ZOOPLANKTON STUDIES IN THE COCHIN ENVIRONS

THESIS SUBMITTED TO THE COCHIN UNIVERSITY IN PARTIAL FULFILMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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C E R T I F I C A T E

This is to certify that this thesis is an authentic record of the work carried out by Mr. P. Haridas, M.Sc. under my supervision at the Regional Centre of National Institute of Oceanography, Cochin and that no part thereof has been presented before for any other degree in any University.

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1. INTRODUCTION.

Estuaries are important areas of human use for fisheries, transportation, food production and recreational pursuits. They form the nursery grounds for the larvae and young ones of numerous marine species, many of them commercially important. However, often they are turned into receptacles of human wastes and subject to pollution from industrial effluents.

Estuaries are highly productive areas and contribute substantially to the productivity of the coastal waters. With the depleting marine food resources and increasing population, the focus has now shifted to aquaculture. Estuaries because of their accessibility and semi enclosed nature, have emerged as ideal sites for these activities.

Various kinds of estuaries from coastal plain estuaries to steep sided fjords exist, all with the common feature of being areas where fresh water meet with sea water, thus forming buffer zones between the marine and limnetic counterparts. The most glaring environmental feature of the estuaries is the wide nature of fluctuations that occur in them. Understandably, estuaries have developed its own flora and fauna which are capable of withstanding or adapting to these changes. A cursory look at any estuarine biota will show predominantly estuarine forms, mixed with some stragglers from the adjoining marine and fresh water environments.

A proper understanding of the environmental parameters and their effects on the biota is a must in the management of any ecosystem. Zooplankton form a vital link in the trophic chain of any aquatic ecosystem. Their production and abundance can be directly linked with the potential of an area both for capture and culture fisheries. Apart from this, their composition and distribution provides interesting insights into many ecological concepts like community structure, species diversity, species coexistence and evolution. In the ensuing account it will be shown that the estuarine zooplankton have its own distinctive assemblages - different from the adjoining marine or fresh water environments - able to withstand the peculiarities nature has imposed on them.

India has several major riverine/estuarine systems (Fig. 1). Along the east coast are the Hoogly, Mahanadi, Godavari, Krishna and Cauvery. On the west coast we have the Narmada and Tapti of the Gujarat and Mandovi-Zuari estuaries of Goa. The Pulicat and Chilka lakes of the east coast and the Vembanad lake of the west coast form large bodies of brackish water. Apart from these, many medium and minor rivers (about 100) also contribute to the estuarine wealth of India. The rivers together have a catchment area of more than 3 million sq. km and a runoff of 1,600 million cu. m (Khosla, 1951; Rao, 1975). The total runoff of the major riverine systems of the east and west coasts of India is given in Table 1. Of this, the discharge from the rivers of the Kerala coast is estimated at 2.56×10^4 million cu. ft/year (Karunakaran, 1982).

The State of Kerala has many estuarine systems, the hydrobiology of which are greatly influenced by the monsoons. Of the tropical monsoonal estuaries of Kerala, the Cochin backwaters have received most of the attention of the scientific community. The present work on zooplankton of brackish water environs of Cochin was made more broad-based as data from seven other estuaries located along a 500 km stretch of the coast also came on hand. Thus this is the first attempt of its kind to study and compare the estuarine zooplankton of a coast receiving the full impact of both the monsoons. However, in carrying out sampling programme covering such a wide area several logistic problems arose and the observations had to be limited to one station each near the mouth in the estuaries, except Cochin backwaters. In the following account, the distribution and other aspects of zooplankton from Cochin backwaters will be used as the spring board to evaluate the similarities and variations in the ecology of estuarine zooplankton in the other areas of study.

1.1. Definitions and classifications of estuaries.

Various definitions have been put forward by different authors for estuaries. 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 are also put forward by Day (1951) and Rochford (1951).

Pritchard (1952a) defined estuary as a semi-enclosed 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 fresh water 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 fresh water inflow nor evaporation dominates. But Pritchard later (1967) modified his original definition for estuaries as "a semienclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water 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.

A classification based on topography has been presented by Pritchard (1952b). He divides the estuaries into four groups: Drowned river valleys or coastal plain estuaries, fjords, bar built estuaries and estuaries produced by tectonic processes.

1. Drowned river valleys or coastal plain estuaries are those 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 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 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 coast-line with frequently more than one river entering the estuary.

4. Coastal indentures formed by tectonic processes like faulting or local subsidence having an excess supply of fresh water form another group.

The original definition of Pritchard is further refined by Caspers (1967) who feels that it would include both estuaries and lagoons. He differentiates lagoons as those 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. Review of the earlier works.

Considerable amount of work on the physical, chemical, biological and other related aspects of various estuaries have come out in the last 30 years. These studies have contributed to a better understanding of the physical and biological processes taking place in the estuarine systems.

Earlier reports on estuaries include studies on the South African estuaries by Day (1951, 1967); Day *et al.* (1952, 1954, 1956); Australian estuaries by Rochford (1951) and Chesapeak Bay by Pritchard (1952a, b, 1954, 1956). Contributions on estuarine hydrography, circulation, fauna and their ecology have come from Bowden (1960, 1963); Emery and Stevenson (1957), Hedgpeth (1957), Jeffries (1962a, b, c, d), Ketchum (1951, 1954) and Odum (1971). A treatise on various aspects of estuarine research and management by outstanding authors is presented in "Estuaries" (Lauff, 1967).

Pioneering studies on the estuaries in India date back to the beginning of this century. The fauna of the Ganges delta was described by Annandale (1907), Alcock (1911) and Kemp (1917). Excellent studies on systematics and taxonomy have come from the Chilka Lake (Annandale and Kemp, 1915; Sewell, 1934). 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. Godavari estuary has been studied in detail in 1964 (ICAR Report) by Chandra Mohan (1963) and Chandra Mohan and Rao (1972). Vellar estuary of Porto Novo has been studied by Seshaiya (1959); Rangarajan (1959); Krishna Moorthy (1961), Ramamoorthy *et al.* (1965), Subbaraju and Krishna Moorthy (1972), Krishna Moorthy and Sundar Raj (1973), Devendran *et al.* (1974). Various aspects like hydrography, circulation, chemistry, phytoplankton, benthos etc. from Mandovi-Zuari estuarine system of Goa have been studied by Rao *et al.* (1972), Singbal (1973), Parulekar *et al.* (1973, 1980), Cheriyan *et al.* (1974, 1975), Bhargava and Dwivedi (1974), Goswami and Singbal (1974), Goswami and Selvakumar (1977), Rao (1976), Varma *et al.* (1975). Compiled information on the more recent works on the various aspects of estuarine biology has come from Natarajan (1975) and Marian (1977).

