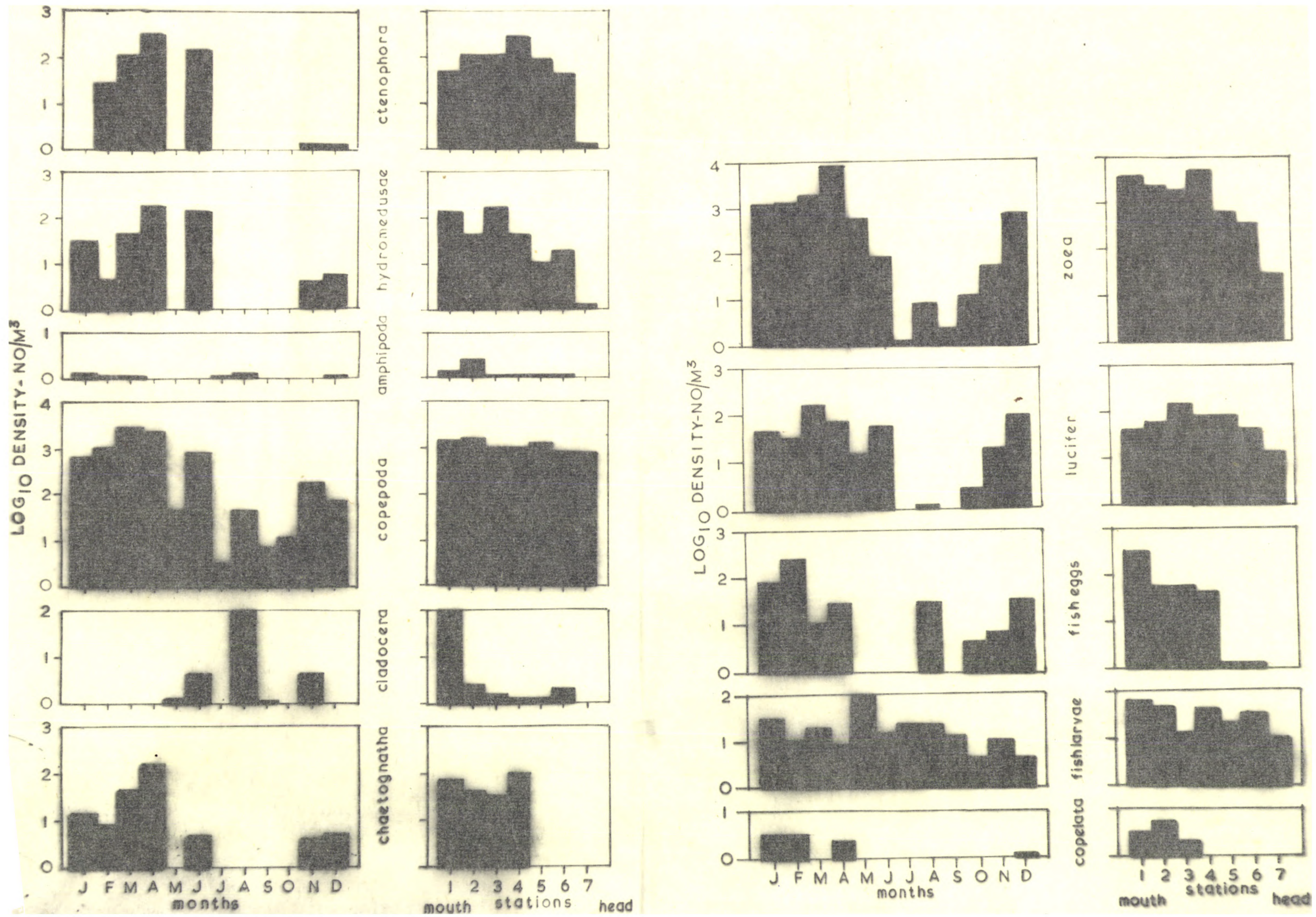
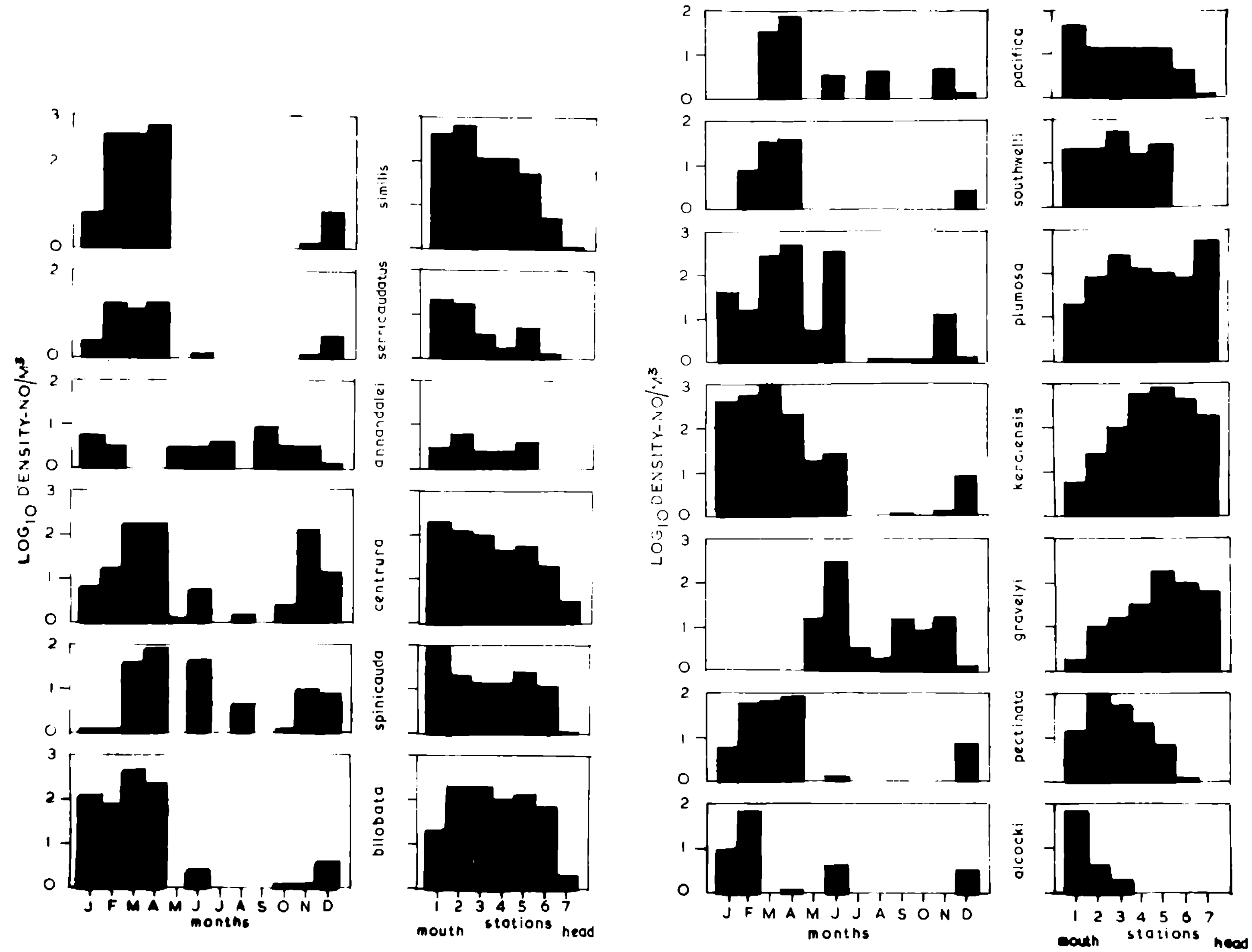

LOG10 DENSITY-NO/M³
ctenophora
hydromedusae
amphipoda
copepoda
cladocera
chaetognatha
zoea
lucifer
fish eggs
fishlarvae
copelata
J F M A M J J A S O N D
months
1 2 3 4 5 6 7
mouth
stations
head

FIGURE 18 : Pattern of distribution of common copepod species in Series: B over space (stations 1 to 7) and time (January to December, 1972).


LOG10 DENSITY-NO/M3
similis
serricaudatus
annandalei
centrura
spinicauda
bilobata
J F M A M J J A S O N D
months
1 2 3 4 5 6 7
mouth stations head
LOG10 DENSITY-NO/M3
pacifica
southwelli
plumosa
kerguensis
gravelyi
pectinata
alcocki
J F M A M J J A S O N D
months
1 2 3 4 5 6 7
mouth stations head

Family Acartiidae contributed to the majority of copepod counts in the estuary (Fig. 16,2). Ten species were recorded from the backwaters, the diversity of the family is higher than that found in any other area. Family Pseudodiaptomidae ranked next by having 8 species. But next to Acartiidae, family Paracalanidae dominated the copepod counts during pre-monsoon. Whereas families Acartiidae and Pseudodiaptomidae included low saline species to replace the high saline ones during monsoonal period, the abundance of species of the family Paracalanidae dwindled during this span.

MYSIDACEA

Mysids were usually absent in the day collections. They showed significant diel variations at all the three stations (Table 7,(36)), higher abundance being at night. Rhopalopthalmu indicus was the common mysid in the estuary. Siriella gracilis and in one occasion Mesopodopsis zeylanica also occurred in the samples. Mysids were more common during the saline period.

CUMACEA

These organisms occurred at times in the estuary when salinity was low. Probably fresh water cumaceans, they were not identified. Maximum density observed was 15.7 $/m^3$ at the mouth in July.

ISOPODA

Sphaeroma sp. and probably other species of isopods were present in the samples usually during night in various months. These wood boring organisms are not completely planktonic, but might have been caught in the net during their excursions (maximum density 4.5 /m^3 at Narakkal in April).

AMPHIPODA

Gammarid amphipods were present round the year in the collections (Table 4, G). They showed marked diel variations, being more abundant during night at all the three stations (Table 7, (37)). The species were not identified, but Corophium sp. is the most common amphipod in the estuary. Amphipods did not show significant seasonal variations except at Narakkal where they showed higher abundance in January, March, April and July. Their actual population cannot be judged from the plankton samples as they come up to the water column only occasionally. They contribute significantly to the benthos of the estuary and have been found to occur in large numbers in mud samples. Observations also showed that they are more abundant in the shallow northern portion of the estuary. Maximum density of amphipods in the plankton samples was recorded from Narakkal (400 /m^3 in January), a station located in this area.

SERGESTIDAE

Acetes spp. were present in various months at the three stations. They usually occurred in the night collections. Maximum density observed was 4.8 /m^3 in July at the mouth. Lucifer hanseni was common during pre-monsoon period and were present up to the head of the estuary. A peak was observed at the mouth in July. Large number of juveniles of this species also occurred in the backwaters. L. typus also showed a more or less similar distribution, but was less common occurring only in small numbers.

INVERTEBRATE EGGS AND LARVAE

Eggs of invertebrates were present at the mouth, Aroor and stations up the estuary in several months. Variations in their distribution was not significant. Maximum density in series: A was observed as 59 /m^3 at the mouth in April and 307.5 /m^3 at station 1 (series: B) in February.

Cyphonautes larvae of Bryozoa and actinotrocha larvae of Phoronida occurred in low numbers (0.2 /m^3) at the mouth and Aroor in April. Alima larvae of squilla was present at the mouth in February and April. Cirripede larvae was present throughout the year except in July with higher abundance in January, March, and April at Aroor and Narakkal (maximum density 105.9 /m^3 at Narakkal in January). Larvae of polychaetes occurred sporadically (maximum density 18.7 /m^3 in June at barmouth).

Decapod larvae constituted the majority of invertebrate larvae in the backwaters. In the total annual zooplankton counts they ranked second, next to copepods (majority in series: B). Zoea larvae of Brachiura was very common and occurred throughout the year at the mouth and except at the peak of the monsoon at the other stations. Higher abundance at the mouth was from October to February, April and May at the mouth; November and January to March at Aroor and in January to April at Narakkal (Maximum density - 3407 /m^3 at Aroor in January). But strangely megalopa larvae were rare and occurred only in small numbers (Table 8).

Larvae of caridea were more or less uniformly distributed throughout the year. Macrobrachium rosenbergii and M. idella are the two giant freshwater prawns common in the backwaters. Zoea and post larvae of these were present in the monsoon and post-monsoon months. Laboratory experiments have shown that M. idella breeds in medium salinities between 12 to 18 ‰(Pillai and Mohamed, 1973). Larvae of other carideans also constituted the composition (maximum density 62.8 /m^3 at Narakkal in July).

Penaeid larvae (protozoea, mysis and post larvae) of species such as Penaeus indicus, Metapenaeus dobsoni, M. monoceros and M. affinis occurred in the estuary in higher abundance during saline period. They were common in the lower reaches.

FISH EGGS AND LARVAE

Fish eggs were more abundant at the lower reaches and during pre-monsoon period (Series: B). But variations were not significant at the three stations although they were absent at the peak of the monsoon. Maximum density observed was 171.2 /m^3 at Aroor in March.

Fish larvae occurred round the year throughout the estuary. Peak density was observed as 282.7 /m^3 at barmouth in July. Larvae usually belonged to the group clupeoidei and families Ambassidae, Mugilidae and Gobidae. Larvae of families Hemiramphidae, Scianidae and Syngnathidae also occurred at the barmouth.

COPELATA

Appendicularians showed higher abundance during post-monsoon and early pre-monsoon periods at the mouth. At Aroor they were abundant in January, March and April. They were present only at the lower reaches (Fig. 17) and were absent during the low saline period except in small numbers in September (maximum density 585 /m^3 at barmouth in February).

THALIACEA

Salps and doliolids are common components of the zooplankton of the tropical marine waters. But they are usually absent in the estuaries. However, a single occurrence of the salp Thalia democratica and the doliolid Dolioletta gegenbauri was noticed at the mouth in June.

Apart from these groups sipunculids, gastropods and bivalves occurred in the estuary. The molluscs were usually observed during low saline months. They were sometimes present in large numbers (maximum density for gastropods 1167.2 /m^3 and bivalves 401.4 /m^3 at the mouth in August). Veliger larvae were conspicuously absent in the samples, this probably is because of the larger mesh size of the net used.

TABLE 7 : Results of analysis of variance

(1) TOTAL BIOMASS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	50894	46			
Seasonal	37059	11	3369	8.53[c]	Apr.
Diel	316	1	316	0.80	-
Tidal	492	1	492	1.25	-
Error	13027	33	394		
	C.D. for Seasonal variation = 28.51				
Aroor					
Total	52461.69	22			
Seasonal	37801.32	11	3436.48	2.35[a]	Jan,Feb,Apr.
Diel	35.30	1	35.30	0.02	-
Eroor	14625.07	10	1462.50		
	C.D. for seasonal variation = 85.20				
Narakkal					
Total	27733.17	19			
Seasonal	13828.78	11	1257.16	1.03	-
Diel	5340.00	1	5340.00	4.36[a]	Night
Error	8564.39	7	1223.48		
	C.D. for Diel variation = 33.77				

ss - Sum of squares
df - degrees of freedom
ms - mean square
C.D. - Critical difference or least significant difference.
a - F - significant at 5% level.
b - F - significant at 1% level.
c - F - significant at 0.1% level.

(2) TOTAL NUMBERS

Source	ss	df	ms	F	Maximum abundanc
Barmouth					
Total	30.75	46			
Seasonal	23.65	11	2.15	10.88^{c}	Apr.
Diel	0.53	1	0.53	2.67	-
Tidal	0.04	1	0.04	0.23	-
Error	6.53	33	0.19		
	C.D. for Seasonal variation = 0.63				
Aroor					
Total	24.91	22			
Seasonal	19.77	11	1.79	4.15^{c}	Jan-Apr.
Diel	0.82	1	0.81	1.89	-
Error	4.32	10	0.43		
	C.D. for Seasonal variation = 1.46				
Narakkal					
Total	235.75	19			
Seasonal	76.88	11	6.99	0.45	-
Diel	50.55	1	50.55	3.26	-
Error	108.32	7	15.47		

(3) EUTIMA COMMENSALIS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	69.17	46			
Seasonal	67.08	11	6.09	107.56^{c}	May,Jun.
Diel	0.11	1	0.11	1.99	-
Tidal	0.10	1	0.10	1.87	-
Error	1.88	33	0.05		
C.D. for Seasonal variation = 0.34					
Aroor					
Total	36.21	22			
Seasonal	35.60	11	3.23	58.63^{c}	Apr.
Diel	0.06	1	0.06	1.10	-
Error	0.55	10	0.05		
C.D. for Seasonal variation = 0.52					
Narakkal					
Total	23.89	19			
Seasonal	23.34	11	2.12	37.23^{c}	Apr.
Diel	0.14	1	0.14	2.59	-
Error	0.41	7	0.05		
C.D. for Seasonal variation = 0.56					

(4) EIRENE CEYLONENSIS

Source	ss	df	ms	F	Maximum abundanc
Barmouth					
Total	63.38	46			
Seasonal	61.48	11	5.58	98.06^c	May,Jun.
Diel	0.01	1	0.01	0.02	-
Tidal	0.01	1	0.01	0.27	-
Error	1.88	33	0.05		
	C.D. for Seasonal variation = 0.34				
Aroor					
Total	30.06	22			
Seasonal	25.77	11	2.34	8.98^c	Mar,Apr,J
Diel	1.67	1	1.67	6.43^b	Night
Error	2.62	10	0.26		
	C.D. for seasonal variation = 1.13 C.D. for diel variation = 1.17				
Narakkal					
Total	21.91	19			
Seasonal	20.93	11	1.99	18.53^c	Mar,Apr,(
Diel	0.22	1	0.22	2.12	-
Error	0.76	7	0.10		
	C.D. for Seasonal variation = 0.77				

(5) BLACKFORDIA VIRGINICA

Source	ss	df	ms	F	Maximum abundan
Barmouth					
Total	49.85	46			
Seasonal	45.65	11	4.15	32.91^{c}	May,Jun.
Diel	0.04	1	0.04	0.35	-
Tidal	0.00	1	0.00	0.00	-
Error	4.16	33	0.12		
	C.D. for seasonal variation = 0.50				
Aroor					
Total	30.01	22			
Seasonal	28.37	11	2.57	31.45^{c}	Apr,Jun.
Diel	0.82	1	0.82	10.02^{c}	Night
Error	0.82	10	0.08		
	C.D. for seasonal variation = 0.63 C.D. for diel variation = 0.25				
Narakkal					
Total	15.64	19			
Seasonal	9.33	11	0.84	1.01	-
Diel	0.45	1	0.45	0.54	-
Error	5.86	7	0.83		

(6) PLEUROBRACHIA SP.

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	94.93	46			
Seasonal	86.37	11	7.85	33.08[c]	Mar,Apr.
Diel	0.61	1	0.61	2.96	-
Tidal	1.14	1	1.14	5.53[a]	High tide
Error	6.81	33	0.20		
	C.D. for seasonal variation = 0.65 C.D. for tidal variation = 0.37				
Aroor					
Total	37.17	22			
Seasonal	34.89	11	3.17	21.39[c]	Mar,Apr.
Diel	0.79	1	0.79	5.37[b]	Night
Error	1.48	10	0.14		
	C.D. for seasonal variation = 0.85 C.D. for diel variation = 0.35				
Narakkal					
Total	28.55	19			
Seasonal	26.17	11	2.37	10.27[c]	Mar,Apr.
Diel	0.75	1	0.75	3.27	-
Error	1.63	7	0.23		
	C.D. for seasonal variation = 1.13				

(7) SAGITTA ENFLATA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	41.15	46			
Seasonal	27.27	11	2.48	4.17[a]	Nov.
Diel	0.17	1	0.17	0.28	-
Tidal	0.09	1	0.09	0.16	-
Error	19.62	33	0.59		
	C.D. for seasonal variation = 1.10				
Aroor					
Total	19.99	22			
Seasonal	13.99	11	1.27	2.29[a]	Dec,Jan,Au
Diel	0.43	1	0.43	0.77	-
Error	5.57	10	0.55		
	C.D. for seasonal variation = 1.66				
Narakkal					
Total	5.37	19			
Seasonal	3.91	11	0.35	1.95	-
Diel	0.18	1	0.18	1.02	-
Error	1.28	7	0.18		

(8) SAGITTA BEDOTI

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	78.24	46			
Seasonal	42.91	11	3.90	3.64^{b}	May,Jun.
Diel	0.01	1	0.01	0.01	-
Tidal	0.01	1	0.01	0.01	-
Error	35.31	33	1.07		
	C.D. for seasonal variation = 1.48				
Aroor					
Total	39.20	22			
Seasonal	30.31	11	2.75	3.84^{b}	Jan-Apr.
Diel	1.70	1	1.70	2.37	-
Error	7.19	10	0.71		
	C.D. for seasonal variation = 1.88				
Narakkal					
Total	17.93	19			
Seasonal	10.41	11	0.94	2.22^{a}	Feb,Mar.
Diel	4.53	1	4.53	10.63^{a}	Night
Error	2.98	7	0.4		
	C.D. for seasonal variation = 1.54				
	C.D. for diel variation = 0.63				

(9) SAGITTA OCEANIA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	39.34	46			
Seasonal	15.37	11	1.39	1.95	-
Diel	0.10	1	0.10	0.15	-
Tidal	0.25	1	0.25	0.36	-
Error	23.62	33	0.71		
Aroor					
Total	35.80	22			
Seasonal	32.76	11	2.97	10.79[c]	Mar,Apr.
Diel	0.28	1	0.28	1.02	-
Error	2.76	10	0.27		
	C.D. for seasonal variation = 1.17				
Narakkal					
Total	6.87	19			
Seasonal	3.25	11	0.29	0.67	-
Diel	0.54	1	0.54	1.24	-
Error	3.08	7	0.43		

(10) EVADNE TERGESTINA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	95.47	46			
Seasonal	77.60	11	7.05	14.33[c]	Nov.
Diel	0.01	1	0.01	0.01	-
Tidal	1.61	1	1.61	3.27	-
Error	16.25	33	0.49		
	C.D. for seasonal variation = 1.10				
Aroor					
Total	41.48	22			
Seasonal	27.96	11	2.54	1.92	-
Diel	0.30	1	0.30	0.23	-
Error	13.22	10	1.32		
Narakkal					
Total	22.94	19			
Seasonal	14.96	11	1.36	1.20	-
Diel	0.06	1	0.06	0.05	-
Error	7.92	7	1.13		

(11) PENILIA AVIROSTRIS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	55.64	46			
Seasonal	28.07	11	2.55	3.20^{b}	Jul,Oct,Nov.
Diel	0.65	1	0.65	0.82	-
Tidal	0.61	1	0.61	0.77	-
Error	26.31	33	0.79		
	C.D. for seasonal variation = 1.28				
Aroor					
Total	13.66	22			
Seasonal	11.90	11	1.08	6.91^{c}	Jun.
Diel	0.19	1	0.19	1.23	-
Error	1.57	10	0.15		
	C.D. for seasonal variation = 0.88				
Narakkal					
Total	12.01	19			
Seasonal	9.66	11	0.87	2.83^{a}	Jun,Jul.
Diel	0.17	1	0.17	0.58	-
Error	2.18	7	0.31		
	C.D. for seasonal variation = 1.31				

(12) COPEPODA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	72.52	46			
Seasonal	63.44	11	5.76	22.02[c]	Apr.
Diel	0.17	1	0.17	0.65	-
Tidal	0.26	1	0.26	1.01	-
Error	8.65	33	0.26		
C.D. for seasonal variation = 0.73					
Aroor					
Total	37.23	22			
Seasonal	26.12	11	2.37	2.69[b]	Jan-Apr.
Diel	2.26	1	2.26	2.56	-
Error	8.85	10	0.88		
C.D. for seasonal variation = 2.09					
Narakkal					
Total	73.35	19			
Seasonal	48.85	11	4.44	1.31	-
Diel	0.78	1	0.78	0.23	-
Error	23.72	7	3.38		

(13) ACROCALANUS SIMILIS

Source	ss	df	mm	F	Maximum abundance
Barmouth					
Total	177.13	46			
Seasonal	165.50	11	15.04	54.69^{c}	Feb, Apr.
Diel	0.06	1	0.06	0.25	-
Tidal	2.48	1	2.48	9.02^{b}	High Tide
Error	9.09	33	0.27		

C.D. for seasonal variation = 0.75
C.D. for tidal variation = 0.43

Source	ss	df	mm	F	Maximum abundance
Aroor					
Total	94.79	22			
Seasonal	89.06	11	8.09	16.95^{c}	Jan-Apr.
Diel	0.94	1	0.94	1.98	-
Error	4.79	10	0.47		

C.D. for seasonal variation = 1.54

Source	ss	df	mm	F	Maximum abundance
Narakkal					
Total	61.56	19			
Seasonal	47.78	11	4.34	7.24^{c}	Jan-Apr.
Diel	9.58	1	9.58	15.96^{c}	Night
Error	4.20	7	0.60		

C.D. for seasonal variation = 1.83
C.D. for diel variation = 0.74

(14) PACALANUS ACULEATUS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	137.13	46			
Seasonal	98.12	11	8.92	7.56[c]	Dec-Feb,May.
Diel	0.00	1	0.00	0.00	-
Tidal	0.04	1	0.04	0.04	-
Error	38.97	33	1.18		
	C.D. for seasonal variation = 1.55				
Aroor					
Total	41.48	19			
Seasonal	34.14	11	3.10	4.23[c]	Jan,Apr.
Diel	0.02	1	0.02	0.03	-
Error	7.32	10	0.73		
	C.D. for seasonal variation = 1.90				
Narakkal					
Total	5.63	19			
Seasonal	3.08	11	0.28	0.83	-
Diel	0.18	1	0.18	0.54	-
Error	2.37	7	0.33		

(15) PARACALANUS CRASSIROSTRIS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	162.07	46			
Seasonal	122.17	11	11.10	9.27^{c}	Feb-May
Diel	0.12	1	0.12	0.11	-
Tidal	0.22	1	0.22	0.18	-
Error	39.56	33	1.19		
	C.D. for seasonal variation = 1.57				
Aroor					
Total	78.69	22			
Seasonal	70.57	11	6.41	8.69^{c}	Jan,Mar,Jun.
Diel	0.74	1	0.74	1.01	-
Error	7.38	10	0.73		
	C.D. for seasonal variation = 1.91				
Narakkal					
Total	21.72	19			
Seasonal	9.66	11	0.87	0.52	-
Diel	0.19	1	0.19	0.12	-
Error	11.87	7	1.69		

(16) CENTROPAGES ALCOCKI

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	121.23	46			
Seasonal	59.59	11	5.41	3.60[b]	Nov,Mar-May.
Diel	0.29	1	0.29	0.20	-
Tidal	11.63	1	11.63	7.72[b]	High tide
Error	49.72	33	1.50		
	C.D. for seasonal variation = 1.76 C.D. for tidal variation = 1.01				
Aroor					
Total	28.53	22			
Seasonal	19.97	11	1.81	2.37[a]	Mar,Jun.
Diel	0.90	1	0.90	1.18	-
Error	7.66	10	0.76		
	C.D. for seasonal variation = 2.07				
Narakkal					
Total	15.18	19			
Seasonal	10.11	11	0.91	1.38	-
Diel	0.40	1	0.40	0.60	-
Error	4.67	7	0.66		

(17) HELIODIAPTOMUS CINCTUS

Source	ss	df	ms	F	Maximum abundance
Aroor					
Total	23.81	22			
Seasonal	22.02	11	2.00	12.01[c]	Jul,Aug.
Diel	0.12	1	0.12	0.74	-
Error	1.67	10	0.16		
	C.D. for seasonal variation = 0.90				
Narakkal					
Total	1.66	19			
Seasonal	0.78	11	0.07	0.61	-
Diel	0.05	1	0.05	0.50	-
Error	0.83	7	0.11		

(18) ALLODIAPTOMUS MIRABILIPES

Source	ss	df	ms	F	Maximum abundance
Aroor					
Total	19.45	22			
Seasonal	17.43	11	1.58	7.88^{c}	Jul,Oct.
Diel	0.01	1	0.01	0.04	-
Error	2.11	10	0.20		
	C.D. for seasonal variation = 0.99				
Narakkal					
Total	0.57	19			
Seasonal	0.27	11	0.02	0.61	-
Diel	0.02	1	0.02	0.50	-
Error	0.28	7	0.004		

(19) PSEUDODIAPTOMUS JONESI

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	159.05	46			
Seasonal	135.15	11	12.28	18.32[c]	Feb-May
Diel	1.30	1	1.30	1.95	-
Tidal	0.46	1	0.46	0.6	-
Error	22.14	33	0.67		
	C.D. for seasonal variation = 1.17				
Aroor					
Total	64.58	22			
Seasonal	44.35	1	4.03	2.29[a]	Nov, Jan, Feb, Apr.
Diel	2.64	1	2.64	1.50	-
Error	17.59	10	1.75		
	C.D. for seasonal variation = 2.95				
Narakkal					
Total	54.12	19			
Seasonal	30.89	11	2.80	1.22	-
Diel	7.12	1	7.12	3.09[a]	Night
Error	16.11	7	2.30		
	C.D. for diel variation = 1.46				

(20) PSEUDODIAPTOMUS SERRICAUDATUS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	130.97	46			
Seasonal	116.48	11	10.58	25.48[c]	Dec-Apr.
Diel	0.24	1	0.24	0.58	-
Tidal	0.52	1	0.52	1.27	-
Error	13.73	33	0.41		
	C.D. for seasonal variation = 0.92				
Aroor					
Total	67.09	22			
Seasonal	53.30	11	4.84	3.71[b]	Jan-Apr.
Diel	0.72	1	0.72	0.55	-
Error	18.07	10	1.30		
	C.D. for seasonal variation = 2.54				
Narakkal					
Total	32.05	19			
Seasonal	15.41	11	1.40	0.64	-
Diel	1.30	1	1.30	0.59	-
Error	15.34	7	2.19		

(21) PSEUDODIAPTOMUS ANNANDALEI

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	121.55	46			
Seasonal	86.06	11	7.82	7.85[c]	Feb,May-Jul.
Diel	2.04	1	2.04	2.05	-
Tidal	0.52	1	0.52	0.53	-
Error	32.93	33	0.99		
	C.D. for seasonal variation = 1.43				
Aroor					
Total	61.54	22			
Seasonal	36.57	11	3.32	1.68	-
Diel	5.18	1	5.18	2.62	-
Error	19.79	10	1.97		
Narakkal					
Total	63.42	19			
Seasonal	16.60	11	1.50	0.90	-
Diel	35.15	1	35.15	21.08[c]	Night
Error	11.67	7	1.66		
	C.D. for diel variation = 1.24				

(22) PSEUDODIAPTOMUS BINGHAMI MALAYALUS

Source	ss	df	ms	F	Maximum abundance
Aroor					
Total	25.18	22			
Seasonal	18.10	11	1.64	2.47[a]	Jul,Aug.
Diel	0.41	1	0.41	0.62	-
Error	6.67	10	0.66		
	C.D. for seasonal variation = 1.81				
Narakkal					
Total	12.78	19			
Seasonal	6.95	11	0.63	0.81	-
Diel	0.35	1	0.35	0.46	-
Error	5.48	7	0.78		

(23) ACARTIA BOWMANI

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	173.31	46			
Seasonal	145.99	11	15.09	68.72[c]	Apr.
Diel	0.06	1	0.06	0.29	-
Tidal	0.01	1	0.01	0.04	-
Error	7.25	33	0.21		
	C.D. for seasonal variation = 0.67				
Aroor					
Total	110.74	22			
Seasonal	87.80	11	7.98	4.79[c]	Jan,Mar,Apr,Jul
Diel	6.26	1	6.26	3.76	-
Error	16.68	10	1.66		
	C.D. for seasonal variation = 2.87				
Narakkal					
Total	47.98	19			
Seasonal	28.01	11	2.54	1.23	-
Diel	5.48	1	5.48	2.65	-
Error	14.49	7	2.06		

(24) ACARTIA CENTRURA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	172.53	46			
Seasonal	151.08	11	13.73	22.20[c]	Jan-Apr.
Diel	0.12	1	0.12	0.21	-
Tidal	0.90	1	0.90	1.46	-
Error	20.43	33	0.61		
	C.D. for seasonal variation = 1.12				
Aroor					
Total	82.95	22			
Seasonal	69.49	11	6.31	4.76[c]	Mar,Apr.
Diel	0.19	1	0.19	0.15	-
Error	13.27	10	1.32		
	C.D. for seasonal variation = 2.56				
Narakkal					
Total	30.98	19			
Seasonal	26.01	11	2.36	6.55[c]	Feb,Apr,Jun.
Diel	2.44	1	2.44	6.78[a]	Night
Error	2.53	7	0.36		
	C.D. for seasonal variation = 1.42				
	C.D. for diel variation = 0.57				

(25) ACARTIA SPINICAUDA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	139.66	46			
Seasonal	92.10	11	8.37	5.84°	Nov-Apr, Jun.
Diel	0.11	1	0.11	0.08	-
Tidal	0.15	1	0.15	0.11	-
Error	47.30	33	1.43		
	C.D. for seasonal variation = 1.71				
Aroor					
Total	70.63	22			
Seasonal	62.12	11	5.64	6.82°	Mar, Apr.
Diel	0.22	1	0.22	0.27	-
Error	8.29	10	0.82		
	C.D. for seasonal variation = 2.02				
Narakkal					
Total	27.08	19			
Seasonal	26.16	11	2.37	283.12°	Jun.
Diel	0.86	1	0.86	103.12°	Night
Error	0.06	7	0.01		
	C.D. for seasonal variation = 0.21				
	C.D. for diel variation = 0.08				

(26) ACARTIA BILOBATA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	192.20	46			
Seasonal	162.87	11	14.80	17.97[c]	Dec-Jun.
Diel	0.01	1	0.01	0.01	-
Tidal	2.13	1	2.13	2.59	-
Error	27.19	33	0.82		
	C.D. for seasonal variation = 1.30				
Aroor					
Total	113.70	22			
Seasonal	106.40	11	9.67	17.50[c]	Jan,Feb.
Diel	1.78	1	1.78	3.23	-
Error	5.52	10	0.55		
	C.D. for seasonal variation = 1.65				
Narakkal					
Total	73.99	19			
Seasonal	60.17	11	5.47	5.98[c]	Jan-Apr.
Diel	7.41	1	7.41	8.11[b]	Night
Error	6.41	7	0.91		
	C.D. for seasonal variation = 2.26				
	C.D. for diel variation = 0.92				

(27) ACARTIA PACIFICA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	159.32	46			
Seasonal	122.99	11	11.18	10.88^{c}	Dec,Mar-Jun.
Diel	1.30	1	1.30	1.27	-
Tidal	1.12	1	1.12	1.10	-
Error	33.91	33	1.02		
	C.D. for seasonal variation = 1.45				
Aroor					
Total	53.19	22			
Seasonal	35.49	11	3.22	1.87	-
Diel	0.42	1	0.42	0.25	-
Error	17.28	10	1.72		
Narakkal					
Total	9.45	19			
Seasonal	4.20	11	0.38	0.51	-
Diel	0.04	1	0.04	0.06	-
Error	5.21	7	0.74		

(28) ACARTIA SOUTHWELLI

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	145.94	46			
Seasonal	111.06	11	10.09	9.64^{c}	Jan,Mar,Apr,Jun.
Diel	0.16	1	0.16	0.15	-
Tidal	0.16	1	0.16	0.16	-
Error	34.56	33	1.04		
	C.D. for seasonal variation = 1.46				
Aroor					
Total	71.10	22			
Seasonal	64.33	11	5.84	10.22^{c}	Mar,Apr.
Diel	1.05	1	1.05	1.84	-
Error	5.72	10	0.57		
	C.D. for seasonal variation = 1.68				
Narakkal					
Total	42.24	19			
Seasonal	38.23	11	3.47	19.82^{c}	Mar,Apr.
Diel	2.77	1	2.77	15.85^{c}	Night
Error	1.24	7	0.17		
	C.D. for seasonal variation = 0.99				
	C.D. for diel variation = 0.40				

(29) ACARTIA PLUMOSA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	120.65	46			
Seasonal	94.43	11	8.58	14.47[c]	May
Diel	3.16	1	3.16	5.34[a]	Day
Tidal	3.47	1	3.47	5.86[a]	Low
Error	19.59	33	0.59		
	C.D. for seasonal variation = 1.10 C.D. for diel variation = 0.63 C.D. for tidal variation = 0.63				
Aroor					
Total	79.10	22			
Seasonal	54.66	11	4.96	2.04	-
Diel	0.07	1	0.07	0.03	-
Error	24.37	10	2.43		
Narakkal					
Total	18.49	19			
Seasonal	11.82	11	1.07	1.13	-
Diel	0.02	1	0.02	0.02	-
Error	6.65	7	0.94		

(30) ACARTIELLA KERALENSIS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	123.02	46			
Seasonal	104.60	11	9.50	17.93^{c}	May
Diel	0.39	1	0.39	0.75	-
Tidal	0.51	1	0.51	0.98	-
Error	17.52	11	0.53		
	C.D. for seasonal variation = 1.04				
Aroor					
Total	52.86	22			
Seasonal	29.49	11	2.68	1.42	-
Diel	4.54	1	4.54	2.41	-
Error	18.82	10	1.88		
Narakkal					
Total	13.77	19			
Seasonal	6.67	11	0.60	0.67	-
Diel	0.79	1	0.79	0.88	-
Error	6.31	7	0.90		

(31) ACARTIELLA GRAVELYI

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	33.98	46			
Seasonal	20.21	11	1.83	5.01[c]	Jul.
Diel	1.40	1	1.40	3.83	-
Tidal	0.26	1	0.26	0.72	-
Error	12.11	33	0.36		
	C.D. for seasonal variation = 0.86				
Aroor					
Total	42.55	22			
Seasonal	34.33	11	3.12	4.46[c]	Jul,Aug.
Diel	1.03	1	1.03	1.47	-
Error	6.99	10	0.69		
	C.D. for seasonal variation = 1.86				
Narakkal					
Total	13.31	19			
Seasonal	10.84	11	0.98	3.59[b]	Jul,Aug.
Diel	0.54	1	0.54	1.98	-
Error	1.93	7	0.27		
	C.D. for seasonal variation = 1.23				

(32) LABIDOCERA PECTINATA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	156.84	46			
Seasonal	142.93	11	12.99	31.83*	Feb-Apr.
Diel	0.29	1	0.29	0.72	-
Tidal	0.14	1	0.14	0.34	-
Error	13.48	33	0.40		
	C.D. for seasonal variation = 0.91				
Aroor					
Total	56.12	22			
Seasonal	53.53	11	4.86	23.20*	Jan-Apr.
Diel	0.49	1	0.49	2.34	-
Error	2.10	10	0.20		
	C.D. for seasonal variation = 1.02				
Narakkal					
Total	19.04	19			
Seasonal	11.93	11	1.08	1.07	-
Diel	0.01	1	0.01	0.02	-
Error	7.10	7	1.01		