The backwaters of Cochin is one of the better studied estuaries in India. General hydrography of the estuary was studied by Ramamirtham and Jayaraman (1963), Darbishire (1967), Wellershaus (1972), Haridas *et al.* (1973) and Shynamma and Balakrishnan (1973). The tidal fluctuations were reported 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 Murty and Veerayya (1972 a, b) and Veerayya and Murty (1974); phosphate regeneration by Reddy and Sankaranarayanan (1972) and nanoplankton by Qasim *et al.* (1974). The organic production and phyto-plankton 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 problem in the estuary has been reported by Unnithan *et al.* (1975), Saraladevi *et al.* (1979), Remani *et al.* (1980 a, b; 1981) and Venugopal *et al.* (1980). The changes in the ecology of the system brought about by man-made changes were reviewed by Qasim and Madhupratap (1979).

The general composition of the zooplankton of Cochin backwaters was published by George (1958). Some aspects of seasonal changes in zooplankton have been studied by Nair and Tranter (1971), Wellershaus (1974) and Menon et al. (1971). Distribution and ecology of some of the groups of zooplankton has been studied by various authors, such as hydromedusae by 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). Species composition and their seasonal fluctuations in the estuary by Madhupratap and Haridas (1975) and Rao et al. (1975). Studies on the tidal influence on the estuarine zooplankton, community structure and ecology of some species of copepods have come from Madhupratap (1978, 1979, 1980). Magnitude of secondary production in the Cochin backwaters has been studied by Madhupratap et al. (1977).

Studies on the other estuarine systems along the Kerala coast are scanty and discontinuous. Some preliminary hydrobiological and planktonological investigations in the river mouth at Korapuzha estuary were made by Suryanarayana Rao and George (1959), George (1958 a, b) and Varkey John (1971); at Beypore by ~~Varkey~~ John and Alexander (1968). Recently Murugan *et al.* (1980) have studied the benthic fauna of Veli Lake. Mathew and Balakrishnan Nair (1980) have studied the phytoplankton of Ashtamudi (Neendakara) estuary. The numerous other estuaries of Kerala coast have received little attention.

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2. MATERIALS AND METHODS.

2.1. Area of work.

Kerala with a coastline of about 600 km is endowed with numerous and extensive brackish water bodies, mostly running parallel to the coastline. Eight major estuarine systems along this coast, covering a distance of 300 km were investigated over a period of one year during 1978, namely Veli at Trivandrum, Neendakara at Quilon, Thottappilly near Alleppey, Cochin backwaters at Cochin, Korapuzha, Kallai and Beypore at Calicut and Mahe near Tellicherry (Fig. 2).

Veli Lake:

The Veli lake is primarily a fresh water body and is one of the smallest of the lakes confined to the southern part of the Kerala State, situated 5 km north-west of Trivandrum. It is 1 km long and 0.3 km broad. A narrow strip of sand bar across the mouth of this lake during the dry season obstructs free exchange of marine and fresh water. The lake is very shallow, depth being 2 to 2.5 m. The bottom is sandy. Observations were made near the sand bar on the lake side.

<u>Neendakara</u>:

The estuary at Neendakara is situated about 9.6 km north of Quilon at 9°28' - 8°45'N lat. and 76°28' - 77°17'E long. This estuary is one of the foremost centres of marine fish landing along the southern Kerala coast. It is also known as Ashtamudi estuary. The point of observation was near the mouth and in this area, the water is always churned up by the propellers of fishing boats and tidal action. The depth at the area of observation is 4 m. The bottom is muddy sand.

<u>Thottappally Lake</u>:

This lake is situated about 25 km south of Alleppey. There is a narrow strip of sand bar across the mouth of this lake. A barrage is constructed on the eastern side in the lake about 0.5 km away from the sand bar to prevent incursion of saline water into the hinterlands so as to enhance paddy cultivation. The spill ways are opened during the monsoon period. The samplings were made still further on the eastern side of the barrage.

Cochin backwaters:

The Cochin backwaters include a system of inter-connected lagoons penetrating the main land and enclosing many islands in between, whose tidal area amounts to approximately 500 sq. km. The backwaters around Cochin is located along 9°58'N, 76°15'E. It has a permanent connection with the Arabian Sea on the western side by a channel about 450 m wide which forms the entrance to the Cochin harbour. At the northern extremity it opens into the Arabian Sea at Azhikode and at the southern end it terminates into a large body of fresh water namely Vembanad lake.

The coastline is of an emergent type formed of a number of narrow sand bars running parallel to the coastline often in several rows (Derbishire, 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 where observations were made is about 13 m deep. The depth of the estuary gradually reduces further upstream to about 2 m at Alleppey. The depth of the area north of the barmouth is uniformly shallow, being 2 to 4 m. The bottom of the estuary is generally muddy.

The major source of fresh water in the estuary are the two large rivers namely Pamba on the south and Periyar on the north. In addition to these, Meenachil and Muvattupuzha rivers and several small tributaries and irrigation channels join the backwaters.

The tidal effects of the estuary is maximum near the mouth, the amplitude of the tides being about 1 m at the harbour area decreasing towards the upper reaches. Incursion of sea water to the upper reaches oscillates depending on the fresh water efflux (Haridas _et al._, 1973).

__Korapuzha estuary:__

The Korapuzha estuary is shallow and 32 km long. Two rivers feed the estuary. The Elathur river joins the Korapuzha backwater system about 1 km away from the mouth. Another stream running from the foot of the high mountain range surrounding the Nedianadu Malai empties into it about 16 km from the river mouth. The depth of the estuary is 4 to 5 m and the bottom is sandy. During monsoon the silt laden fresh water run down the river suppressing the ebb tide almost completely.

Kallai estuary:

Kallai estuarine system has its origin as a small stream from Kannamangalam and flows down through Kannathupalam and Mankava to Kallai town and then joins the Arabian Sea. It has a length of 30 km. All along the river banks there are large numbers of coir cottage industry units and considerable amount of coconut husks are dumped into the river for retting. These husks get sedimented at the bottom and due to organic decay of these, a black layer is formed on the substratum mixed with sand. Further, large number of logs are kept in this river for conditioning all through the year. These logs also foul the water. During the rainy season water level rises up by 2 to 4 m in this river. In fact torrential flow of fresh water from uplands cleans the river seasonally. Because of the small size of the river the tidal currents enter upstream into the river by about 18 to 20 km.

Beypore estuary:

Beypore estuary has its source principally in the Nilgiri Hills and flows down as a major river through Nilambur, Mambad, Arikkod, Mavoor, Kanniyamparamba, Feroke and Beypore and empties into the Arabian

Sea. The rivers Cherupuzha and Irinjipuzha open into this estuary at Kanniamparamba and Mavur respectively.

The river Chaliyar which receives the effluents from the Rayon factory at Mavur also joins this estuary. During monsoon the water level rises up by 4 to 5 m and the water becomes turbid. The bottom is sandy.

Mahe estuary:

River Mayyazhi (Mahe) has its origin in the Western Ghats. The drainage basin has similar characteristics as those of other three rivers of north Kerala described earlier. It enters the Arabian Sea at Mahe, a small Union Territory and part of Pondicherry State. During the monsoon seasons the water level at the point of sampling rises by about 1.5 to 2 m. The bottom is muddy sand and has an average depth of 5 m. Stake net fishery operates here almost round the year. It has a small fishing harbour and is a landing centre for the green mussel Mytilus viridis collected by local divers. This river also has retting yards in it.

2.2. Methods.

All observations were conducted monthly in the year 1978. Observations were made at one station near the mouth at all the estuaries except Cochin backwaters. In the Cochin backwaters apart from collecting monthly information at a station fixed at the mouth, the distribution of zooplankton to the interior of the estuary was also studied. For this purpose zooplankton and environmental characters were observed from 6 more stations in four months, representing various seasons, viz. January (early premonsoon), April (peak saline period), July (monsoon) and November (postmonsoon). The stations were fixed to cover the entire backwaters from its mouth (at Cochin) to its head (Alleppey) (Fig. 3).

2.2.1. Sampling procedure:

Water samples were collected from the surface with a clean plastic bucket and from mid depth and bottom using a water sampler for the estimations of hydrographical parameters. The temperature was recorded immediately after sampling using a thermometer. Salinity was estimated using Mohr-Knudsen titration method and oxygen by Winkler's technique. Zooplankton was collected by oblique hauls from the bottom to surface using an HF net (Hensen-Frazier net, mouth area 0.25 m^2, length 3 m, mesh size 300 micron).

A flow meter (Rigosha Model No.850) was attached to the mouth of the net to estimate the volume of the water filtered. The net was gradually drawn from the bottom to the surface, the duration of haul being 5 minutes. Zooplankton was preserved in 5% formaline.

The plankton samples were filtered, drained of excess water using absorbent paper and added to known volume of water to find out the displacement of volume. Subsamples were often taken for the analysis using a Folsom Plankton Splitter. Large organisms like hydro-medusae, ctenophores and chaetognaths were removed and counts taken for the whole sample. The subsample was then spread on a counting tray and counted to species level as far as possible. The whole sample was used for counting whenever the sample was small. The counts were then transformed into numbers per unit volume of water filtered using the flowmeter data.

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3. HYDROGRAPHY.

Assessment of environmental features and their changes is essential for understanding the ecology and inter-relations of the organisms inhabiting an area. Several studies mentioned earlier have contributed to the understanding of hydrobiological aspects of Indian estuaries. The State of Kerala gets the rainfall from both Southwest and Northeast monsoons and they have profound influence on the hydrography and biology of the estuaries. The seasons can broadly be divided (although this is somewhat arbitrary, since the onset of rainfall varies from year to year) into premonsoon (January to April), monsoon (May to October) and post-monsoon (November-December) periods. However, at the mouth regions of most of the estuaries saline conditions prevail at the beginning of the monsoon period also (May-June) although the salinity towards the interiors is brought down.

3.1. Cochin backwaters.

3.1.1. Salinity:

The most important factor controlling the biological processes in tropical estuaries is the monsoon and the associated changes in salinity. Wide variations were observed in the salinity structure of the water column in this estuary during the different seasons (Fig. 4 A).

Premonsoon:

A more or less vertically homogeneous pattern in salinity distribution was observed by the beginning of premonsoon. Salinity values were high (> 30‰.) both at surface and bottom. It steadily increased through the season and registered the maximum value (34.8‰.) in April. The influence of the saline water could be traced upto the head of the estuary (Fig. 4 B). The recovery after the monsoon was gradual and the values towards the head increased from 3.9‰. in January to 13.0‰.by April. Some amount of stratification occurred at the middle reaches during the early premonsoon. But the water column became well mixed during the peak premonsoon period.

Monsoon:

The onset of monsoon in May brought about a total change in the physical characteristics of the environment. Large quantities of fresh water were discharged into the backwaters through the rivers and land runoff during the monsoons. During the year of observation (1978) rains started from May and lasted upto October with intermittent breaks.

The surface salinity fell from 34.8‰ in April to 9.5‰ in May. Bottom salinity varied from 36‰ to 33.8‰ at mouth of the estuary. The water column became stratified showing a two-layered flow. In June an increase in salinity was observed both at the surface and bottom due to a short break in the monsoon. Bottom salinity reached 35.8‰ which was the highest value recorded. The presence of this high saline water in the bottom layers was probably due to the intrusion of upwelled Arabian Sea water into the channel (see 3.1.2) during this period. Surface salinity reached near zero values in July when the monsoon was at its peak. It showed an increasing trend in August and September owing to an abatement of the force of the monsoons but decreased again in October when the rainfall increased. Towards the upper reaches the estuary remained fresh water dominated throughout the monsoon (Fig. 4 B).

Postmonsoon:

By November surface salinity started to show an increase. The water column continued to be stratified with high saline water (32.1‰) at the bottom. Sea water started to dominate by December, stratification being less apparent, the conditions leading into homogeneous situation of the premonsoon.