(33) OITHONA RIGIDA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	74.83	46			
Seasonal	39.12	11	3.55	3.37[b]	Jan-Apr.
Diel	0.14	1	0.14	0.14	-
Tidal	0.75	1	0.75	0.72	-
Error	34.82	33	1.05		
	C.D. for seasonal variation = 1.47				
Aroor					
Total	31.53	22			
Seasonal	31.35	11	2.85	157.46[c]	Apr.
Diel	0.00	1	0.00	0.00	-
Error	0.18	10	0.01		
	C.D. for seasonal variation = 0.29				
Narakkal					
Total	31.54	19			
Seasonal	30.72	11	2.79	54.56[c]	Feb,Apr.
Diel	0.45	1	0.45	8.93[b]	Night
Error	0.37	7	0.05		
	C.D. for seasonal variation = 0.53				
	C.D. for diel variation = 0.21				

(34) OITHONA BREVICORNIS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	91.69	46			
Seasonal	50.84	11	4.62	3.98[b]	Nov,Jan, Feb,Jun.
Diel	1.70	1	1.70	1.47	-
Tidal	0.82	1	0.82	0.71	-
Error	38.33	33	1.16		
	C.D. for seasonal variation = 1.54				
Aroor					
Total	40.36	22			
Seasonal	28.88	11	2.62	2.33[a]	Feb-Apr,Jun.
Diel	0.22	1	0.22	0.20	-
Error	11.26	10	1.12		
	C.D. for seasonal variation = 2.36				
Narakkal					
Total	14.49	19			
Seasonal	8.45	11	0.76	0.91	-
Diel	0.14	1	0.14	0.17	-
Error	5.90	7	0.84		

(35) OITHONA HEBES

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	69.99	46			
Seasonal	46.96	11	4.26	6.43[c]	Nov,Jun,Sep.
Diel	0.03	1	0.03	0.01	-
Tidal	1.09	1	1.09	1.65	-
Error	21.91	33	0.66		
	C.D. for seasonal variation = 1.16				
Aroor					
Total	38.09	22			
Seasonal	23.12	11	2.10	1.44	-
Diel	0.36	1	0.36	0.25	-
Error	14.61	10	1.46		
Narakkal					
Total	13.67	19			
Seasonal	5.71	11	0.51	0.46	-
Diel	0.12	1	0.12	0.11	-
Error	7.84	7	1.11		

(36) MYSIDS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	34.65	66			
Seasonal	17.98	11	1.63	4.33[c]	Jan,Feb,May.
Diel	4.15	1	4.15	11.00[c]	Night
Tidal	0.05	1	0.05	0.15	-
Error	12.47	33	0.37		
	C.D. for seasonal variation = 0.88				
	C.D. for diel variation = 0.50				
Aroor					
Total	24.53	22			
Seasonal	11.74	11	1.06	1.85	-
Diel	7.00	1	7.00	12.10[b]	Night
Error	5.79	10	0.57		
	C.D. for diel variation = 0.69				
Narakkal					
Total	16.89	19			
Seasonal	7.04	11	0.64	0.79	-
Diel	4.19	1	4.19	5.20[a]	Night
Error	5.66	7	0.80		
	C.D. for diel variation = 0.86				

(37) AMPHIPODA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	92.12	46			
Seasonal	12.93	11	1.17	1.06	-
Diel	42.69	1	42.69	38.66[c]	Night
Tidal	0.05	1	0.05	0.05	-
Error	36.45	33	1.10		
	C.D. for diel variation = 0.8706				
Aroor					
Total	45.96	22			
Seasonal	19.35	11	1.75	1.68	-
Diel	16.14	1	16.14	15.43[c]	Night
Error	10.47	10	1.04		
	C.D. for diel variation = 0.9299				
Narakkal					
Total	38.25	19			
Seasonal	27.19	11	2.47	3.08[b]	Jan, Mar, Apr, Jul.
Diel	5.43	1	5.43	6.77[b]	Night
Error	5.63	7	0.80		
	C.D. for seasonal variation = 2.11 C.D. for diel variation = 0.86				

(38) LUCIFER HANSENI

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	99.99	46			
Seasonal	71.75	11	6.52	8.40^{c}	Feb-May
Diel	1.59	1	1.59	2.05	-
Tidal	1.01	1	1.01	1.31	-
Error	25.64	33	0.77		
	C.D. for seasonal variation = 1.26				
Aroor					
Total	56.57	22			
Seasonal	49.99	11	4.54	8.53^{c}	Jan-Apr.
Diel	1.25	1	1.25	2.35	-
Error	5.33	10	0.53		
	C.D. for seasonal variation = 1.62				
Narakkal					
Total	28.31	19			
Seasonal	21.85	11	1.98	7.68^{c}	Feb,Mar.
Diel	4.64	1	4.64	17.94^{c}	Night
Error	1.82	7	0.25		
	C.D. for seasonal variation = 1.20 C.D. for diel variation = 0.49				

(39) LUCIFER TYPUS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	56.50	46			
Seasonal	21.89	11	1.99	2.27[a]	Apr,May,Jul.
Diel	2.28	1	2.28	2.61	-
Tidal	3.36	1	3.36	3.84	-
Error	28.98	33	0.87		
	C.D. for seasonal variation = 1.34				
Aroor					
Total	29.61	22			
Seasonal	18.56	11	1.68	2.24[a]	Jan.
Diel	3.52	1	3.52	4.33[a]	Night
Error	7.53	10	0.75		
	C.D. for seasonal variation = 1.93				
	C.D. for diel variation = 0.78				
Narakkal					
Total	2.48	19			
Seasonal	1.10	11	0.10	0.59	-
Diel	0.18	1	0.18	1.05	-
Error	1.19	7	0.17		

(40) INVERTEBRATE EGGS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	80.01	46			
Seasonal	27.22	11	2.47	1.75	-
Diel	4.07	1	4.07	2.88	-
Tidal	2.09	1	2.09	1.48	-
Error	46.63	33	1.41		
Aroor					
Total	32.94	22			
Seasonal	12.96	11	1.17	0.61	-
Diel	0.57	1	0.57	0.30	-
Error	19.41	10	1.94		
Narakkal					
	Absent				

(41) POLYCHAETE LARVAE

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	59.55	46			
Seasonal	16.82	11	1.52	1.25	-
Diel	2.20	1	2.20	1.80	-
Tidal	0.04	1	0.04	0.03	-
Error	40.49	33	1.22		
Aroor					
Total	30.66	22			
Seasonal	17.11	11	1.55	1.47	-
Diel	2.93	1	2.93	2.76	-
Error	10.62	10	1.06		
Narakkal					
Total	5.46	19			
Seasonal	2.25	11	0.20	0.50	-
Diel	0.35	1	0.34	0.85	-
Error	2.86	7	0.40		

(42) CIRRIPEDE LARVAE

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	93.18	46			
Seasonal	25.04	11	2.27	1.18	-
Diel	1.06	1	1.06	0.55	-
Tidal	3.19	1	3.19	1.65	-
Error	63.89	33	1.93		
Aroor					
Total	69.54	22			
Seasonal	51.62	11	4.69	2.86[a]	Jan, Mar, Apr.
Diel	1.48	1	1.48	0.91	-
Error	16.44	10	1.64		

C.D. for seasonal variation = 2.85

Source	ss	df	ms	F	Maximum abundance
Narakkal					
Total	45.83	19			
Seasonal	36.13	11	3.28	3.24[b]	Mar, Apr.
Diel	2.59	1	2.59	2.56	-
Error	7.11	7	1.01		

C.D. for seasonal variation = 2.38

(43) ZOEA LARVAE

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	73.16	46			
Seasonal	44.71	11	4.06	4.78[c]	Oct-Feb, Apr, May.
Diel	0.38	1	0.38	0.46	-
Tidal	0.01	1	0.01	0.01	-
Error	28.06	33	0.85		
	C.D. for seasonal variation = 1.32				
Aroor					
Total	61.61	22			
Seasonal	54.89	11	4.99	7.44[c]	Nov, Jan-Mar.
Diel	0.01	1	0.01	0.02	-
Error	6.71	10	0.67		
	C.D. for seasonal variation = 1.82				
Narakkal					
Total	66.95	19			
Seasonal	52.70	11	4.79	6.02[c]	Jan-Apr.
Diel	8.68	1	8.68	10.91[b]	Night
Error	5.57	7	0.79		
	C.D. for seasonal variation = 2.11 C.D. for diel variation = 0.86				

(44) CARIDEA LARVAE

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	87.10	46			
Seasonal	16.92	11	1.53	0.74	-
Diel	0.02	1	0.02	0.01	-
Tidal	1.34	1	1.34	0.64	-
Error	68.82	33	2.08		
Aroor					
Total	27.19	22			
Seasonal	9.80	11	0.89	0.52	-
Diel	0.39	1	0.39	0.23	-
Error	17.00	10	1.70		
Narakkal					
Total	37.82	19			
Seasonal	21.08	11	1.91	1.13	-
Diel	4.85	1	4.85	2.86	-
Error	11.89	7	1.69		

(45) FISH EGGS

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	127.00	46			
Seasonal	46.90	11	4.26	1.93	-
Diel	5.32	1	5.32	2.42	-
Tidal	1.97	1	1.97	0.89	-
Error	72.81	33	2.20		
Aroor					
Total	58.53	22			
Seasonal	37.84	11	3.44	1.71	-
Diel	0.57	1	0.57	0.28	-
Error	20.12	10	2.01		
Narakkal					
Total	0.46	19			
Seasonal	0.21	11	0.02	0.61	-
Diel	0.01	1	0.01	0.50	-
Error	0.24	7	0.03		

(46) FISH LARVAE

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	66.00	46			
Seasonal	20.66	11	1.87	1.43	-
Diel	1.98	1	1.98	1.52	-
Tidal	0.14	1	0.14	0.11	-
Error	43.22	33	1.30		
Aroor					
Total	19.55	22			
Seasonal	10.63	11	0.96	1.23	-
Diel	1.06	1	1.06	1.36	-
Error	7.86	10	0.78		
Narakkal					
Total	23.47	19			
Seasonal	14.93	11	1.35	1.11	-
Diel	0.01	1	0.01	0.04	-
Error	8.53	7	1.21		

(47) COPELATA

Source	ss	df	ms	F	Maximum abundance
Barmouth					
Total	128.20	46			
Seasonal	89.79	11	8.16	7.78°	Nov-Feb.
Diel	3.06	1	3.06	2.92	-
Tidal	0.71	1	0.71	0.68	-
Error	34.64	33	1.04		
	C.D. for seasonal variation = 1.47				
Aroor					
Total	59.31	22			
Seasonal	46.98	11	4.27	4.51°	Jan,Mar,Apr.
Diel	2.85	1	2.85	3.01	-
Error	9.48	10	0.94		
	C.D. for seasonal variation = 2.16				
Narakkal					
Total	10.95	19			
Seasonal	5.44	11	0.49	0.69	-
Diel	0.55	1	0.55	0.78	-
Error	4.96	7	0.70		

TABLE 8: Distribution of Groups/Species (those not represented in graphs) at Barmouth, Aroor and Narakkal in 1971-72.

Months	Barmouth	Aroor	Narakkal
A. HYDROMEDUSAE			
Blackfordia virginica			
January	-	1	-
February	-	1	-
March	-	6	1
April	2	-	2
May	3	15	-
June	8	-	1
Eucheilota menoni			
December	1.5	-	-
January	1.0	-	-
March	2.0	23	3.0
April	1.2	-	-
June	3.2	-	-
Eirene menoni			
March	-	3.5	2.0
June	-	0.1	-
May	3.0	-	-
September	-	0.3	-

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
January	-	1	-
February	-	1	-
March	-	3	2
April	1	1	3
May	17	-	-
June	12	34	1
<u>Eutima commensalis</u>			
December	-	1	-
January	-	1	1
February	-	1	1
March	-	8	2
April	1	49	16
May	17	-	-
June	12	1	-
<u>Eutima neucaledonia</u>			
April	-	0.6	-
<u>Hydromedusae</u> (<u>Unidentified</u>)			
March	6	10	0.4
April	1.5	2	0.3
June	7.0	7.1	0.1
September	1.0	-	-

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
B. SIPHONOPHORA			
Diphyes chamissonis			
December	1.0	-	-
Lensia subteloides			
June	-	-	3.0
November	0.9	-	-
C. CTENOPHORA			
Pleurobrachia sp.			
January	-	0.8	-
February	7	2	1
March	13.6	25.2	12
April	18	5	15
May	2	-	-
June	3.0	2	-
Beroe Sp.			
January	-	0.2	-
March	0.4	0.8	-
June	1.1	-	-
D. CHEATOGNATHA			
Sagitta enflata			
November	2	-	-
December	6	2	1
January	1	3	-

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
February	1	1	1
June	1	1	-
September	-	1	-
October	1.2	-	-
<u>S. bedoti</u>			
December	1	1	-
January	1	10	1
February	3	5	3
March	5	1	1
April	4	2	-
May	19	-	-
June	16	5	-
September	1	4	-
October	1	-	1
<u>S. oceania</u>			
March	3	4	3
April	11	46	1
May	1	-	-
<u>S. robusta</u>			
December	0.2	-	-
February	-	1.0	-
June	28	-	-

TABLE 8 (Condt.)

Months	Barmouth	Aroor	Narakkal
E. INVERTEBRATE EGGS			
November	2	-	-
December	6	-	-
January	-	1	-
March	3	16	-
April	59	-	-
May	-	2	-
June	16	2	-
August	1	-	-
September	1	22	-
October	7	-	-
F. POLYCHAETE LARVAE			
November	-	1	-
January	1	-	-
February	1	2	-
March	1	2	-
April	-	-	1
May	1	-	-
June	19	5	-
July	4	-	-
August	1	-	-
September	1	-	-

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
G. CIRREPEDE LARVAE			
November	20	2	-
December	2	-	-
January	4	34	106
February	36	-	-
March	5	5	16
April	-	38	69
May	2	-	-
June	2	94	2
August	1	-	-
September	1	59	-
October	1	-	-
H. PROTOZOEA			
November	7	-	-
December	8	-	-
January	7	-	0.5
February	72	-	-
March	32	19	-
April	7	2	-
June	1	-	0.4
August	0.2	-	0.4
September	0.3	-	0.1
October	1	-	0.2

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
I. ALIMA LARVAE			
February	0.2	-	-
March	0.2	-	-
April	0.3	-	0.2
J. MEGALOPA LARVAE			
January	-	-	0.4
February	-	0.5	-
April	0.5	-	0.1
K. CARIDEA LARVAE			
November	1	26	-
December	5	1	1
January	5	5	54
February	4	3	-
March	9	46	25
April	6	13	21
May	2	14	-
June	6	8	-
July	26	2	63
August	9	1	1
September	1	12	1
October	18	2	2

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
L. OSTRACODA			
November	0.2	-	-
April	1.2	-	-
May	1.0	-	-
October	-	0.7	-
M. CUMACEA			
November	0.6	-	-
December	0.3	-	-
May	1.0	-	-
June	1.5	2.0	-
July	15.7	1.5	-
August	0.1	1.0	-
September	0.1	-	-
N. ISOPODA			
Sphaeroma sp.			
December	0.4	-	-
January	-	-	1.0
March	-	1.6	-
April	-	0.6	4.5
May	1.2	0.5	-
June	0.3	0.3	2.0
July	-	1.0	-
August	0.02	0.1	0.04
October	0.4	0.1	1.5

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
O. MYSIDS			
January	1	1	-
February	1	1	-
March	2	24	10
April	3	2	1
May	1	-	-
June	-	1	-
July	-	1	-
P. SERGESTIDAE			
Acetes spp.			
January	-	1.5	-
February	-	0.6	-
April	1.0	0.3	1.1
May	1.5	2.4	-
June	2.5	1.0	-
July	4.8	-	0.5
October	0.5	0.1	-
Lucifer hanseni			
December	2	-	-
January	1	33	2
February	5	51	5
March	6	21	8
April	20	5	3

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
May	24	-	-
June	1	1	-
July	458.9	-	-
September	1	14	-
October	1	-	-
L. typus			
January	-	6	1
February	-	3	-
March	1	-	1
April	8	2	-
May	2	-	-
June	1	-	-
July	18	-	-
September	-	2	-
October	1	-	-
Q. COPEPODA			
Canthocalanus pauper			
February	0.5	-	-
March	5.0	-	-
Undinula vulgaris			
November	0.3	-	-
January	1.1	-	-
February	-	0.6	-

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
Eucalanus monachus			
December	0.9	-	-
January	2.5	-	-
June	-	1.9	-
E. crassus			
December	1.0	-	-
January	1.8	-	-
E. subcrassus			
December	0.2	-	-
January	2.0	-	-
Centropages furcatus			
December	1.0	-	-
January	2.5	-	-
June	-	1.9	-
C. tenuiremis			
February	-	-	13
March	54.2	-	-
June	-	0.2	-
September	0.04	-	-
C. trispinosus			
December	6.5	-	-
January	19	-	-
February	-	-	11

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
Heliodiaptomus cinctus			
May	-	0.5	0.2
July	75	14	-
August	0.3	4	-
October	-	0.8	-
Allodiaptomus mirabilipes			
May	-	0.3	0.1
July	18	6.0	-
August	-	0.2	-
September	-	0.5	-
October	-	1.1	-
Archidiaptomus aroorus			
October	-	2.1	-
Pseudodiaptomus aurivilli			
May	4.0	-	-
June	-	0.2	0.2
P. mertoni			
June	7.7	-	-
P. tollingarae			
September	0.3	-	-

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
P. binghami malayalus			
February	-	-	0.1
July	-	7.0	6.0
August	0.2	15.5	0.4
October	-	0.2	0.1
Temora turbinata			
November	12	-	-
January	1.5	-	-
March	-	1.1	-
June	-	0.9	-
T. stylifera			
January	11.5	-	-
Calanopia elliptica			
January	6.0	-	-
February	5.5	-	-
March	1.5	0.8	-
C. minor			
January	1.6	-	-
Labidocera acuta			
May	4.5	-	-
L. kroyeri var. galliensis			
April	48	-	-
June	3	-	-

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
Acartia erythraea			
December	75	-	-
April	6.5	2.1	1.2
Euterpina acutifrons			
April	-	-	2.4
May	4.3	-	-
Nitocra spinipes			
January	1.2	-	-
May	0.4	-	-
June	1.0	0.7	-
Parategastes caprinus			
June	0.2	-	-
Oithona rigida			
January	7	-	-
February	35	4	38
March	2	-	-
April	3	37	9
June	1	-	-
O. brevicornis			
November	34	1	-
December	3	1	-
January	-	11	-

TABLE 8 (Contd.)

Months	Barmouth	Aroor	Narakkal
February	12	6	5
March	-	40	-
April	-	4	1
June	1	1	-
September	-	3	-
October	12	1	-
<u>*O. hebes*</u>			
November	46	15	-
January	-	3	-
February	-	1.2	2
March	-	1	4.2
June	1	1	0.2
July	1	1.1	-
August	3	0.8	-
September	2	12	-
<u>*O. Nana*</u>			
January	0.4	1.2	0.2
February	-	0.3	-
March	-	1.3	-

TABLE 8 (Contd.

Months	Barmouth	Aroor	Narakkal
Corycaeus Sp.			
January	12.7	-	-
February	1.5	-	-
Saphrina Sp.			
June	-	0.7	-
R. GASTROPODS			
November	-	117	-
December	0.2	-	-
January	-	10	-
April	1.5	-	328
May	1.0	-	-
June	18.0	224	5
August	1167	-	-
September	214	15	0.4
October	12	-	-

TABLE 8 (Contd.)

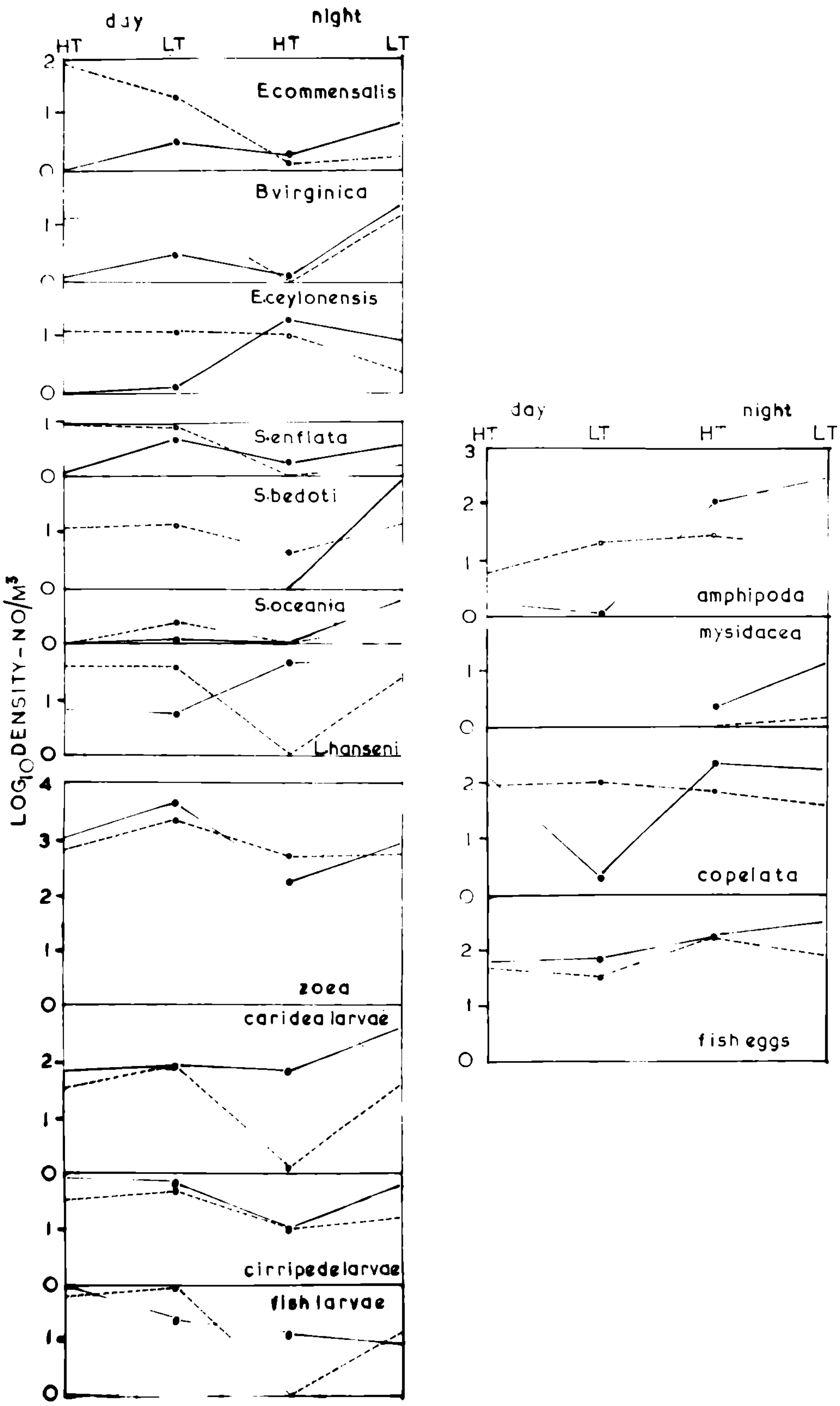
Months	Barmouth	Aroor	Narakkal
S. BIVALVES			
April	2.0	-	-
August	401	-	-
September	0.05	-	0.1
T. THALIACEA			
<u>Thalia democratica</u>			
June	0.2	-	-
<u>Dolioleta gegenbauri</u>			
June	2.0	-	-

4.4. Diel variations - Vertical migration

Information regarding diurnal variation of zooplankton from tropical waters especially from estuaries is meagre. These variations are chiefly associated with the vertical migration behaviour of zooplankton, a well known phenomenon, the zooplankton generally showing a higher abundance in the surface layers during night than day time. Such differences have been observed in the surface waters of Cochin backwater by Pillai and Pillai (1973).

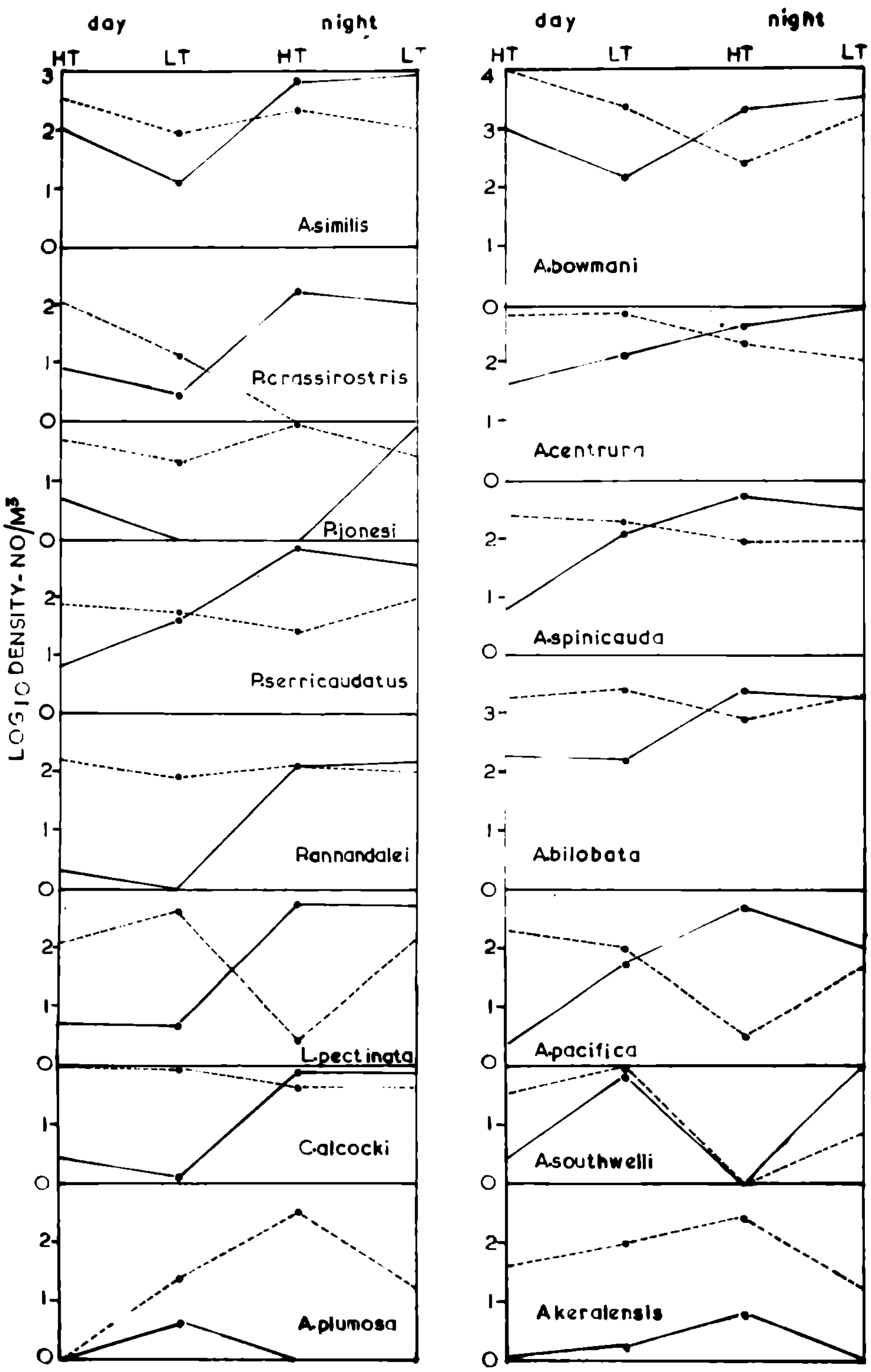
The analysis of variance for diel variations at the three stations based on HT-net hauls showed that significant variations were more common at Narakkal than the other two stations. Here the biomass and the abundance of several groups and species were significantly higher during night. This station is shallow and the high illumination of the water column probably drives the zooplankton to take refuge very close to the bottom or in the bottom mud during day time. But the other two stations are comparatively deeper and zooplankton can escape to the more acceptable light intensities at the bottom layers of the water column. HT-net hauls were taken from the bottom to surface and this accounts for the lack of diel variation in abundance at the other two stations. This also indicates that such hauls give reasonably uniform picture of the zooplankton population in such deeper stations of the estuary irrespective of the time of collection.

FIGURE 19 : Average density distribution of different groups/species of zooplankton at barmouth, Cochin (Series: B) at surface (continuous line) and bottom (broken line).



day
night
HT
LT
HT
LT
LOG10 DENSITY-NO/M3
E.commensalis
B.virginica
E.ceylonensis
S.enflata
S.bedoti
S.oceania
L.hanseni
zoea
caridea larvae
cirripede larvae
fish larvae
amphipoda
mysidacea
copelata
fish eggs

FIGURE 20 : Average density distribution of different species/groups of zooplankton (continued) at barmouth, Cochin (Series: B) at surface (continuous line) and bottom (broken line).



day
night
HT
LT
HT
LT
LOG10 DENSITY-NO/M3
A.similis
P.crassirostris
P.jonesi
P.serricaudatus
P.annandalei
L.pectinata
C.alcocki
A.plumosa
A.bowmani
A.centrura
A.spinicauda
A.bilobata
A.pacifica
A.southwelli
A.keralensis

FIGURE 21 : (a) Succession of the dominant species (Chaetognatha) at barmouth, Cochin, Aroor and Narakkal from November, 1971 to October, 1972.

E - *Sagitta enflata*; B - *S. bedoti*;

O - *S. oceania*; R - *S. robusta*.

(b) Succession of the dominant species (Copepoda) at different stations (Series: B) from January to December, 1972.

G - *Acartiella gravelyi*;

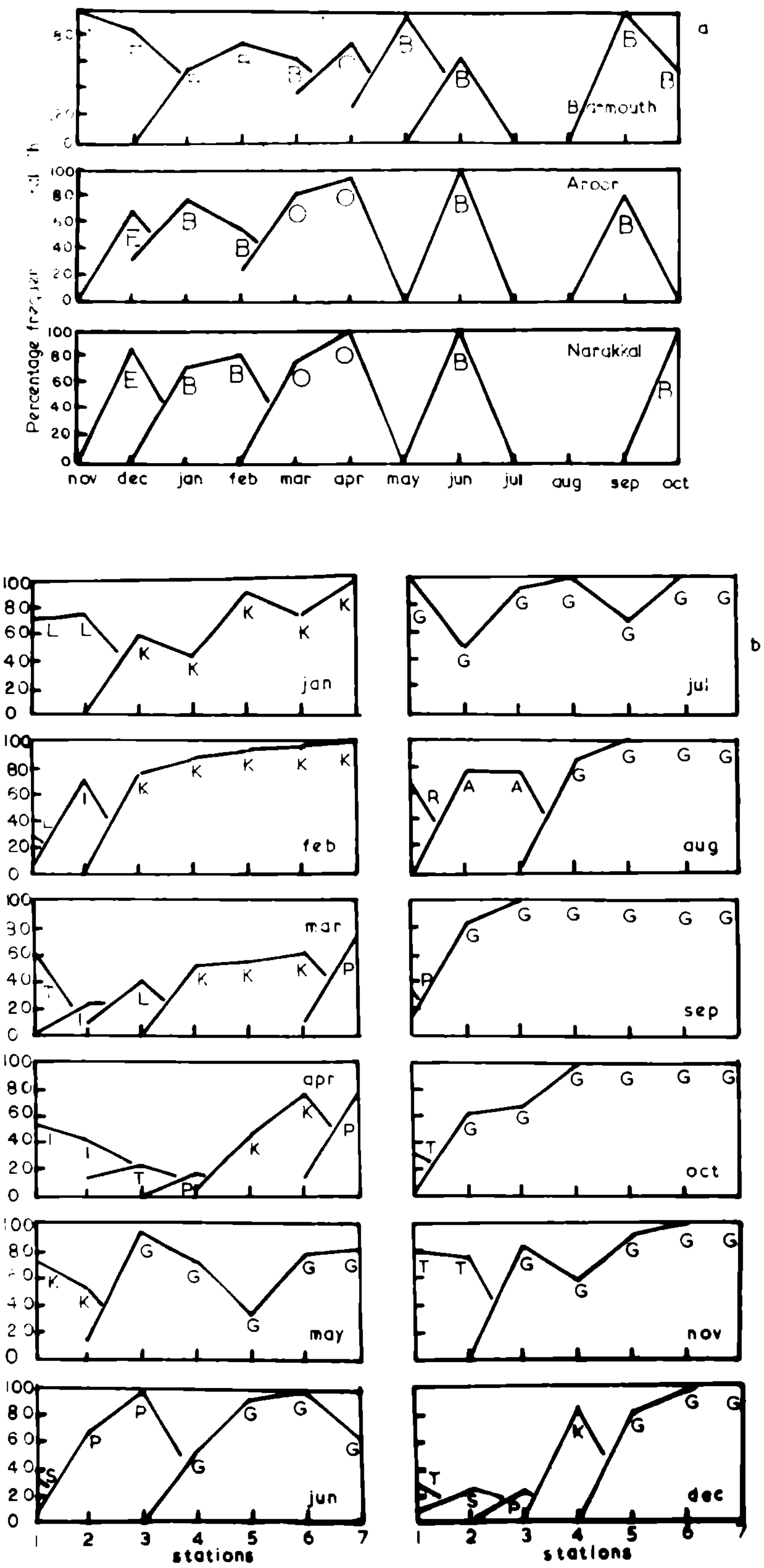
I - *Acrocalanus similis*;

K - *Acartiella keralensis*;

L - *Acartia bilobata*;

P - *A. plumosa*; S - *A. spinicauda*;

T - *A. centrura*


a
Barmouth
Aroor
Narakkal
Percentage frequency
nov dec jan feb mar apr may jun jul aug sep oct
b
Percentage frequency of total
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
stations
stations

Amphipoda and mysidacea exhibited significant diel variations at all the three stations. They, especially the latter appear to come out into the water column from the mud only during night. This has been observed for cumacea, mysidacea and crab megalopae from Southampton waters (Grindley, 1972). Acartia plumosa was more abundant during day at the mouth, but their occurrence at this station seems to be controlled by the tides (see 4.5).

Vertical migration of the zooplankton groups/species was assessed from their density distribution at the surface and bottom layers in day and night as observed from the Clark-bumpus hauls at the mouth (Figs. 19, 20).

Higher concentration of almost all species of zooplankton occurred at the surface during night when compared with day time. But the concentrations of larvae showed a different pattern. Caridea larvae, cirripede larvae, fish eggs and fish larvae showed slightly higher densities at the surface layer both during day and night. But among them cirripede larvae and fish eggs and zoea showed more or less uniform depth-wise distribution irrespective of time. Increase in densities at surface layers during night was shown by all other species except Acartia plumosa and Acartiella keralensis. A sharp decrease in densities at the bottom layers during night was shown only by a few species. Most species like Acrocalanus similis, Pseudodiaptomus serricaudatus, P.annandale

P. jonesi, *Centropages alcocki*, *Acartia bowmani*, *A. centrura*, *A. spinicauda* and *A. bilobata* and groups such as fish eggs, copelata, amphipoda, cirripede larvae and zoea showed more or less uniform densities at the bottom layers during day and night. Thus, the pattern of vertical migration did not indicate a complete movement of the whole plankton population, but rather a tendency of part of the population to spread towards the surface at night.

Acartia plumosa and *Acartiella keralensis* showed higher concentration at the mouth in the bottom layers. This was because these two species shifted to the mouth region only during monsoon season when salinity in the interior of the estuary became too low for their survival. But at the mouth salinity was low at the surface layers due to the freshwater efflux. Hence these species were confined at the bottom layer during night also This confinement to the bottom layer during night when surface salinity was low at the mouth in May was observed for other high saline species like *Sagitta bedoti*, *Acrocalanus similis*, *Acartia centrura*, *A. bilobata*, *Pseudodiaptomus jonesi* and hydromedusae. The presence of low saline water at the surface has been found to inhibit the vertical migration of estuarine zooplankton in River Test at Southampton (Grindley, 1973).

4.5. Tidal variations

Tidal variations were not pronounced for the zooplankton component at the mouth of the estuary. Variation was significant for only a few species viz. Pleurobrachia, Acrocalanus similis, Centropages alcocki and Acartia plumosa. Higher abundance was noticed during high tide except for A. plumosa which was more numerous during low tide. This must be because the population of this species which was present in medium salinities towards middle and upper reaches during pre-monsoon drifted down to the mouth region with the onset of the monsoon during low tide. Sameoto (1975) has observed a periodic fluctuation correlated with tide in the zooplankton biomass and several copepod species from St. Margaret's Bay. No doubt, tidal exchanges contribute a lot to the exchange of water and recruitment species in the estuary, but it would seem that the zooplankters are able to adjust and maintain their position within the estuary during tidal exchanges. It is also possible that the population of the common species which extends over a large area during the period of their abundance vascillates so that the total picture of distribution at the mouth would remain largely the same although individuals get shifted with the tidal motions.

4.6. Secondary Production

Some preliminary estimates of secondary production were attempted from the data. The assessment is based on the average of three sets of collections from the estuary viz. Series : A, Series : B (see Chapter 2) and the Estuarine Survey Project (unpublished data, Regional Centre of NIO, Cochin, 1975) under which extensive surveys were conducted throughout the backwaters during pre-monsoon and monsoon periods. The dry weight estimations were done after removing larger organisms such as hydromedusae and ctenophores.

Biomass (dry weight) in the estuary ranged between 0.7 to 384 milligrams per cubic metre of water. The average zooplankton production in the estuary was estimated as 31.8 milligrams dry weight per cubic metre per day (11.6 gms per cubic metre per year). This gave a P/B ratio (IBP Handbook, 1971) of 0.08 per 24 hours or a P/B ratio of approximately 30 per year. Separate estimates for the saline period and low saline period revealed the low productivity at secondary level during latter season. It amounted to only 8.0 mg/m^3/day compared with 60 mg/m^3/day during saline period.

Average net primary production in the lower reaches of Cochin backwaters have been estimated to be 124 g^{C}/m^2/year (Qasim *et al*., 1969). Based on their findings that 90 % of total primary production is confined to about 1.5 m, the total primary production for the lower reaches was computed. Assuming the metabolic requirements of zooplankton in terms of carbon to be 12 % of its dry weight (Menzel and Ryther, 1961), it has been found that the zooplankton grazing at the lower reaches is only 12.5 % of total annual primary production. If the rate of primary production is extrapolated for the entire estuary, the magnitude is still higher, consumption being only 2.7 %. This is in total agreement with the findings of Qasim et al. (1969) that there is a large surplus of unutilized basic food in the estuary available for 'alternate pathways'.

4.7. General considerations

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

Monsoons reversed the picture totally. The effect of the monsoonal efflux immediately reflected on the hydrography and zooplankton population. Zooplankton became scant except at the mouth. The majority of the population at the mouth consisted of medium saline or low saline species in May and July. A temporary salinity recovery and occupation of high saline species occurred at the lower reaches in June. From August onwards zooplankton population was comparatively low at the mouth also.

Acartiella gravelyi was the only species that could successfully thrive in the estuary during monsoon season. The structure of the mandible of this species is adapted for grasping and piercing rather than grinding (Tranter and Abraham, 1971) suggesting it to be a carnivorous form. Thus primary food in the estuary is barely utilized during low saline period. This colossal waste of primary food washed out during this season may be contributing to the fertility of the coastal waters.

Backwaters served as the breeding and nursery ground for many commercially important fishes and decapods. Prawns constitute 60 - 70 % of the total annual fish landings of Kerala backwaters (Jhingran and Gopalakrishnan, 1973).