Salinity recovery was rapid at the mouth and gradual at the upper reaches. Even after the rain fall was decreased, the fresh water flow was still strong enough to restrict the incursion of marine water towards the head of the estuary during the postmonsoon period.

3.1.2. Temperature:

Fluctuations in temperature were not much and as pronounced as that of salinity but the seasonal changes were reflected in the temperature structure also.

Premonsoon:

Temperature was higher during the premonsoon season. In January the surface temperature was around 28°C. There was a gradual increase as the season progressed and by April the surface temperature reached 31.6°C. The water column was well mixed and homogeneity prevailed with little difference in temperature between the upper and bottom layers (Fig. 4 A).

Monsoon:

The effect of monsoon was reflected in the temperature distribution also. Temperature suddenly dropped from 31.6°C in April to around 26.0°C in May at both surface and bottom. It increased to 29.8°C in June corresponding to a temporary break in monsoon and fluctuated between 28°C and 30°C during the monsoon season. Steep vertical gradient in temperature existed during this season. Lowest temperature (24.4°C) was recorded at the bottom in July. The difference between the surface and bottom temperature fell within the range of 1.6°C to 5.1°C from June to October.

Thus, during the monsoon period, especially in July-August, thermal stratification was very steep. The cold high saline water at the bottom layers is probably the upwelled Arabian Sea water entering the channel. Presence of cold dense waters upwelled from the sub-surface levels of Arabian Sea in the continental shelf and its incursion into the mouth area of Cochin backwaters has been reported during these months earlier (Banse, 1959; Ramamirtham and Jayaraman, 1960, 1963; Venugopal *et al.*, 1979).

Postmonsoon:

During this season, temperature differences between the surface and bottom became less sharp and by December the water column became more or less homogeneous.

3.1.3. **Oxygen:**

The pattern of oxygen distribution was also similar to that of salinity and temperature. During premonsoon, the surface and bottom oxygen content did not show any significant variations and the values ranged between 2.0 ml/l to 3.0 ml/l.

Surface oxygen content showed a general increase during the monsoon period. It increased to 4.0 to 5.0 ml/l in July and August. But the bottom values decreased during this period, the minimum observed being 0.3 ml/l in August (Fig. 4 D). The very low oxygen content at the bottom layers during July-August was further evidence to the presence of upwelled water. The low oxygen content generally found in the bottom during monsoon period is probably owing to the high turbidity and low light penetration (Qasim *et al.*, 1968; Venugopal *et al.*, 1979) limiting primary production in these layers.

During the postmonsoon period, the surface and bottom oxygen values were more or less same and the water column fairly homogeneous. However the surface values were still less, compared to the monsoonal period.

3.2. Comparison with other estuaries.

The hydrographical characteristics of Cochin backwaters is typical of other estuarine systems of Kerala coast. In all these estuaries monsoon is the key factor bringing about the annual cyclic changes in the hydrobiology of the environment. As mentioned earlier, the most important parameter controlling the biological processes in tropical estuaries is salinity. The large quantities of fresh water which inundate the estuaries during the monsoon often abruptly alters the salinity structure and causes total transformation in the faunal composition.

The basic difference in the physical characteristics of Cochin backwaters with other estuaries studied is that the Cochin backwaters form a large basin of brackish water into which several rivers empty. The other estuaries apart from Veli and Thottappilly (which are primarily fresh water lakes having limited periodic connection with the sea) are river mouths where estuarine conditions develop. More over the channel area of Cochin backwater system is constantly dredged and deepened to accommodate port traffic while the mouth of other estuaries are comparatively shallower (some dredging operations are conducted periodically at Beypore and Neendakara also). However, the general hydrography at the mouth regions of Neendakara, Kallai, Beypore, and Mahe estuaries is more or less similar to Cochin Back-water system and hence only the salient features are discussed.

3.2.1. Comparison of Neendakara, Kallai, Beypore, Korapuzha and Mahe estuaries.

Salinity:

Salinity distribution in these estuaries was similar during the premonsoon period. At Neendakara the surface salinity ranged between 31.4‰ to 34.2‰ while at the bottom it varied between 32.1‰ to 34.4‰ (Fig. 5). At Kallai maximum salinity of 35.7‰ was recorded in April (Fig. 6). At Beypore, the salinity after registering a maximum (33.3‰.) in February fell during the subsequent months of the season and at the peak of premonsoon, in April, it was only 29.2‰. at bottom (Fig. 7). The conditions were similar at Korapuzha and Mahe estuaries also. The water column was well mixed and the values ranged between 30‰ to 35‰ during the premonsoons (Figs. 8 and 9).

Salinity fell with the onset of monsoon in May. At Neendakara it was reduced from 34.2‰ in April to 16.9‰ at the surface and 18.6‰ at the bottom (Fig. 5). Similar decrease was noticed at Korapuzha, Kallai, and Mahe but the salinity remained high at Beypore. A slight reduction in the force of monsoon on the southern parts of Kerala in June resulted in a temporary rise in salinity in the estuaries at Cochin, Neendakara, Veli and Thottappilly. But again it fell to near zero values both at surface and bottom in all the estuaries with the heavy rains in July. But at Neendakara the surface and bottom salinities were reduced only to 6.6 and 14.4‰, respectively in July probably because of the lesser rainfall in this area.

Vertical stratification during monsoon was less pronounced in these estuaries as compared to that in Cochin backwaters. However, a lesser gradient was observed at Kallai, Beypore and Korapuzha during the later part of the monsoon period (Figs. 6, 7 & 8). Virtually no stratification occurred at Neendakara and Mahe estuaries (Figs. 5 & 9). The probable reason for the less marked stratification compared to Cochin backwaters is that the sand bar at the mouth of the latter is deepened periodically allowing free incursion of sea water along the bottom as a typical salt wedge.

Because of the same reason, the salinity recovery in some of these estuaries was slower in the early pre-monsoon period (November) compared to Cochin backwaters. The regional variations in the rainfall also influenced this to some extent. By December the salinity started increasing in all the estuaries.

Temperature:

Temperature also fell in tune with the pattern of salinity distribution (Figs. 5-9). In general, it fell by 7.0 to 8.0°C in monsoon compared to the pre-monsoon values. But a sharp gradient in the vertical thermal structure was not apparent in these estuaries unlike Cochin backwaters except at Kallai (Fig. 6). The differences between surface and bottom in general were only about 1.0 to 1.5°C. At Kallai the highest gradient observed was 3.5°C in August.