Development of commercial species of prawns Penaeus indicus, P. monodon, Metapenaeus dobsoni and M. affinis takes place in the estuary.

Wide variations, both spatial and temporal, in total zooplankton counts have been reported from estuaries else where also. Zooplankton standing crop ranging from $180/m^3$ to $300,000\ /m^3$ have been observed in the estuaries 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 et al.(1975). In South Africa, Knysna estuary, where the rain fall is more or less evenly distributed throughout the year has an abundant fauna compared with St. Lucia estuary where rains flood the system during part of the year (summer) and having little flow in winter (Day, 1967). Occurrence of only low numbers of zooplankton when there is a high flow of freshwater similar to Cochin backwater system have been observed in Werribee river, Victoria (Arnott and Hussainy, 1972).

Dominant component of the zooplankton composition have also been reported to vary in different waters. Copepods predominate the zooplankton in Vellar estuary, Porto Novo (91 %) and Australian estuaries (81 %). Cirripede naupliui dominate in Southampton water (Raymont and Carrie, 1958) and York river, USA (Jeffries, 1964). Polychaete larvae are the major component in Raritan Bay and both polychaete and lamellibranch larvae dominate in the Narragansett Bay. In Cochin backwaters copepods dominated the total counts in Series : A (79%) whereas decapod larvae chiefly consisting of zoea larvae of Brachyura showed higher abundance (58%) in Series : B.

Species of the family Acartiidae are well adapted to estuarine conditions and are found in the estuaries throughout the world. Experimental studies (Lance, 1962) have shown that Acartia tonsa, A. bifilosa and A. discaudata are able to withstand considerable salinity variations. Acartia probably attains dominance in brackish waters because low salinity excludes the more metabolically efficient oceanic species (Conover, 1956). Acartia is the most common calanoid copepod of Southampton waters (Raymont and Carrie, 1958). A. clausi and A. tonsa dominate the zooplankton of New England estuaries (Jeffries, 1962 c). Common species on the south coast of Britain are A. clausi, A. discaudata and A. bifilosa and A. clausi and A. latisetosa in Black Sea and Mediterranean Sea. Species of Acartia and Pseudodiaptomous have been reported to constitute the majority of the zooplankton in Richards Bay, South Africa (Grindley and Wooldridge, 1974).

In Cochin backwaters also species of Acartiidae dominated the zooplankton composition although the species are different from those in the higher latitudes. In the east coast, Acartia spp. are common in the Godavari estuarine system

(Chandramohan, 1963). But *Oithona* spp. have been reported as the dominant copepod in the Vellar-Coleroon estuarine system although some seven species of Acartiidae have been recorded from this area (Subbaraju and Krishnamurthy, 1972).

The common copepod species of the Cochin backwaters exhibited a wide range of salinity tolerance (> 35‰). Of them only *Centropages alcocki* and *Labidocera pectinata* are abundant in the coastal waters. Other common high saline species of the estuary belonging to the families Acartiidae and Pseudodiaptomidae except *Pseudodiaptomus serricaudatus* are rare in the coastal waters of Cochin area (Rosamma Stephen, personal communication). The species which were only stragglers into the estuary were common in the inshore waters. Grindley and Wooldridge (1974) found that the salinity tolerance of Pseudodiaptomus species of Richards Bay, South Africa 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 adaptations 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 stragglers in the estuary although salinity was high at the lower reaches during pre-monsoon.

C H A P T E R 5

REPOPULATION OF BACKWATERS

5. REPOPULATION OF BACKWATERS

The monsoonal cascades flush most of the zooplankton population out of the backwaters. Salinity remained at zero or near zero values throughout the estuary during this season (Haridas _et al._, 1973) rendering it inhospitable for the species which flourished in the estuary during saline period. The mechanisms by which intermonsoon waters get repopulated in considered in this chapter.

Madhupratap and Haridas (1975) suggested that there are two possible ways operating to effect this: (1) Recruitment of estuarine and marine and euryhaline marine organisms takes place from the coastal waters when salinity incursion begins. These 'seeds' propogate and penetrate further up the estuary along with the salinity intrusion. (2) True estuarine species and low saline organisms may have resting stages to tide over adverse environmental conditions, which are triggered back to activity with the advent of conducive conditions. The possibility of the presence of resting stages in estuary for copepods have been suggested earlier by Tranter and Abraham (1971) and for hydromedusae by Vannucci _et al._ (1970). Resting stages for the hydromedusae _Eutima commensalis_ are known to occur (Santhakumari and Vannucci, 1971). Some evidence of this can be gathered from the distribution of hydromedusae in the present study also (see 4.3). The occurrene of resting eggs for copepods have been confirmed since then from Japanese waters (Kasahara et al., 1974).

Expsrimental studies were conducted to find out possible resting eggs in the Cochin backwaters and some amount of success was achieved. Kasahara et al. (1974) observed that the resting eggs were capable of hatching on incubating them at appropriate temperature even after several months of storage. In Cochin backwater system which is a tropical estuary temperature fluctuations are not wide and hence salinity fluctuation was considered as the principal causative factor for the formation of resting eggs.

Mud samples were taken with a grab from the middle reaches of the estuary during the low saline period of 1975. Top layer of mud (1 cm) was spooned out to polythelene bags. These samples were seived through 100 μ mesh with distilled water and the residue examined under a dissection microscope. The probable resting eggs (those similar to the figures given by Kasahara et al. (1974) were separated and transferred to dishes containing saline water (15 to 25 ‰) and kept slightly below room temperature. About 50% of them hatched into naupliui identified to be of copepods. Further identification was not possible as the naupliui unfortunately did not survive.

Another approach was made to the problem. Egg bearing females of Nitocrha spinipes Boek and Pseudodiaptomus serricaudatus T. Scott were transferred to low saline water (3 ‰). Most of them liberated eggs within 3 to 4 hours. The adults of P. serricaudatus died probably due to low salinity, but Nitocrha spinipes continued to live in the low salinity. The eggs of N. spinipes hatched immediately. The eggs of Pseudodiaptomus serricaudatus did not hatch in low saline water, but among those transferred immediately to 25 ‰ salinity, a few hatched. This indicated that an abrupt lowering of salinity would induce egg release and a possibility of the normal eggs of high saline species being transformed to resting eggs in the event of a salinity shock. Nitocrha spinipes has been observed to tolerate a wide salinity range and this was probably the reason for their eggs hatching in low salinity.

Further studies to ascertain the species having resting eggs in the backwaters, density distribution of the eggs and intensive sampling at the mouth and lower reaches during early period of salinity recovery to study the recruitment from inshore waters are necessary before any conclusive picture on the repopulation of the backwaters can be drawn.

C H A P T E R 6

SPECIES DOMINANCE, SUCCESSION AND DIVERSITY

6. SPECIES DOMINANCE, SUCCESSION AND DIVERSITY

Zooplankton population of the backwaters is rich only during the saline period consisting of six months or so in an year. When the monsoonal flows cease, the system is virgin, practically unexploited at secondary level. Repopulation of the backwaters begins during post-monsoon months, the invasion of various high saline species up the estuary is time bound, but this is essentially due to the curbs imposed upon by the rate and extent of salinity recovery. The pattern of succession can be gathered from the numerical dominance exerted by various species.

Among chaetognaths (Fig. 21, a) *Sagitta enflata* dominat only during the early stages of succession viz. post-monsoon months. *S. bedoti*, the most common chaetognath in the estuary was more abundant during other periods, except in the peak salinity months, when *S. oceania* was dominant. At the mouth *S. robusta* also showed dominance in June, but this species was only an adventitious immigrant which could not penetrate deeper into the estuary.

Copepods always showed higher numerical dominance among zooplankton. In family Paracalanidae (Fig. 22, a) *Acrocalanus similis* was the most successful species during salinity regime. Two other species *Paracalanus aculeatus* and *P. crassirostris* were able to muster importance only during the less stable conditions of the saline period, i.e. post-monsoon and later in June when salinity temporarily recovered during monsoon season.

In Pseudodiaptomidae (Fig. 22, b), *Pseudodiaptomus serricaudatus* and *P. jonesi* showed higher dominance during post-monsoon and pre-monsoon months at the mouth and Aroor. *P. annandalei* had the ascendancy during low saline months. The dominance showed by this species in March at Narakkal was peculiar, but indicates the resourcefullness of this species to thrive in high saline, but slightly stratified waters (Salinity 27.0 to 30.4 ‰, from surface to bottom). *P. binghami malayalus*, a low saline species dominated the Pseudodiaptomidae population at the peak of the monsoon at Aroor (salinity 0 ‰ throughout water column).

Acartiidae in the estuary comprised of 10 species. Of these *Acartia erythraea* occurred only rarely and *A. southwelli* although occurred in good numbers in some months did not show absolute dominance at any time. (Tranter and Abraham (1971) have observed this species showing dominance in April at the lower reaches). Other high saline species dominated at the mouth during post-monsoon, pre-monsoon and late monsoon periods (Fig. 22, c). Only in May, July and August medium saline species like *A. plumosa* and *Acartiella* keralensis predominated. The trend was similar at other stations also, only during early period of succession(Novemb when salinity at these stations were not high, Acartia plumosa and later during monsoon Acartiella gravelyi dominat the counts. Acartia bowmani and A. bilobata were the two most successful species during salinity regime at the lower reaches (Fig. 22, d) closely followed by A. centrura and Acrocalanus similis. Pseudodiaptomus annandalei and Acarti keralensis were the usual dominants during low saline period but the former only at the lower reaches where the water col exhibited stratification.

Acartia plumosa and Acartiella keralensis always predominated at the middle and upper reaches during salinity regime (Fig. 21, b). Species like Acartia bilobata, A. cent plus A. bowmani and Acrocalanus similis did penetrate up to the head along with the incursion of salinity but could not dominate. Had the monsoons failed, or been delayed, it was quite possible that salinity in these areas would have incre further resulting in the domination by these species. Acartiella gravelyi was the only species that could flourish during low saline period in these areas (Fig. 21, b).

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

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 dominanc and contributed to the bulk of the biomass. But apart from numerical dominance, the ecological dominance exerted by othe groups, especially carnivores such as hydromedusae, ctenophor and chaetognatha cannot be overlooked. These being larger organisms formed a significant portion of the biomass eventhough occurring in smaller numbers. Their utility, whether positive or negative, in the energy transfer of the trophic system is also of considerable importance.

It is generally accepted that stability increases diversity. Sanders (1969) in his stability-time hypothesis recognises two classes (1) physically controlled community with a small number of species per unit number of individuals and (2) biologically accommodated community with a larger number of species per unit number of individuals. He states "as the gradient of physiological stress increases resulting from increasing physical fluctuations or unfavourable physical conditions regardless of fluctuations, the nature of community gradually changes from a predominantly biologically accommodated to a predominantly physically controlled community". He includes tropical estuaries under the latter.

Unlike tropical marine environment symbolic of stability, conditions in tropical estuaries are under constant fluctuatio In a 'monsoonal estuary' like Cochin backwaters, some semblanc of stability is achieved only during pre-monsoon period, but this period is too short to develop high diversity. In other words, the operating species in the estuary have 'broad niches and utilising their adaptability to the fluctuating environmen extracts ~~the~~ maximum within the available period.

The diversity indices given in Fig. 23, A were calculated using the formula of Fisher et al. (1943).

$S = \alpha \log_e \left(1 + \frac{N}{\alpha} \right)$ where, S is the number of species present in a sample and N is the number of individuals of all species taken together in a sample.

It was observed that a higher diversity is maintained during salinity regime. The increase shown at Narakkal in June and at the mouth in June and September corresponded with an increase in salinity during monsoonal period. Earlier observation based in Series: B (Madhupratap et al., 1975) has also shown a similar situation, diversity was very low during the monsoon. A progressive diminution of average index values seen from head to mouth indicates a less explo ted biotope which resulted from the delay or gradient in salinity incursion.

Diversity and along with it biomass increased during early periods of succession and at the mouth, after a peak in January, it stabilised into a lower value. At Narakkal and Aroor this occurred about a month later. Diversity dropped with the onset of the monsoon at Aroor and Narakkal but only later by July at the mouth although the species composition was different from pre-monsoon months.

The average for the year showed that higher number of species occurred at the mouth (21) compared to Aroor (16) and Narakkal (10). It was still lower towards the upper reaches. But the species composition at the mouth also included stragglers which contribute little to the ecology of the system. If they are omitted when considering dive as a means of biotope utilization and niche division, the number of species gets limited to the true estuarine, estu and marine and the more common euryhaline marine species.

Six hypothesis have been put forward by various auth to explain the gradients in diversity. (Krebs, 1972). (1) Time hypothesis - all communities diversify in time a older communities have more species than younger ones. (2) Theory of spatial heterogenity - the more heterogeneous and complex, the physical environment becomes, the more comple the plant and animal communities supported and higher species diversity results. (3) Competition hypothesis - there is more competition in tropics and hence niches are narrow. (4) Predation hypothesis - predators regulate by holding down prey numbers thus reducing competition which allows additions of more prey species. (5) Theory of environmental stability - the more stable environmental parameters are, more species will be present. (6) Productivity hypothesis - great production results in greater diversity.

Pinpointing reasons for lack of diversity is difficult. "Niches can be defined only in retrospect, because the niche of any species has biotic dimensions determined by evolution (Connell and Orias, 1964). It is impossible to look at a vacant habitat and to determine the number of potential nic (Krebs, 1972). Spatial heterogenity is not wanting in the backwaters. ~~Primary food is also available in plenty in th backwaters.~~ Primary food is also available in plenty in th system (Qasim, 1970). The cause for the absence of enough number of species to exploit the different situations espe during low saline period is to be looked elsewhere. Lack stability, time to diversify and the physiological stress imposed by the environment should be the main reasons.

FIGURE 22 : Succession of the dominant species (Copepoda) at barmouth, Cochin, Aroor and Narakkal from November, 1971 to October, 1972.

(a) Paracalanidae

C - *Paracalanus crassirostris*;

I - *Acrocalanus similis*;

U - *Paracalanus aculeatus*

(b) Pseudodiaptomidae

A - *Pseudodiaptomus annandalei*;

J - *P. jonesi*; M - *P. binghami malayalus*;

S - *P. serricaudatus*

(c) Acartiidae

(d) Total Copepoda

A - *Pseudodiaptomus annandalei*;

B - *Acartia bowmani*;

C - *Paracalanus crassirostris*;

F - *Acartia pacifica*;

G - *Acartiella keralensis*;

I - *Acrocalanus similis*;

J - *Pseudodiaptomus jonesi*;

K - *Acartiella keralensis*;

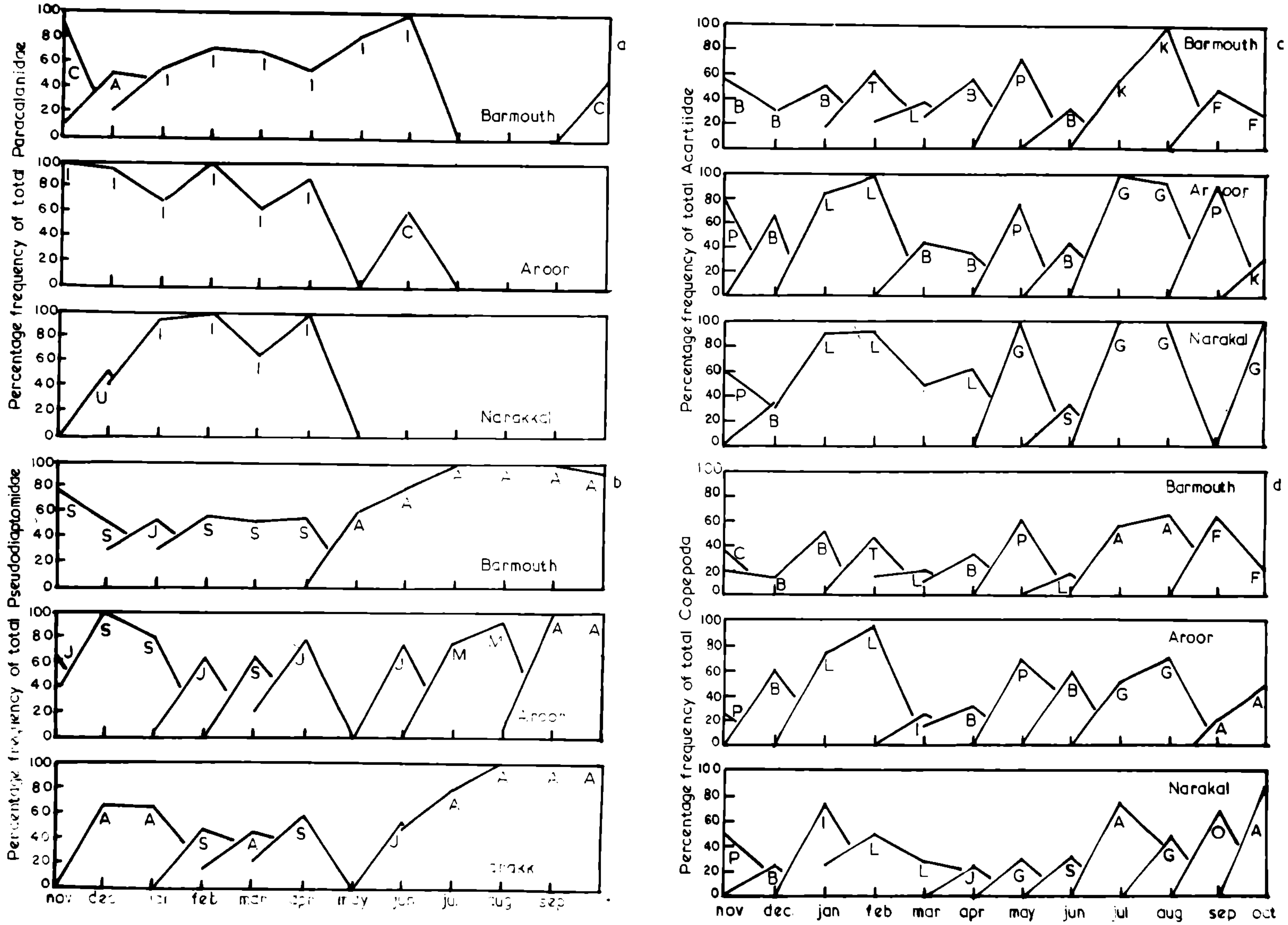
L - *Acartia bilobata*;

O - *Oithona brevicornis*;

P - *Acartia plumosa*;

S - *A. spinicauda*;

T - *A. centrura*


a
b
c
d
Barmouth
Aroor
Narakkal
Narakal
Percentage frequency of total Paracalanidae
Percentage frequency of total Pseudodiaptomidae
Percentage frequency of total Acartiidae
Percentage frequency of total Copepoda
nov
dec
jan
feb
mar
apr
may
jun
jul
aug
sep
oct

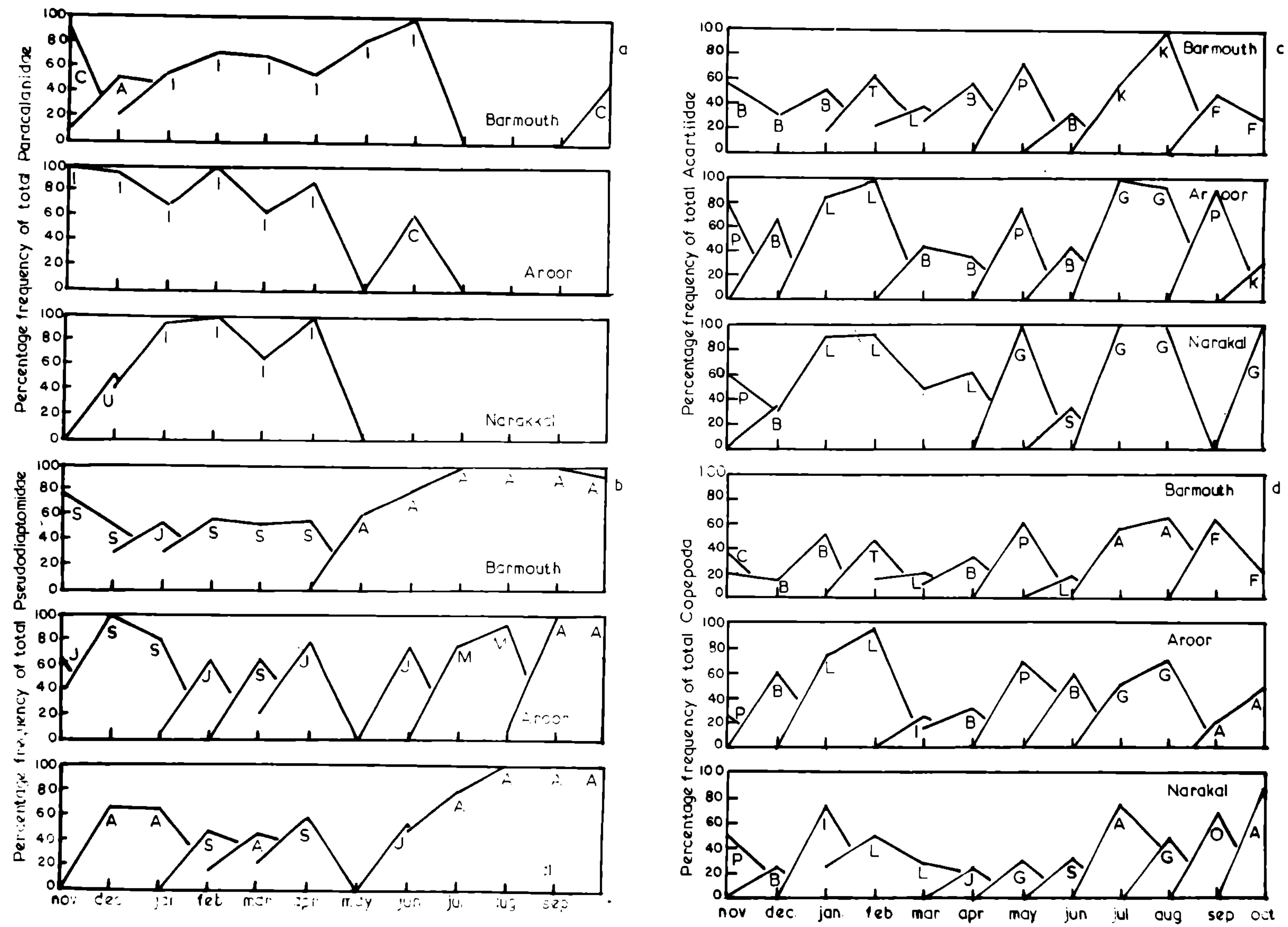

Percentage frequency of total Paracalanidae
Percentage frequency of total Pseudodiaptomidae
Percentage frequency of total Acartiidae
Percentage frequency of total Copepoda
Barmouth
Aroor
Narakkal
Narakal
a
b
c
d
nov dec jan feb mar apr may jun jul aug sep oct

FIGURE 23 : (A) Species diversity index at barmouth, Cochin, Aroor and Narakkal.

(B) Dendrogram from correlation coefficients (vertical scale) among the more common Copepod species at barmouth, Cochin.

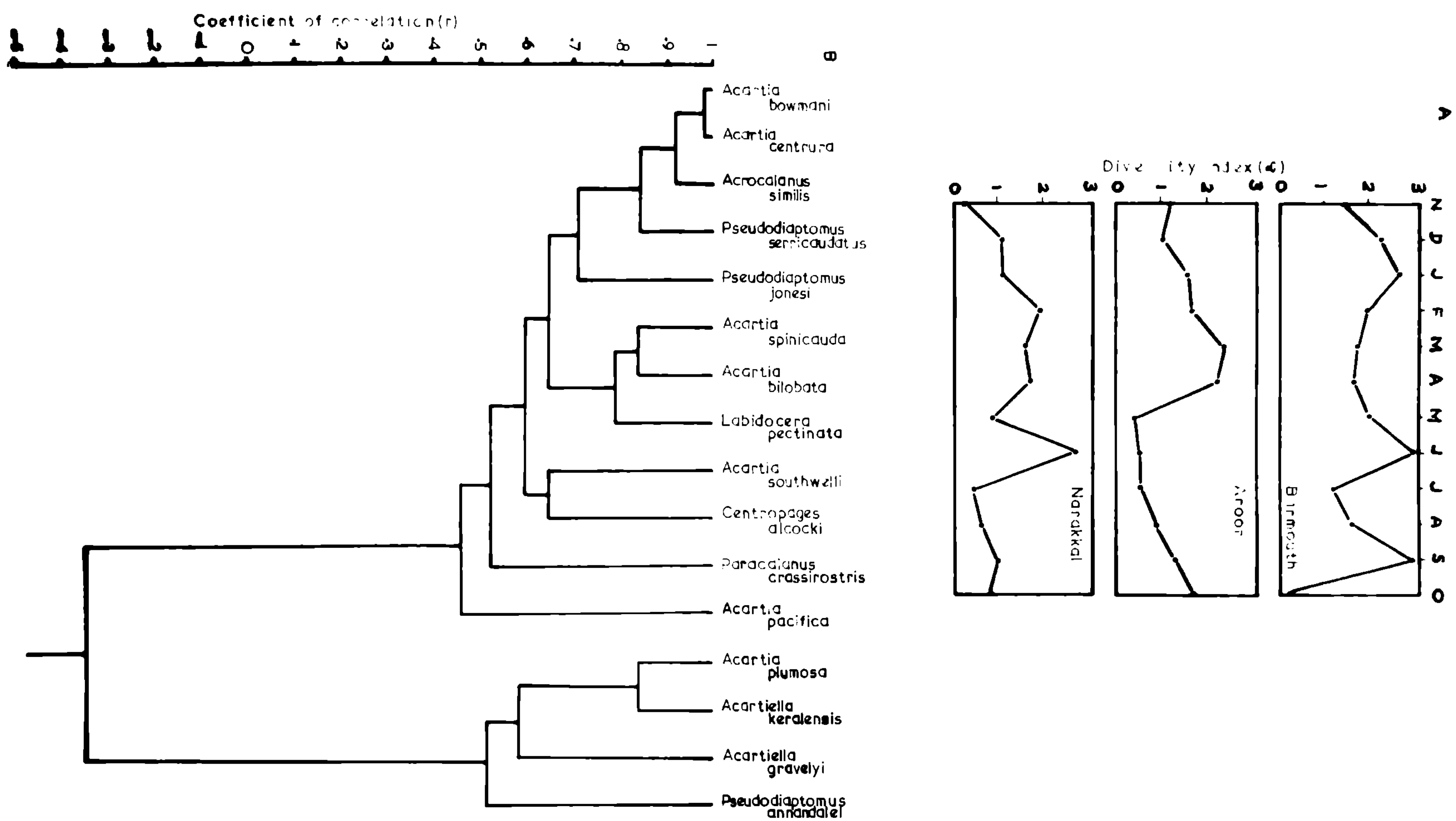
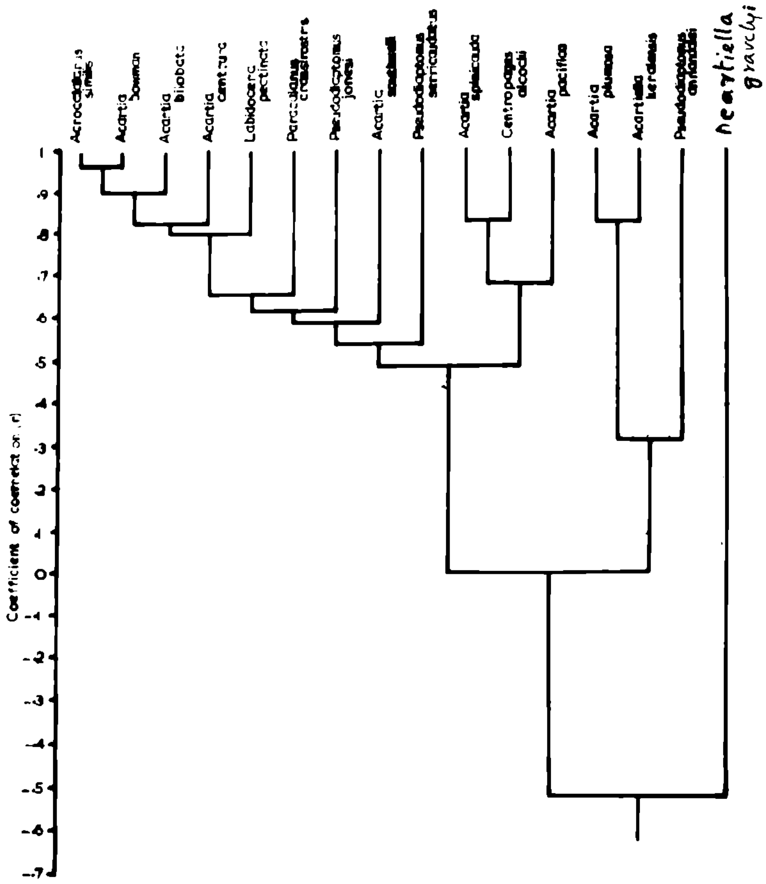
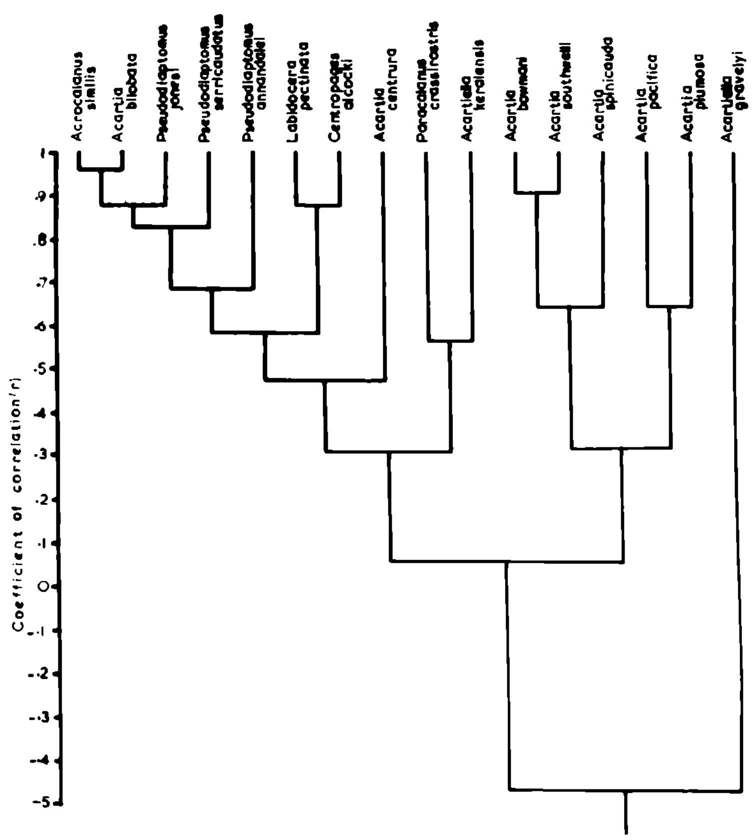

B
Acartia bowmani
Acartia centrura
Acrocalanus similis
Pseudodiaptomus jonesi
Acartia spinicauda
Acartia bilobata
Labidocera pectinata
Centropages alcocki
Paracalanus crassirostris
Acartia pacifica
Acartia plumosa
Acartiella keralensis
Acartiella gravelyi
Pseudodiaptomus annandalei
A
Narakkal

FIGURE 24 : Dendrogram from correlation coefficients (vertical scale) among the more common Copepod species at Aroor (A) and Narakkal (B).

A


Acartia
Acartia
Acartia centrura
Labidocera
Pseudodiaptomus jonesi
Acartia
Pseudodiaptomus
Acartia spinicauda
Centropages alcocki
Acartia pacifica
Acartia plumosa
Acartiella keralensis
Pseudodiaptomus annandalei
Coefficient of correlation
1
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
-·1
-·2
-·3
-·4
-·5
-·6
-·7

B


Acrocalanus similis
Acartia bilobata
Pseudodiaptomus jonesi
Pseudodiaptomus serricaudatus
Pseudodiaptomus annandalei
Labidocera pectinata
Centropages alcocki
Acartia centrura
Paracalanus crassirostris
Acartiella keralensis
Acartia bowmani
Acartia southwelli
Acartia spinicauda
Acartia pacifica
Acartia plumosa
Acartiella gravelyi
Coefficient of correlation (r)
1
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
-·1
-·2
-·3
-·4
-·5

C H A P T E R 7

SPECIES ASSOCIATIONS

7. SPECIES ASSOCIATIONS

Organisms in an environment do not exist alone, hence they interact. The nature of the interactions can be positiv or negative, they may accommodate each other and coexist or compete. Some studies on coexistence in different families of calanoid copepods of the estuary have been conducted earlier (Tranter and Abraham, 1971; Madhupratap et al., 1975) Here, I have sought to identify the pattern of association between species of copepods that consistently occurred in the estuary irrespective of generic or family differences.

Correlation matrices were formed after converting the figures for numerical abundance to their respective logarithm values and using the formula for correlation coefficient.

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{n \sigma x \sigma y}$$

For constructing dendrograms (Figs. 23, B, 24, 25), the first group was chosen on the basis of highest correlation coefficient. The similarity of this group with each of the other were worked out using the methods of Mountford (1962).

Correlation matrices at group levels at barmouth, Aroor and Narakkal were also constructed (Table 9). But correlati(at group levels are not very informative since each group ma;

contain species with different distribution or ecological significance. Since most of the groups were more abundant during the high saline period there were more positive if not significant correlations between most of them. Carnivores such as hydromedusae, ctenophora and chaetognatha were significantly positively correlated at all stations. Cladocera, a group which at times suddenly burst into activity from apparent inertia and some of the larvae were negatively correlated with most of the other groups.

Acartiella gravelyi always showed negative association with the rest of the species. This was because it was the only dominant monsoonal species. Acartia plumosa and Acartiella keralensis, two species which preferred medium salinities were significantly positively correlated at barmouth, Aroor in series: A and overtime (series: B). Ove space, A. keralensis showed significant correlation with Acartiella gravelyi. This was because both species were more abundant at the middle and upper reaches (Fig. 21, b), but during different periods. Acartia plumosa also joined with this group although the level of correlation was not significant. The ecological differentiation between the coexisting species Acartia plumosa and Acartiella keralens have been shown based on their mandibular structure (Trant and Abraham, 1971). Pseudodiaptomus annandalei was groupe with these species at barmouth, Aroor and over time. Over space this species joined with other species which did nc

TABLE 9 : Correlation matrix for major groups of zooplankton (1971-72)

A: BARMOUTH

	Cteno-phora	Hydrome-dusae	Chaetognatha	Amphipoda	Copepoda	Cladocera	Fish eggs	Fish larvae	Copelata	Cirripede larvae	Lucifer	Zoea	Caridea larvae
Ctenophora													
Hydromedusae	0.70^{b}												
Chaetognatha	0.60^{a}	0.55											
Amphipoda	0.08	0.40	-0.27										
Copepoda	0.54	0.09	0.22	0.46									
Cladocera	-0.50	-0.20	-0.31	0.12	-0.19								
Fish eggs	0.28	0.37	0.57	-0.16	0.32	-0.17							
Fish larvae	0.11	-0.10	-0.32	0.52	0.45	-0.17	-0.32						
Copelata	0.15	-0.01	0.33	-0.17	0.12	0.02	0.60^{a}	-0.34					
Cirripede larvae	0.01	-0.20	0.28	-0.11	-0.04	-0.06	0.53	0.62^{a}	-0.34				
Lucifer	0.47	0.29	-0.05	0.47	0.65^{a}	-0.31	-0.02	0.74^{b}	-0.25	-0.40			
Zoea	0.31	0.09	0.22	0.29	0.61^{a}	-0.17	0.66^{a}	0.20	0.38	0.31	0.45		
Caridea larvae	0.07	-0.04	-0.30	0.21	0.17	-0.29	-0.46	0.87^{c}	-0.57^{a}	-0.49	0.54	-0.13	

Significant at : a = 5% level; b = 1% level; c = 0.1% level

TABLE 9 (Contd.)

B: AROOR

	Ctenophora	Hydromedusae	Chaetognatha	Amphipoda	Copepoda	Cladocera	Fish eggs	Fish larvae	Copelata	Cirripede larvae	Lucifer	Zoea	Caridea larvae
Ctenophora													
Hydromedusae	0.87^{c}												
Chaetognatha	0.78^{b}	0.88^{c}											
Amphipoda	0.32	0.10	0.14										
Copepoda	0.55	0.54	0.75^{b}	0.02									
Cladocera	0.16	0.15	0.10	-0.29	-0.15								
Fish eggs	0.81^{b}	0.67^{a}	0.77^{b}	0.21	0.72^{b}	0.36							
Fish larvae	0.12	0.11	0.10	0.38	0.55	-0.15	0.43						
Copelata	0.69^{a}	0.82^{b}	0.95^{c}	0.01	0.78^{b}	-0.06	0.68^{a}	0.10					
Cirripede larvae	0.63^{a}	0.76^{b}	0.66^{a}	0.01	0.36	0.59^{a}	0.69^{b}	-0.04	0.51				
Lucifer	0.80^{b}	0.70^{a}	0.86^{c}	0.39	0.77^{b}	0.10	0.93^{c}	0.45	0.78^{b}	0.62^{a}			
Zoea	0.41	0.51	0.67^{a}	-0.40	0.83^{c}	0.06	0.59^{a}	0.24	0.71^{b}	0.44	0.58^{a}		
Caridea larvae	0.75^{b}	0.64^{a}	0.48	0.16	0.41	0.39	0.63^{a}	0.15	0.41	0.61^{a}	0.61^{a}	0.38	

TABLE 9 (Contd.)

C: NARAKKAL

	Ctenophora	Hydromedusae	Chaetognatha	Amphipoda	Copepoda	Cladocera	Fish eggs	Fish larvae	Copelata	Cirripede larvae	Lucifer	Zoea	Caridea larvae
Ctenophora													
Hydromedusae	0.87^{c}												
Chaetognatha	0.86^{c}	0.80^{b}											
Amphipoda	0.07	-0.08	-0.17										
Copepoda	0.68^{a}	0.55	0.69^{a}	0.49									
Cladocera	0.14	0.47	0.17	-0.27	-0.08								
Fish eggs	0.09	0.08	0.49	-0.19	0.35	-0.22							
Fish larvae	0.65^{a}	0.56	0.50	0.64^{a}	0.86^{c}	-0.11	0.01						
Copelata	0.04	0.14	0.42	-0.25	0.21	-0.09	0.96^{c}	-0.10					
Cirripede larvae	0.72^{b}	0.81^{b}	0.47	0.31	0.64^{a}	0.27	-0.44	0.78^{c}	-0.25				
Lucifer	0.76^{b}	0.71^{b}	0.72^{b}	0.27	0.80^{b}	0.20	0.45	0.70^{b}	0.41	0.67^{a}			
Zoea	0.67^{a}	0.67^{a}	0.64^{a}	0.28	0.81^{b}	-0.10	0.37	0.62^{a}	0.34	0.67^{a}	0.88^{c}		
Caridea larvae	0.47	0.34	0.11	0.82^{b}	0.58^{a}	-0.15	-0.18	0.77	-0.19	0.62^{a}	0.57^{a}	0.56	

penetrate up the estuary such as Acartia southwelli and Centropages alcocki. At Narakkal it was associated with high saline species at a lesser level of significance (P< 0.0

With regard to the other common species which occurred mostly in high saline waters viz. Acrocalanus similis, Paracalanus crassirostris, Centropages alcocki, Pseudodiaptom serricaudatus, P. jonesi, Labidocera pectinata, Acartia centr A. bowmani, A. spinicauda, A. bilobata, A. pacifica and A. southwelli, it was observed that all of them showed significant correlation (P< 0.05) with each other. Only exceptions were Paracalanus crassirostris and Acartia pacifica at barmouth, Pseudodiaptomus serricaudatus and the group Centropag alcocki - Acartia spinicauda - Acartia pacifica at Aroor, Acartia centrura and Paracalanus crassirostris at Narakkal a Centropages alcocki over space and time in series: B. But these species were recognised to show significant correlatic with other species at some other stations. Cassie (1963) reviewing literature on correlation coefficients of plankto states that it is difficult to distinguish any consistent pattern in coefficients so far ascertained since, for the same pair of species, they may change in magnitude or even in sign from day to day. Variations in species groupings did exist over the three stations, space and time, but the pattern remained the same in a broad sense. Also, except Paracalanus crassirostris all the other high saline specie were highly significantly correlated ($P < 0.001$) with each other at one station or other. This showed that their occurrences overlapped or they coexisted.