Oxygen:

Oxygen content at the surface layer in these estuaries was generally higher compared to Cochin back-waters. At Neendakara it fluctuated between 3.3 ml/l to 3.8 ml/l during the premonsoon. It further increased to 4.9 and 5.3 ml/l in August and November (Fig. 5). The bottom values did not vary much from the surface values during early monsoon period. But from August a difference of about 1.5 ml/l was observed between them. The distribution of surface oxygen at Kallai was different. From 2.3 ml/l in April it increased to 4.7 ml/l in June. Values then decreased steadily during the monsoon season and registered the minimum in October (Fig. 6). The bottom values showed similar trend of distribution as that of surface without much difference except in April and May. A steady increase in the surface oxygen content was noted at Beypore estuary from the premonsoon to monsoon period (Fig. 7). The maximum value 5.5 ml/l was observed in August. Here also the bottom oxygen did not show any significant variation from that of the surface. The oxygen distribution did not exhibit any definite trend which could be correlated to seasons at Korapuzha and Mahe where high and low values occurred in all seasons (Figs. 8 & 9).

One notable aspect emerging in the comparison of the hydrographic parameters is the absence of upwelled Arabian Sea water in any of these estuaries during the July-August period unlike the Cochin backwaters probably owing to the shallower nature of their mouths.

3.2.2. Comparison of Veli and Thottappilly lakes.

These two lakes on the southern part of the Kerala coast differ from the other estuarine systems in their hydrobiological aspects. The Veli lake has a sand bar across its mouth which permits exchange of fresh and marine waters only for a short span of time. At Thottappilly a man-made barrage obstructs free inflow of water from the sea (see 2.1).

<u>Salinity</u>:

At Veli the surface salinity was low throughout the year. Maximum value recorded was 4.5‰ in November. During the premonsoon the values ranged from 0.7‰ to 3.2‰. Bottom salinity was higher during this period, registering the maximum in March (23.8‰) (Fig. 10). It fell to near zero values during monsoon and the water column became practically fresh. During the post-monsoon the bottom salinity increased to 13.4‰ while the surface values remained low. Murugan *et al.* (1980) have also observed low salinities in this lake but maximum value they recorded was only 4.8‰.

The Thottappilly lake was dominated by fresh water throughout the year. The salinity was very low, always less than 3‰ during all the seasons except in January when the bottom salinity was 7.8‰ (Fig. 11).

Temperature:

High temperature prevailed during the premonsoon at Veli. From 31.2°C in January it increased to the maximum of 34°C in March (Fig. 10). During the monsoon the values fell and fluctuated between 25°C and 30°C. The minimum was observed in October. During post-monsoon the surface temperature was around 30°C. The bottom values did not show any variation from those of the surface during all seasons since it is a shallow area (2.5 m).

The temperature distribution was almost similar at Thottappilly also with maximum temperature (33.0°C) being recorded in March and April at the surface and minimum (26.5°C) in July at the bottom (Fig. 11). The bottom temperature was only slightly less compared to the surface except in July and October.

Oxygen:

The surface water at Veli had high oxygen concentrations throughout the year ranging between 4.0 ml/l to 5.9 ml/l except during early premonsoon period (January and February). Oxygen in the bottom layer was lower in most of the months, maximum difference being recorded in August (Fig. 10).

Oxygen distribution at surface at Thottappilly was more or less similar to the Veli lake (Fig. 11).

The major difference of Thottappilly and Veli lakes from the other estuaries is the presence of low saline water at the surface throughout the year. While at Thottappilly the bottom salinity also remains low more or less throughout, salinity goes quite high at Veli lake in post and premonsoon seasons. The origin of this high saline bottom water at Veli although there is no free connection with the sea is subject to some speculation.

It is perhaps best explained in terms of the dynamics of a coastal aquifer (Glover, 1959; Cooper, 1959). It involves ocean tides, the rise and fall of the ground water table and the bed of the sand bar acting as a permeable medium. A zone of diffusion is formed in the bed and sea water and fresh water become intimately mixed in this zone. To quote Cooper "it appears to be reasonably certain that wherever a zone of diffusion exists in a coastal aquifer a flow of sea water from the floor of the sea into the zone of diffusion will occur. The flow may be interrupted or reversed during low stages of tide or high stages of the water table but on the average it will persist in a land ward direction".

Thus the salinity increase in the bottom layer of Veli lake may be through this diffusion, occurring along the bed. (However, the presence of some typically coastal species in the Veli lake in some months - see Chapter 4 - makes it impossible to arrive at a firm conclusion. There could also be a possibility of some water spilling over during intense wave action and sinking to the bottom of the lake).

At Thottappilly the configuration of the terrain where collections were made is different. The barrage is built about 0.5 km away from the sand bar and the collections were made from inside the spillway. The distance from the sea to the place of collection may account for the lower salinity at the bottom encountered at this station.

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4. ZOOPLANKTON.

Estuaries are transition areas between the more stable conditions of neighbouring sea and fresh waters and exhibit increased gradients and fluctuations of abiotic and biotic factors (Kinne, 1967). The physico-chemical conditions and their fluctuations in an estuary are determined by the tide, the quality and quantity of the river water discharged and the morphology of the area. The unpredictability of these factors render estuaries physically controlled rather than biologically accommodated habitats (Sanders, 1969). The zooplankton occupying this biotope have to be tremendously accommodative to put up with the stress. Thus, true estuarine organisms form a class by themselves apart from the more common euryhaline marine fauna, and to a lesser extent stenohaline fauna and fresh water organisms which frequent these waters.

The composition, distribution and abundance of various groups and species of zooplankton in the eight estuaries studied are presented in this chapter. Three way analysis of variance was performed to study the significant differences between groups and species, area and season (Snedecor, 1960; Fisher and Yates, 1957). The model used for the analysis was

$$Y_{ijkv} = \mu + \alpha_i + \beta_j + Z_k + \delta_{ij} + \delta_{ik} + C_{ijk} + E_{ijkv}$$

where

μ = Grand mean

α_i = i^{th} species effect

β_j = j^{th} station effect

Z_k = k^{th} month effect

δ_{ij} = interaction between i^{th} species and j^{th} station

δ_{ik} = interaction between i^{th} species and k^{th} month

δ_{jk} = interaction between j^{th} station and k^{th} month

C_{ijk} = The deviation of the cell mean from the values expected on the assumption that they would be the grand mean plus the species, station and months effect plus the three first order interactions and E_{ijkv} = random effects which are normally distributed with mean = zero and variance = σ^2.