Classical ecological theories imply that coexistence of species requires ecological differentiation between them. Hardin's (1960) competitive exclusion principle states "complete competitors cannot coexist". Niches of Acartiella gravelyi, A. keralensis, Acartia plumosa and Pseudodiaptomus annandalei are rather well defined and differentiated. But evaluation of the ecological differentiation of other high saline species is difficult. Jeffries (1967) states "Subtl differences can collectively culminate to make one species perform better than its competitor in a particular situatio What is not yet clear is the degree of ecological differenc required to permit coexistence, and we are not sure how thi difference should be measured (Slobodkin, 1962). Measurin these differences in marine copepods is hard".

To measure the ecological differentiations, the niche component of each coexisting species will have to be identi fied. Apart from environmental factors, this would also consist of generation length, morphological variations, fo requirement etc. of individual species. These are difficu to be estimated from natural plankton communities, especially estuaries, where spatial organisation is again and again destroyed by turbulence (Margalef, 1968). Tranter and Abr (1971) have tried to establish the ecological differentia between closely coexisting high saline species of Acartiidae in the estuary based on their mandibular structure. In their opinion "the differences which do exist are not sufficient to establish niche separation".

Assuming that ecological differentiations do exist between the various high saline species, competition would then become intraspecific. This would also be fatal for the species unless spatial width of the niches expand. This can be concieved to happen in the estuary for the high saline species with the increase in extent of salinity penetration.

Species of the family Pseudodiaptomidae and Acartiidae are quite diverse in the backwaters. Species belonging to the latter are especially successful thriving in abundance and many of them coexist. Jeffries (1967) states that congeneric associates help in the efficient utilisation of the biotope by competing for common resources at times of the year when biotope is least stable, wasting a minimum in acquiring the maximum.

Competition can sustain when the number of competing species are limited and resources are plenty. The low species diversity suggests that equillibrium in niche divisi is not attained in the estuary. The number of common high saline species occurring in the estuary is limited to about 12. Qasim (1970) has observed that primary food is in exces in the estuary as the zooplankton grazing is insufficient to utilise it completely (see 4.6). The idealised situation with niches defined and divided and each species with clear ecological differentiation need not occur under such circumstances. Also, a certain amount of competition - whether inter specific or intraspecific - does occur in all natural communities.

Hutchinson (1958) has given situations when competitive exclusion would not be expected to occur, (1) in colonising species which live in unstable environments that never reach equillibrium, (2) in species that do not compete for resourc and (3) in fluctuating environments that reverse the directi of competition before extinction is possible.

Even if the common high saline species occurring in the estuary are competitors and their niches overlap, the incurs of salinity provides all of them opportunity to expand thei niches spatially. The better adapted, or the more tolerant species, will be able to exploit the situation better and escape to the upper regions first from the more severe comp tition at the lower reaches. Thus habitat selections (MacArthur, 1965) occur. But as salinity increases towards the head region, other species which were restricted to the low reaches also would penetrate to this area. Competition at different rates occurs at all stages in such situations.] the ultimate survival of the better adapted and the elimin of the others is automatically averted by the monsoonal efflux which flushes all of them out before saturation can occur over the entire estuarine system.

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C H A P T E R 8

DISCUSSION AND SUMMARY

8. DISCUSSION AND SUMMARY

1. Interactions of the environment and zooplankton organisms inhabiting the Cochin backwaters, a tropical estuarine system, was studied based on the data collected during the years 1971-72. The estuary is extensive, extending from Alleppey to Azhikode with two openings into the Arabian Sea, one at Cochin and another at Azhikode. It is shallow except at the mouth region at Cochin where it is periodically dredged to accommodate the traffic in the Cochin harbour. It is a bar-built estuary and the tides are semidiurnal. Hydrographic data and plankton collections were taken from stations fixed in the estuary.

2. Fluctuations in the estuary are of extreme nature especially with regard to salinity. The backwaters remain saline only for a period of six months, or so, which represents the relatively more stable period in the estuary. Salinity values are high throughout the system during this period, with a gradient from head to mouth. Marine component dominates during this period and zooplankton population is rich and diverse.

Monsoon have pronounced influence on the ecology of the system which capitulated to the freshwater discharges bringing about a total change in the environment and fauna. Salinity values fell to zero or near zero values throughout the estuary except at the mouth. A general fall in temperature and an increase in oxygen values at the surface was observed during this period. Some information on the presence of upwelled Arabian Sea water at the mouth could be deduced from the salinity, temperature and oxygen values, Zooplankton abundance fell drastically, only a few low saline species could inhabit the estuary.

3. Water column is well mixed and more or less vertically homogeneous during the peak salinity period. It is stratified only in the post-monsoon and early pre-monsoon months. At the mouth stratification could be observed during monsoon period also, the penetration of tidal influx was restricted to this area. The flow pattern could not be stringently attributed to a particular kind as classified by Bowden (1967), but assumed varying patterns depending upon the strength of freshwater efflux.

4. Thus, monsoonal flows exert profound influence on every aspect of estuarine hydrography and its ecology such as nutrients (Sankaranarayanan and Qasim, 1969), salinity, temperature, oxygen and zooplankton. Although primary production in the estuary does not show marked variations

with season (Qasim *et al*., 1969), the composition is different during the monsoon season (Devassy and Bhattathiri, 1974). Caspers (1967) analysing the classifications and definitions of the estuary 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 be called as a 'tropical monsoonal estuary'.

5. Displacement volume, total numbers and higher numerical abundance of most groups and species of zooplankton showed significant higher abundance during pre-monsoon period. Crustacea and among them Copepoda contributed to the bulk of the biomass and total numbers. Seventy six species, of them 49 from copepoda, were identified from the estuary.

Carnivores (of the first order) such as hydromedusae, ctenophora and chaetognatha were more numerous during the saline period when there was a higher standing stock of other zooplankton. *Blackfordia virginica*, *Eirene ceylonensis* and *Eutima commensalis* among hydromedusae formed the most common species. Chaetognaths showed a succession pattern from post-monsoon months to the peak salinity months in the order *Sagitta enflata* - *S. bedoti* - *S. oceania*.

Surprisingly, cladocerans were more common during low salinity period. They showed discontinuity in their spati[al] and temporal distribution, often bursting into blooms from apparent inertia.

Copepod species of the saline period consisted of estuarine, estuarine and marine, euryhaline marine species and adventitious immigrants. Family Acartiidae comprising 10 species formed the majority of copepods in the estuary. Common high saline species occurred at the lower reaches during post-monsoon months and penetrated further up the estuary along with the incursion of salinity. They were washed out in the monsoonal efflux. This was the general pattern of distribution showed by high saline species of other groups too. All the same, variations could be notice in the distribution between various high saline species. Among all the groups only a single copepod species, Acartia gravelyi, successfully thrived in the estuary during low salinity regime. Other low saline species occurred in smal numbers only.

Decapod larvae stood next to copepoda in the order of abundance. Larvae and postlarvae of various commercially important decapods were identified in the collections. T estuary forms the breeding and nursery ground for them an other fishes as could be recognised from the abundance of invertebrate larvae, fish eggs and fish larvae.

Amphipods, sergestids and appendicularians were als common during the saline period. Other groups such as siphonophora, ostracoda, mysidacea, cumacea, isopoda an thaliacea are of relatively lesser importance in the ec of the estuary at secondary level.

6. Diel variations in total numbers were not significant for many groups and species. This is attributed to the nature of the HT-net hauls which were taken from bottom to surface. More significant diel variations with higher abundance during night was observed at Narakkal, a shallow station. Amphipods and mysidacea exhibited significant diel variations at all the stations. Other species seem to take refuge in the bottom waters during day time at deeper stations. But a vertical migration behaviour showing higher abundance at night was observed for most species. The tendency was for part of the population to spread upward rather than a complete movement. Indications of presence of low salinity water at the surface inhibiting vertical migration was observed for high saline species.

7. Although tidal exchanges are a key factor in the dynamics of the estuary, most species did not show significan variations with tides in numerical abundance at the mouth. Slobodkin and Sanders (1969) state that if the changes in an environment are predictable such as the tidal exchanges in an estuary the animals might adapt to it in two ways. It may become euryhaline or stenohaline, but develops behaviou mechanisms in response to tidal changes which keep it in tl water of same salinity through out the tidal cycle by havi some kind of a biological clock or signal. But there is ı appreciable salinity changes in this estuary during premonsoon months and such behavioural responses may not be

important except when stratification occurs. Another possibility is that although the individuals are carried away with tidal currents the other individuals of the population of the species which extends over a large area may replace them so that the numerical abundance would remain roughly the same.

8. The average zooplankton production in the estuary was estimated to be 31.8 mg dry weight/cubic metre/day. The production during high saline period is much higher compared with low saline period. Thus the efficiency in the utilisation of the biotope at secondary level is considerably low during the low salinity regime.

9. The 'successful species' in the estuary during the saline period exhibited a wide range of salinity tolerance. Evenso, they could not comply with the extreme nature of the environment during monsoon period. The physiological stress probably became too high for these species. Factor analysis showed salinity as the primary environmental factor associate with the changes in the zooplankton abundance of the estuary. But surprisingly, the estuary does not possess an abundant low saline fauna of zooplankton to replace the high saline species as one would naturally expect to happen in the evolu tionary sequence since the change from high saline period to low salinity is rather 'predictable'. Perhaps, apart from salinity, strong currents down stream, turbidity or th

nonavailability of the 'right' food may be rendering the environment 'severe'.

10. Repopulation of the intermonsoon waters of the backwaters after monsoonal wash out seems to be effected in two ways. True estuarine species may have quiescent stages to tide over adverse environmental conditions which become active when salinity reaches appropriate threshold and through recruitment from coastal waters. Experimental studies to find resting eggs had met with some amount of success.

11. Copepods showed the highest numerical dominance among zooplankton groups. The pattern of succession gathered from the dominance broadly outlined three seres. They consisted of high saline species, low saline species and species preferring medium salinities. Redundance of any of the serals appear to be based on salinity fluctuations and dominance achieved at the optimum. While numerical abundance is an index of dominance, it does not always project a total picture Ecological dominance, especially of primary carnivores of the system cannot be overlooked.

12. Bioceonosis of the Cochin backwater system can be recognised as a physically controlled community. Species diversity is low particularly during low saline period as the stress component increases. Although the environment i under constant fluctuation; some semblance of stability is achieved during pre-monsoon period. The variations in

diversity could be explained to some extent based on salinity fluctuations. The total diversity of the community is a function of niche development and may therefore increase or decrease at various stages (Patten, 1962). The complex nature of changes in diversity trends during succession is outlined by Margalef (1968). The reasons for the variations in diversity can be more complicated than it would appear prima facie.

13. An analysis of the species associations between the common species of copepods that consistently appeared in the collections also distinguish the three seral stages. A high degree of correlation was exhibited by high saline species. The degree of ecological differentiation between them is not lucid. This can probably be established only by studying the biology of the individual species. On the other hand it is suggested that the peculiarities of this system allow the to survive as competitors, since it is conceivable for the competing species to expand their overlapping niches in spa with time because of the facility provided by salinity intrusion. The elimination is automatically brought about by the monsoonal effluxes before the severity of the compe tition leads to it.

14. "No single measurement is intrinsically significant. All measurements derive their interest from their context and richness of predictive generalisations that can be produced from them" (Slobodkin, 1962 b). Study of the zooplankton forms only a fragment of the ecosystem of the estuary. Comprehending the gamut of even this cannot be attained over a single study in such a complex and intriguing system. The preludes to this by various authors have been of considerable help in the interpretation of its various aspects. Even still this study is hoped to form only a component in projecting the ultimate spectrum since variations are probable in such an intricate and dynamic environment.

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A P P E N D I X

DISTRIBUTION OF ZOOPLANKTON IN SPACE AND TIME IN A TROPICAL ESTUARY

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(Paper presented at the third All India Symposium on Estuarine Biology, 4-6, February, 1975, Held at Cochin)

DISTRIBUTION OF ZOOPLANKTON IN SPACE AND TIME IN A TROPICAL ESTUARY

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ABSTRACT

The variations in zooplankton abundance in the backwaters from Cochin to Alleppey was studied for a year. The patterns of ecological distribution of various groups and species were essentially controlled by the hydrographic changes. The seasonal cycle encountered in the hydrographical conditions were exhibited by the zooplankton species also. Of the environmental factors salinity acts as the major factor determining the viability of the various species in the estuary. Except for a few low saline species higher abundance of most of the zooplankton organisms were encountered during the high saline premonsoonal period. The monsoons which periodically flushes out the estuary and renders it unstable for part of the year induces considerable changes in the environment and population. During the peak of the monsoon the water in the estuary became practically fresh and the total biomass of the zooplankton was greatly reduced. The gradual recovery during the postmonsoonal period attained its maximum by late premonsoon period.

INTRODUCTION

The backwaters of Kerala along with its net work of anastamosing canals spread and extend almost throughout the coastline and form important areas of fisheries and other human use. It opens into the Arabian Sea at Cochin and this facilitates free mixing of sea water with the fresh water which originates from the rivers that empty into the backwaters. The regular tidal rhythm influences the mixing and flow patterns giving it the features of an estuary. Apart from the tides, the seasonal outbursts of the monsoons have great bearing in controlling the environmental factors and thereby the distribution of the organisms of the estuary.

The zooplankton of the estuary has been studied earlier by several authors. GEORGE (1958) has given an account of the general composition of the zooplankton. The biomass and the faunal composition has been studied by NAIR and TRANTER (1971) and MENON et al. (1971); hydromedusae by VANNUCCI et al. (1970) and SANTHAKUMARI and VANNUCCI(1971); Chaetognaths by VIJAYALAKSHMI NAIR (1971); Copepods by WELLERSHAUS (1969,1970); species of the family Acartiidae by TRANTER and ABRAHAM (1971) and Calanoid copepods by PILLAI (1971) and PILLAI et al. (1973). The seasonal and spatial distribution of the zooplankton covering a major portion of the backwaters from Cochin where the estuary has direct connection to the sea, to Alleppey where it terminates into a large body of fresh water - the

Vembanad Lake forms the subject of this study.

MATERIAL AND METHODS

Zooplankton samples were collected from seven stations fixed along the backwaters from Cochin to Alleppey in every month of the year 1972. (HARIDAS et al., 1973). The hauls were oblique from bottom to surface using a HT Net (mesh size 300 µ) with a flow meter attached. Hydrographic features such as salinity, temperature and oxygen were recorded along with it

RESULTS

The salinity distribution underwent drastic changes during the span of the investigation. Based on it, the period could be divided into three seasons. During the premonsoon period from January to April the influence of the saline water could be traced up to the head of the estuary. However, its magnitude decreased with the distance from the mouth. The water column was well mixed and no sharp differences in salinity occurred at any depth. The salinity values fell with the onset of the monsoons. Except in the bottom layers at the lower reaches salinity was low throughout the estuary. Towards the head, the water became practically fresh. Clear stratification of the water column was seen at the lower reaches marking off the extent to which the tidal influx could penetrate. The postmonsoonal period of November-December represented the period of gradual recovery of salinity starting at the mouth to merge into the premonsoonal conditions of the succeeding year. Eventhough the average temperature values fell with the monsoon, the differences were not much, ranging between 1°C to 2.3°C (HARIDAS et al., 1973).

The seasonal and spatial fluctuations in the zooplankton distribution was reflective of the salinity changes in the estuary. The biomass and the total numbers of zooplankton at various stations were higher throughout the estuary during the premonsoon period. They fell during the monsoon and increased at the lower reaches during the postmonsoon season. Crustacea constituted about 93% of the total annual zooplankton counts. An increase in the biomass seen at the mouth during the monsoonal period was owing to an influx of hydromedusae and ctenophores in large numbers following a break in the rains and a subsequent temporary increase of salinity in June.

Hydromedusae

Hydromedusae were present throughout the estuary in the premonsoon period. They disappeared when the salinity became low except for an influx, persumably from outside the barmouth, in June. In December a few of them occurred at Station 2. The common species which constituted the majority of the hydromedusae were Eutima commensalis, Eirene ceylonensis and

Blackfordia virginica. Their counts were higher at the middle reaches of the estuary.

Ctenophora

Their distribution was more or less similar to that of hydromedusae. _Pleurobrachia_ sp. was the dominant form.

Chaetognatha

The species _Sagitta enflata_ was present at the lower and at the middle reaches of the estuary during premonsoon season. After being absent during the low salinity conditions they reappeared at the lower reaches in the postmonsoon period. _S. bedoti_ also showed a similar kind of distribution except that they were present at the mouth in June. _S. oceania_ occurred throughout the estuary during late premonsoon period and were present in large numbers at Stations 1 to 4.

Copepoda

Copepods were present throughout the backwaters in all seasons. However, consistent high numbers were recorded during the high saline period. Their numbers which fell with the monsoon began to increase again at the mouth regions during the postmonsoon period. Of the family Paracalanidae, the species _Acrocalanus similis_ and _Paracalanus aculeatus f. major_ were present in large numbers especially at the lower and middle reaches during high salinity regime. Acrocalanus monachus and Paracalanus crassirostris f. cochinensis also occurred during this period. The species Centropages alcocki and C. trispinosus were present at the lower reaches in January and February. C. tenuiremis occurred in large numbers at the mouth in August. Heliodiaptomus cinctus and Allodiaptomu mirabilipes were two monsoonal species which occurred only during low salinity regime. Pseudodiaptomus serricaudatus was present throughout the estuary in the peak salinity month of April. In the other months of premonsoon and postmonsoon period it occurred at the lower and middle reaches. P. annandalei occurred at the lower and middle reaches of the estuary in most of the months. The species P. mertoni was encountered at the mouth when salinity was high. P. binghami/malayalus was present in small numbers during the monsoonal period. Of the family Pontellidae, Labidocera pectinata was the common species and were frequent during the high saline period.

The species of the family Acartiidae constituted the majority of the copepods of the estuary. The species Acartia centrura, A. bilobata and A. spinicauda extended throughout the estuary during premonsoon period. Their abundance dwindled during the low salibity period when they were restricted to the lower reaches. Though the species Acartiella keralensis occurred at all stations they were present in lesser numbers at the lower reaches during high salinity regime. Later they moved down the estuary when the salinity became very low at the head. Acartia plumosa also showed almost same trends of distribution as that of Acartiella keralensis. Acartiella gravelyi which is a low saline species was absent in the pre-monsoon period. It occurred at all stations during the monsoon, and at stations where the salinity had not yet recovered in early postmonsoon season.

Cladocera

This group was present during monsoon and postmonsoon periods. Evadne tergestina and Penilia avirostris were the two species present in the estuary.

Amphipoda

Gammarid amphipods were present in small numbers in the estuary in all seasons. Higher abundance was noticed during the premonsoonal period.

Lucifer

The two species Lucifer hanseni and L. typus occurred throughout the estuary during high salinity period. Their distribution was restricted to the lower and middle reaches during the other seasons. Their numbers after being low in the monsoon increased again during postmonsoonal period.

Invertebrate eggs

Eggs of invertebrates were present throughout the estuary during high salinity regime. They occurred in small numbers at the lower reaches during the monsoons and increased by the end of the postmonsoon period.

Decapod larvae

Large numbers of decapod larvae especially brachiuran zoea were present in the estuary. They constituted majority of the total annual zooplankton counts.

Fish eggs and larvae

The distribution of fish eggs showed higher abundance during premonsoon season. But the number of fish larvae were high in all seasons of the year and were present in all stations.

Other organisms as polychaete larvae, alimalarvae, actinotrochalarvae, cyphonautus larvae, ostracods, cumaceans and copelates were also present in some of the collections. The larvae occurred mostly at the mouth of the estuary during the high salinity regime.

DISCUSSION

Salinity acts as the major factor controlling the distribution of the organisms in the backwaters. The entire estuary becomes saline and rich in animal life during the premonsoonal period. About 90% of the common species occurring in the estuary registered their peak abundance during this period. The optimum conditions in which most of these estuarine species flourish seems to be ~~from~~ somewhat away from the mouth to the middle reaches as their densities were higher at these stations. This area represents a more stable environment when compared to the mouth which is subjected to disturbances due to tidal mixings.

The seasonal variations induced by the monsoons directly affects the salinity distribution. The salinity influx became restricted to the bottom layers at the lower reaches showing a two layered flow and the occurrences of the high saline species were restricted to this area. The estuary became scantly populated when compared with premonsoon period. Only a few low saline species and those tolerent to lesser salinities such as *Heliodiaptomus cinctus*, *Allodiaptomus mirabilipes*, *Pseudodiaptomus annandalei*, *P. binghami malaylus* and *Acartiella gravelyi* thrived in the middle or upper reaches of the estuary. A gradual repopulation of the estuary following a recovery of the salinity began in the postmonsoonal season. The "seeds" of zooplankton drifting in from the sea and the possible resting stages which may occur in the backwaters when the environmental conditions are adverse and spring back to activity when the salinity regains, breed and repopulate the estuary during the succeeding high salinity period.

The structure of associations of the zooplankton are also indirectly linked with salinity because the stability of the niches is controlled by its distribution. The distribution of various species undulates up and down the estuary depending on the salinity variations. Species having similar distribution can be assumed to invade similar niches. TRANTER and ABRAHAM (1971) have observed the coexistence of the species of the family Acartiidae in the backwaters. Based on the distribution, the various species of Acartiidae observed during this study also groups into Acartia centrura, A. spinicauda and A. bilobata; A. plumosa and Acartiella keralensis and A. gravelyi which is in conformity to the coexistence pattern outlined by them.

ACKNOWLEDGEMENT

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ARCHIDIAPTOMUS AROORUS, A NEW SPECIES AND A NEW SPECIES OF COPEPODA (CALANOIDA, PSEUDODIAPTOMIDAE) FROM COCHIN BACKWATERS, INDIA

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ARCHIDIAPTOMUS AROORUS, A NEW GENUS AND A NEW SPECIES OF COPEPODA (CALANOIDA, PSEUDODIAPTOMIDAE) FROM COCHIN BACKWATERS, INDIA.

By

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Analysis of the zooplankton samples collected from Cochin backwaters showed the presence of 41 specimens of hitherto undescribed copepods. Close examination revealed that although they could be assigned to the family Pseudodiaptomidae, they posses many primitive features along with a combination of characters of the families Diaptomidae and Pseudodiaptomidae. Hence a new genus is being erected and the specimens described under that as a new species.

Archidiaptomus new genus

The new genus differs chiefly from the commonly recognised generic characters of the existing genus *Pseudodiaptomus* in the following aspects: the first antenna of the female consists of 24 segments; right geniculate antenna of the male has 4 terminal segments and well developed endopods are present in the first legs of both sexes.

The new genus includes one species namely Archidiaptomus aroorus collected from Aroor, Cochin backwaters.

Type species: Archidiaptomus aroorus new species.

Etymology: The genus is named Archidiaptomus for the primitive characters it possesses.

Archidiaptomus aroorus (new species) sp. nov

Type material: All the types are deposited in the reference collection of Indian Ocean Biological Centre with the following catalogue numbers. Holotype ♀, IOBC - 0242 - 08 - 46 - 1975; allotype ♂, IOBC - 0243 - 08 - 46 - 1975; Paratypes 10 ♀, 5 ♂; IOBC - 0244 - 08 - 46 - 1975. All types collected from Aroor, Cochin backwaters, 9°58'N, 76°15'E on the 12th October, 1972 in oblique haul using HT net (mouth area 0.25 m^2, mesh size 300 µ); salinity 0.5 ‰, temperature 29.1°C.

Etymology: The specific name is given after the locality 'Aroor' from where it was collected.

Description:

Female:- Total length 1.44 to 1.50 mm (fig.1). Prosome about twice the length of urosome, bluntly rounded anteriorly. Four segments of urosome and caudal rami (fig. 2) showing relative lengths of about 13.8 : 5 : 6.4: 4 : 7.5. Caudal rami more than twice as long as wide, middle seta the longest. Genital segment slightly longer than wide, projected ventrally (fig.3) and having on the anterior lateral sides a pair of small lobes, each with a row of small spines. Distally on the dorsal side it bears 3 rows of spinules incomplete in the middle and 2 pairs of bristles on the lateral sides. A pair of small spines present in the second urosome segment.

Antenna 1 (fig. 4) 24 segmented extending to the end of the genital segment. Exopod of second antenna with two segments each. Gnathal lobe of mandible with 8 teeth and a small seta. Maxillae and maxillipede with setal armature as shown in figures.

P 1 with 3 segmented exopod and endopod. Third endopod segment with 6 setae and a small spine at the tip. P 2 to P 4 similar, first and second segments of exopods bear a small inner spine in addition to a longer one, on the outer side.

P 5 biramous, symmetrical (fig. 15). Endopod single segmented reaching the middle of Re 2 with a claw like process at the tip. Re 1 bears a single long outer spine, Re 2 with 4 spines, the terminal one longest.

Male:- Total length 1.08 to 1.18 mm (fig. 5). Prosome similar to female in shape. Urosome 5 segmented (fig. 6) relative lengths of urosome segments and caudal rami about 6.5 : 6 : 5.3 : 5 : 4.3 : 5.5. Right first antenna geniculate, 20 segmented, segments 7 to 12 and 17 with one spine each (fig. 7) A 2 to P 4 as in female.

P 5 biramous, asymmetrical (fig. 16). Endopods on both sides extending to the middle of Re 2 with bristles as figured. Left Re 1 distally bears a spine on the outer side and a longer curved spine laterally. Re 2 with a long proximal spine and the segment terminates into 2 claw like spines. Right Re 2 with an inner bristle and a spine two third distally on its outerside. Segmentation between Re 2 and Re 3 indistinct, the latter forms a long spine with a bristle proximally on its inner side.

DISCUSSION

Family Pseudodiaptomidae include the genus Pseudodiaptomus established by Herrick in 1884 to accommodate the species pelagicus which has not been recorded subsequently. Since then, the number of species in this genus has increased to 37. Marsh (1933) placed 9 species of the family under the genus Schmackeria Poppe and Richard, 1890 which, according to him, differs chiefly in the presence of a long curved projection on the inner border of the second basipod segment of the left fifth foot of the male. Johnson (1939) erected a new subgenus Pseudodiaptallous to include a new species euryhalinus from La Jolla, California. Sewell (1956) placed Pseudodiaptomus sensu stricto, Schmackeria and Pseudodiaptallous as three sub-genera of Herrick's original genus Pseudodiaptomus sensu lato. These classifications are not always followed by taxonomists and Pseudodiaptallous appears tobe the only valid sub genus under the genus Pseudodiaptomus. The reasons for the revival of Schmackeria as a separate genus from Pseudodiaptomus sensu lato by Marsh, however, does not appear to be sustaining, especially as they do not differ in the females except in the shape of the posterior corners of the last thoracic segment which is too inapt tobe considered in the diagnosis of generic differences.

The new genus Archidiaptomus aroorus, although, has many features that are 'pseudodiaptomid' which would justify its inclusion in the family Pseudodiaptomidae, sharply differs from the existing species of the genus Pseudodiaptomus. Also, some of them do not conform with the recognised generic characters of the genus Pseudodiaptomus. It possesses many 'primitive' characters and strong affinities to the family Diaptomidae. Hence it is placed in a new genus.

The two segmented exopod of the female fifth leg is typical of Pseudodiaptomidae though some what peculiar in form. But it is unique in maintaining fully developed endopods of an unusually spinous form. This appears to be a primitive or generalised condition placing this genus very close to Diaptomid The exopods of the right and left fifth legs of the male are fully developed as in Pseudodiaptomidae (in Diaptomidae left one is usually smaller). But it is again unusual in maintaining the primitive feature of both endopods being fully developed whereas in Pseudodiaptomus the endopods of the male fifth legs are either rudimentary or lacking.

The urosome is 4 segmented in female (3 segmented in Diaptomidae) and 5 segmented in male as in Pseudodiaptomidae and the ornamentation of the genital segment is also somewhat pseudodiaptomid in character. The first antenna has a greater number of segments than the species of the genus Pseudodiaptomus (mostly 20 - 22, 23 in some) and in having 24 segments approaches the 25 segmented nature of Diaptomidae which is considered as a primitive condition in calanoid copepoda. The right geniculate first antenna of the male has four terminal segments as ~~in~~ is usually found in Diaptomidae (2 to 3 in Pseudodiaptomidae). The first swimming leg has 3 segmented endopod typical of Pseudodiaptomidae as against 2 segmented condition in Diaptomidae. While the unarmed nature of the outer margin of the second exopod segment of the first swimming leg is a feature shared by the species of both families, the rounded form of the posterior angles of the metasome and the long caudal rami of the present species are pseudodiaptomid characters.

Family Pseudodiaptomidae includes marine, brackish and fresh water species. Twenty two species and one subspecies have been recorded from Indian Ocean area (Pillai, 1970). Distribution of the species of the families Pseudodiaptomidae and Diaptomidae is remarkably diverse in the brackish and fresh water regions of India. Seven species and one subspecies of Pseudodiaptomidae and three species of Diaptomidae have been recorded from Cochin backwaters (Pillai, 1971; Madhu Pratap and Haridas, 1975). Species of Pseudodiaptomidae have been observed to be quite hardy tolerating a wide range of salinity fluctuation (Grindley and Grice, 1969; Grindley, 1974). They certainly form a fascinating group of animals with the species having a wide and often curiously isolated distribution. Burckhardt (1913) suggested the probability of the species of Pseudodiaptomidae being in the process of migration from sea to fresh water. Sewell (1956) was of the opinion that the original 'home' of Pseudodiaptomus Herrick sensu lato was the western side of the Pacific Ocean from where they migrated to different areas during late cretaceous and developed into different species. But the occurrence of Archidiaptomus aroorus in low salinity conditions would suggest a new angle of approach if it could be considered as the common ancestral form from which both Pseudodiaptomidae and Diaptomidae have evolved or as an intermediary form because of its strong affinities with both families.

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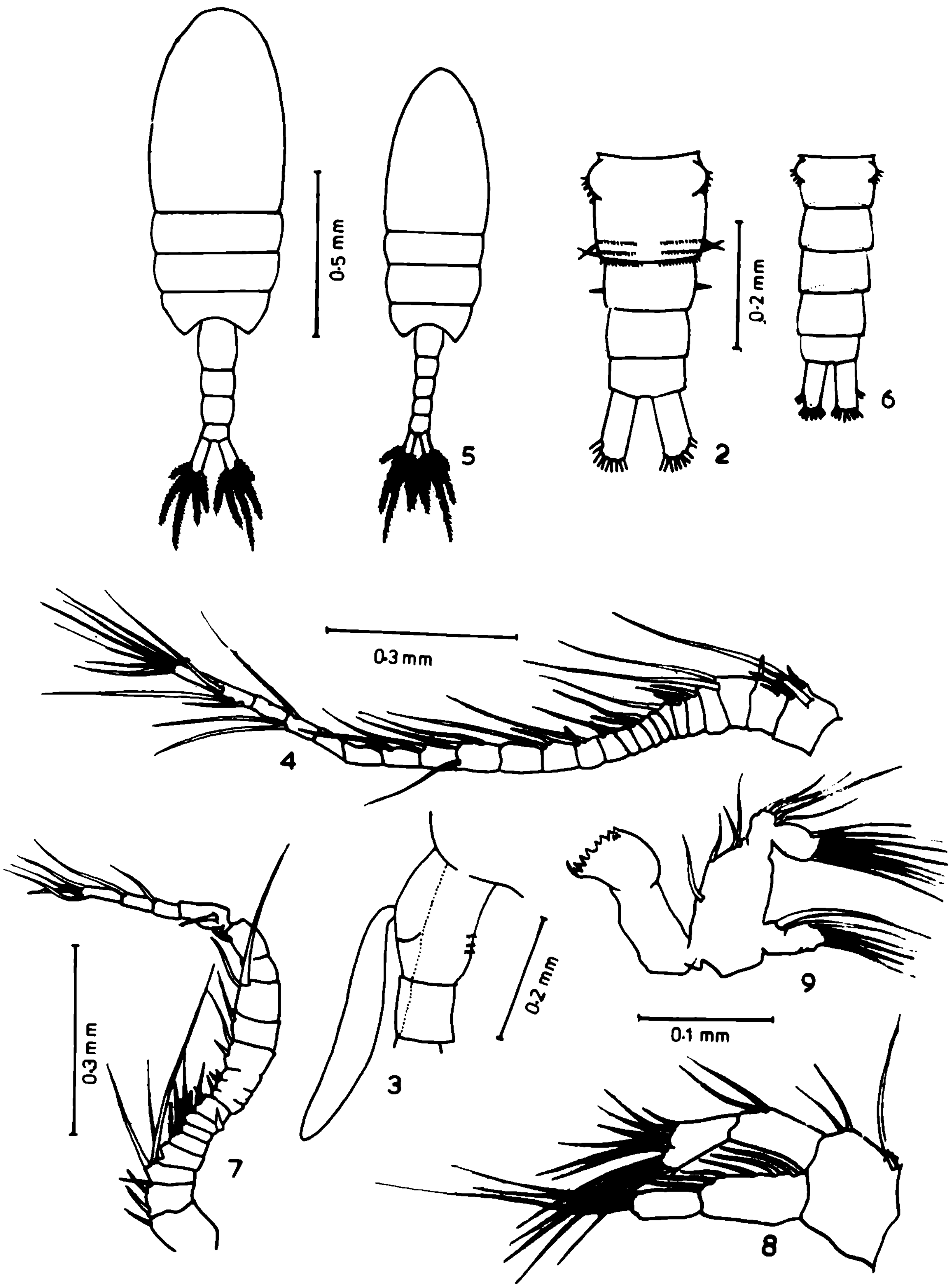
LEGEND TO FIGURES

Figs. 1 - 9. *Archidiaptomus aroorus*.

1, female, dorsal view.
2, female urosome, dorsal view.
3, female genital segment, lateral view.
4, female first antenna.
5, male dorsal view.
6, male, urosome, dorsal view.
7, male first antenna.
8, female, second antenna.
9, female mandible.

Figs.10-16. *Archidiaptomus aroorus*.

10, female, first maxilla.
11, female second maxilla.
12, female maxillipede.
13,,female first leg.
14, female fourth leg.
15, female fifth leg.
16, male fifth leg.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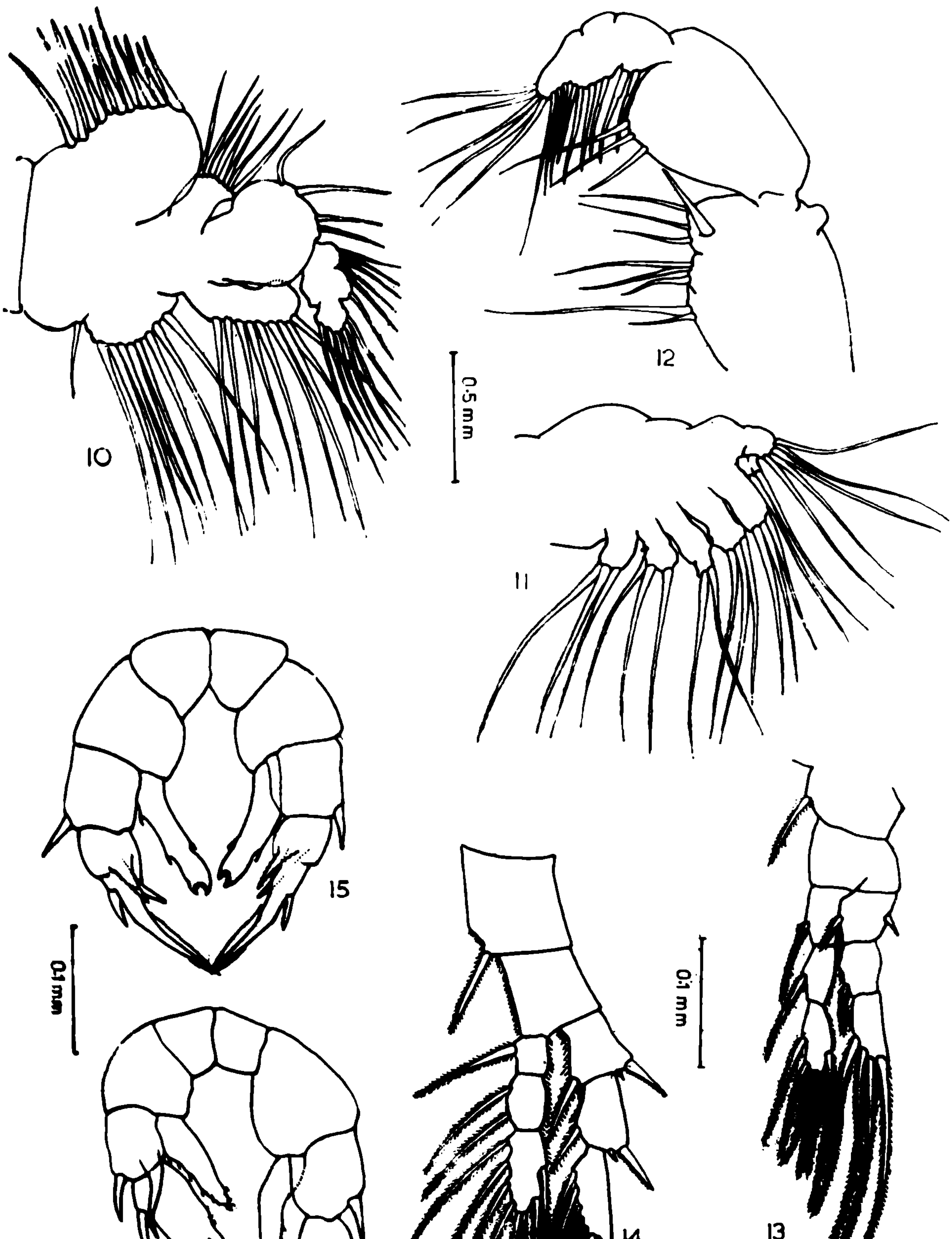
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ecological associations and their implications are minimal from these waters. An attempt is made here to make a comprehensive study of the nature of species assemblages within major groups and their ecological distribution covering both spatial and temporal features with relation to environmental fluctuations.

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