4.1. Zooplankton biomass and abundance.

Monthly biomass and total number of zooplankton in the eight estuarine systems are listed in Table 2 (A) and Table 2 (B). Analysis of variance (Table 3 A and Table 3 B) showed that significant variations between seasons as well as between estuaries existed for biomass and total zooplankton counts. Maximum biomass occurred in April and May followed by February and March. Minimum was observed in August-September. Maximum counts were also in May and April and July, August and September showed the minimum. Cochin backwaters topped the list in both biomass and total counts. Karapuzha and Kallai ranked next and minimum abundance was observed at Thottappilly. Higher abundance of zooplankton observed in May apart from premonsoon months is because the observations were made at the mouth area of the estuaries where salinity was fairly high in this month also. Also, many medium saline species shift to this area when salinity became too low in the interiors of the estuaries.

Maximum abundance in Cochin backwaters was noticed in April (8.2 ml/10 m^3 and 10,4107 nos/10 m^3). Kallai which ranked next in the abundance showed only 3.5 ml/10 m^3 (total number - 30297 nos/10 m^3) during this month.

In the other estuaries maximum population was usually in April, however the month when peak biomass was recorded varied. This also showed that the total numbers and biomass are not __always__ correlated since if larger organisms like mysids and sergestids or other decapod larvae are present, the picture of the biomass can be very much altered. The average values for pre-monsoon for biomass varied 0.005 and 4.9 ml/10^3 and zooplankton counts from 280 to 48200/10 m^3 at Thottappilly and Cochin backwaters respectively.

Biomass values fell sharply during the monsoon period. Averages for biomass fell by 47% at Cochin, 37.5% at Kallai, 19.2% at Korapuzha, 72.5% at Beypore, 90.9% at Mahe, 74.5% at Vali and 40% at Thottappilly when compared to the premonsoon. Similar decrease could be observed in the total numbers of zooplankton also.

It may be mentioned that the zooplankton counts and biomass at the mouth of an estuary during monsoon period could be sometimes a little deceptive. The trend of the values in Table 2 A and Table 2 B do not strictly conform to the general idea that zooplankton become scarce in the estuaries during the monsoon. This is because at the mouth area even a slight let up in rain or river discharge can result in moderate salinity recovery (especially during high tide) bringing in the higher saline estuarine zooplankton elements. Also, often many medium saline species are able to thrive in this area, atleast for short durations during this season, as would be shown in the forthcoming sections. Regional differences in rainfall, depth at the mouth, and general configuration of the estuary could also lead to these variations. A true picture would emerge when the abundance of zooplankton inside the estuary also is taken (Table 3 C) which shows sparse population during this season.

During the postmonsoon months (November-December) most of these estuaries with a free connection to the sea showed an increase in salinity as well as in zoo-plankton population. But the recovery was still slow towards the upper reaches.

Results of the three way analysis of variance (Table 4 A) showed that among the major groups of zoo-plankton Copepoda was significantly higher in numerical abundance followed by zoea larvae and sergestids and the minimum was observed for Ctenophora and Cladocera, All the first order interactions between seasons, areas and groups were significant at 1% level. Comparatively maximum abundance of zooplankton was in Cochin backwaters followed by Kallai, Korapuzha, Beypore, Veli and Mahe. Least abundance was noticed in Thottappilly and Neendakara estuaries. In all the estuaries, Copepoda was the dominant group, maximum density being attained usually in April except at Beypore, Neendakara and Thottappilly where they occurred more in November, December and October respectively.

4.2. Composition and distribution of zooplankton.

The zooplankton of these estuaries comprised of various groups belonging to almost all phyla. Altogether sixteen major groups were identified namely hydromedusae, siphonophora, Ctenophora, Chaetognatha, Copepoda, Ostracoda, Cladocera, Cumacea, Isopoda, Amphipoda, Mysidacea, Sergestidae, invertebrate eggs and larvae, fish eggs and larvae, Copelata and Thaliacea. The distribution of total zooplankton, common groups and species in the estuaries are given in Figs. 13-27. Seasonal distribution of major groups in the estuaries is presented in Table 8. (The distribution in May and June is treated separately from other months of monsoon period, since saline conditions prevailed at mouth areas of most estuaries in these months and often a mixed assemblage of high and medium saline species was encountered).

Seventy three species from various groups were identified from Cochin backwaters. Of these, 47 belonged to Copepoda. The biomass and total number of zooplankton were lower in Neendakara estuary when compared to others. However, 44 species belonging to various groups occurred in this estuary and was next to Cochin backwaters in the number of species. This is followed by Vali (39 species), Korapuzha (36), Beypore (34), Kallai (29), Mahe (28), and Thottappilly (24). The systematic list of species and the presence and absence of these in various estuaries are given in Table 6. The general distribution of groups and species which are not common and not represented in the figures are given in Table 7.

4.2.1. Hydromedusae:

These carnivorous organisms are all high saline forms and occur in estuaries principally during inter-monsoon period. Santhakumari and Vannucci (1971) recorded nineteen species of hydromedusae from the Cochin backwater system. They have reported some species of hydromedusae in the Cochin backwaters to be endemic to this area. Only six common species namely *Blackfordia virginica*, *Eutima commensalis*, *E. neucaledonia*, *Eirene menoni*, *E. ceylonensis* and *Eucheilota menoni* were identified in the present study. Among these *Eutima commensalis*, *Blackfordia virginica* and *Eirene ceylonensis* were found to be most abundant in the estuary and agrees with earlier findings of Vannucci *et al.* (1970) and Madhupratap and Haridas (1975). These three species together accounted for 92% of the numerical abundance of hydromedusae in the Cochin backwater system. All these species showed higher abundance in May and June at the mouth area (340 and 430 /10 m^3 respectively) (Fig. 18). They were absent during monsoon and postmonsoon period except for the sole appearance of *Eucheilota menoni* in December.

The common hydromedusae species occurred in large numbers in the middle and upper reaches of the estuary during premonsoon period (Fig. 17). By April they were present right upto the head (Station 7) and peak density of 1030/10 m^3 was observed in the middle reaches. These species exhibited considerable salinity tolerance and while *Eutima commensalis* occurred only in salinity above 18‰, *Blackfordia virginica* and *Eirene ceylonensis* occurred in salinity as low as 8‰. (Fig. 20).

Hydromedusae were completely flushed out of the backwaters by July. The three common species made their first appearance in the middle reaches of the estuary in the early premonsoon (January) period (Fig. 17), when the salinity recovered. Their population shifted to the mouth only later by March-April. Their presence in the middle of the estuary during the early premonsoon supports the view of Vannucci *et al.* (1970) that the hydroids of the hydromedusae undergo a quiescent stage to tide over the unfavourable low saline environment and become active when the salinity conditions become optimal.

Hydromedusae had a less diverse population in the other estuaries. Only three species viz. *Eutima commensalis*, *Eirene ceylonensis* and *Blackfordia virginica* were usually observed in these waters. *Eutima commensalis* was the most abundant species among them. All these species were encountered in high saline months. Higher densities were usually observed in April and May. At Neendakara the distribution of hydromedusae was somewhat different compared to other estuaries. Here, the species *E. commensalis* was observed by September and the other two species appeared a little later (*E. ceylonensis* in October and *B. virginica* in November - Fig. 20).

They occurred throughout the postmonsoon season in fairly good numbers. This is probably because the conditions were favourable for them since salinity recovery was faster at Neendakara both at the surface and bottom due to lesser rainfall after July. Even by September salinity was around 32‰ throughout the water column. It fell in November due to a spate of heavy rains but it did not affect the density of hydromedusae at Neendakara.

These three species were observed at Korapuzha and Beypore during the premonsoon period and also in December. Eutima commensalis and Eirene ceylonensis were the two species which were common at Mahe and Kallai estuaries. Maximum population of Eutima commensalis was observed in April at Beypore (3440/10 m^3), Eirene ceylonensis in the same month at Kallai and Korapuzha (210/10 m^3) and Blackfordia virginica in March at Beypore (100/10 m^3) (Figs. 19 & 20). Eutima neucaledonia was observed at Mahe in fairly good numbers in the premonsoon period (112/10 m^3) (in April).

These three common species occurred sparsely in April at Thottappilly (12/10 m^3). At Veli lake they were observed in April and May (maximum density - 300/10 m^3, Table 7).

The three common hydromedusae species which occurred in these estuaries are essentially brackish water forms. Blackfordia virginica is a euryhaline species usually found in temperate and tropical estuaries and swamps and even in Caspian Sea and has a scattered geographical distribution (Vannucci et al., 1970). Eirene ceylonensis also attain peak densities in the estuaries though it has been recorded from coastal waters of Trivandrum (Nair, 1951) and Bombay (Lele and Gae, 1935). Eutima commensalis is confined to the estuarine waters only. The other species which occurred at the mouth of estuaries are neritic.

The average annual density of hydromedusae varied from 441/10 m^3 at Beypore to 2/10 m^3 at Thottappilly. The numerical abundance of hydromedusae is much less compared to groups like copepods (they formed only 1.6% of the annual total counts from all estuaries). Nevertheless, the ecological dominance exerted by the highly predaceous groups like hydromedusae, Ctenophora, and Chaetognatha cannot be overlooked. These groups flourish only when their food (herbivorous zooplankton like copepods) are abundant. Higher numerical abundance of these groups often drastically reduce the copepod population in the particular area. At Beypore, in April, when hydromedusae and ctenophores together constituted 63.4% of the total zooplankton population (6816/10 m^3), the density of copepods was only 1035/10 m^3 (9.6% of the total counts). A similar situation was observed in May also. But in March when density of hydromedusae was only 590/10 m^3, the copepods constituted 61% of the zooplankton population. Earlier observations (unpublished data, Estuarine Survey Project, Regional Centre of National Institute of Oceanography, Cochin, 1975) also showed that copepod densities were drastically reduced when there was a teeming abundance of hydromedusae and ctenophores. Copepod densities were 11 and 381/10 m^3 at two stations where that of hydromedusae were 1930 and 2050/10 m^3 respectively. However, at a nearby station copepod density was 7891/10 m^3 where the density of hydromedusae was 37/10 m^3.

4.2.2. Siphonophora:

Two species, Diphyes chamissonis and Lensia subtiloides occurred in these estuaries except Veli and Thottappilly. At Cochin, Neendakara and Beypore they were observed during the postmonsoon months (Table 7). Both the species were present at Cochin during this period. Only Diphyes chamissonis occurred at Beypore (22/10 m^3 in November) while *Lensia subtiloides* was observed at Neendakara (24/10 m^3 in November). At Mahe *L. subtiloides* was observed in May. Maximum abundance of this group was noted at Kallai (326/10 m^3 in April) comprising both the species.

These two species are common in the inshore waters of India (Daniel and Daniel, 1963; Rangarajan, 1973). These species do not propagate in the estuaries and their occurrence at these river mouths is purely accidental. Obviously they are stragglers into the estuaries.

4.2.3. Ctenophora.

Pleurobrachia globosa and *Beroe* sp. were the two species that occurred in these estuaries. They did not occur at Veli and Thottappilly. *P. globosa* was the common species and their distribution was similar to that of hydromedusae (Figs. 13-15) being abundant during high saline months. Peak abundance was noted at Beypore (3226/10 m^3) and Korapuzha (1916/10 m^3) in April. This species also occurred in large numbers in the middle and upper reaches of Cochin backwater system during premonsoon period. (Maximum density - 2180/10 m^3 in April at Station 4).

Evadne sp. was observed in small numbers at Cochin and Neendakara during high saline months.

4.3.4. Chaetognatha.

This group was common in the estuaries during the saline period. In the Cochin backwater system maximum abundance of Chaetognatha was noted in May (200/10m^3). Four species, *Sagitta enflata*, *S. bedoti*, *S. oceanica* and *S. robusta* were identified from this system. Two more species - *S. pulchra* and *Krohnitta pacifica* have been recorded earlier from this estuary (Vijayalakshmi Nair, 1971; Sreenivasan, 1971). Of the four species encountered *S. bedoti* was the most common with peak abundance in May (190/10m^3). *S. enflata* was more common during post-monsoon months (maximum density 60/10m^3 in December - Fig. 18). *S. oceanica* appeared during the peak saline months of March and April and dominated the chaetognath population in this period. *S. robusta* was observed in June and December in small numbers.

During the monsoon the chaetognaths were washed out of this estuary. With salinity recovery they appeared at the mouth in low numbers by November and gradually spread further towards the head along with the salinity incursion (Fig. 17). By April they were present at the head, though in low numbers.

Chaetognaths were less abundant in other estuaries. They were totally absent at Thottappilly and were poorly represented at Kallai. *Sagitta enflata* and *S. bedoti* were the two species commonly observed in other estuaries. In Neendakara estuary *S. bedoti* was the common species and occurred throughout the year except January, June and December while *S. enflata* was observed in low numbers during the postmonsoon season. *S. oceania* was recorded from this estuary in April. *S. bedoti* occurred in all the months except during the low saline period from June to October at Beypore (peak density - $128/10m^3$ in January - Fig. 20) and in premonsoon months and June at Mahe (peak density - $372/10m^3$ in April - Fig. 18). At Korapuzha *S. enflata* was the more common species during the premonsoon while *S. bedoti* dominated during postmonsoon. *S. enflata* occurred only in a couple of months at Beypore and Mahe. The two species were present in April and May at Vali.

The three carnivorous groups viz. hydromedusae, ctenophora and Chaetognaths together constituted only 4.3% of the total zooplankton counts. Nevertheless, as mentioned earlier they have profound influence on the population of other zooplankton groups, especially Copepoda.

Chaetognatha are exclusively marine forms and all the species recorded in the present study from the estuaries are common in the inshore waters of India. However, the species Sagitta bedoti has been observed to breed in the Cochin backwater system during high saline period (Nair, 1973). This species is by far the commonest chaetognath occurring in the estuaries. In the Cochin backwaters, S. enflata was more abundant in postmonsoon season whereas S. bedoti dominated during early premonsoon. In the peak saline period of March-April S. oceania was the dominant form. No such clear pattern in distribution of chaetognaths was discernible in the other estuaries. The Chaetognatha occurring in the estuaries are probably only extensions of their population from adjoining inshore waters and the three common species recorded in the estuaries are obviously able to withstand some salinity variations. S. enflata, S. bedoti, and S. oceania occurred, albeit scantly, in salinities as low as 17.0, 8.5 and 1 3.0‰ respectively.

4.2.5. Cladocera.

Three species of Cladocera, *Evadne tergestina*, *Penilia avirostris* and *Podon polyphemoides* were recorded from the estuaries of Kerala coast during this study. *P. polyphemoides* was observed only at Kallai, Beypore and Veli in small numbers. The distribution of Cladocera in the estuarine systems have been discussed earlier by Madhupratap (1981). This group was usually observed in the monsoon or post-monsoon months. Maximum density recorded was 3420/10m^3 in November. In other estuaries also they had a similar distribution and were found during the low salinity period (Table 8), except at Korapuzha where *E. tergestina* was observed in April in low numbers (8/10m^3).

Cladocera form a dominant component of the limnetic zooplankton. In the oceans they often bloom into large swarms because of their ability to reproduce parthenogenetically. The three species observed in the estuaries are essentially neretic and are common in the coastal and open waters of Indian Ocean (Della Croce and Venugopal, 1972). But they were usually not observed in the estuaries during the high saline premonsoon months. Their presence in the estuaries in very low salinities is therefore surprising. Cladocera were present in the interior parts of the Cochin backwaters during the low saline monsoon period, albeit their distribution being discontinuous both in space and time (Madhupratap and Haridas, 1975). Similar observations have been made by Nair and Tranter (1971) in the Cochin backwaters and Goswami and Selvakumar (1977) in Mandovi-Zuari estuaries of Goa.

Peak populations of cladocerans have been recorded along south west coast of India during Southwest monsoon season (Haridas et al., 1980). Selvakumar (1970) observed cladoceran swarm off Goa in October associated with a diatom peak.

Their abundance in the coastal waters along the west coast is however not restricted to the monsoon period. Devassy et al. (1979) have recorded cladoceran swarms off Goa in April. Purushan et al. (1974) observed cladocerans to be abundant along south west coast of India in February-April. A swarm of *Penilia avirostris* associated with blue green alga *Trichodesmium* and Pteropod *Creseis acicula* has been reported off Cochin in March (Sakthivel and Haridas, 1974).

Curiously, the cladoceran population in the inshore waters during this period did not penetrate into the estuary even when the salinity was as high as 35%.

during peak premonsoon period. Wickstead (1963) had suggested a relation between diatom concentration oxygen level and cladoceran abundance. Association of Cladocera with phytoplankton especially diatoms is fairly well known. Along the west coast of India there is a general outburst of phytoplankton with the out break of monsoon and associated decrease of salinity (Qasim *et al.*, 1972). Competition from other zooplankton organisms which thrive in abundance during the saline period may be restricting the occurrence of cladocerans in the estuaries during this season. But during the monsoon period oxygen in the surface layers increases and there is a decrease in the zooplankton abundance in the estuaries (Haridas *et al.*, 1973; Rao, 1977). This and higher primary production (Qasim, 1970; Devassy and Bhattathiri, 1974) in the estuaries during this period may facilitate the viability of cladocerans during low saline period.

4.3.6. Ostracoda.

Euconchoecia aculeata was observed in very low numbers at Neendakara and Cochin during peak premonsoon month (April) when the salinity was very high. This species is a common neritic form in the south west coast of India (Jacob George et al., 1975) which produce salinities higher than 34‰. Their presence in these estuaries may be accidental. Other fresh water ostracods were also present in the estuaries during monsoon period in small numbers.

4.2.7. Copepoda.

In the marine and estuarine zooplankton copepods almost invariably dominate the counts. These small crustaceans play a vital role in the food chain of the aquatic environment. Mostly herbivorous, they form the bridge between the primary and tertiary levels. However, many copepods are omnivorous and some are known to be carnivorous. Copepoda consists of thousands of species, but in estuaries like other fauna only those adapted to this fluctuating environment thrive.

In the present study Copepoda constituted 67.7% of the annual counts. Calanoid copepods constituted the majority of the counts as well as species composition. The backwaters of Cochin sustained a higher standing stock of this group compared to other estuaries.

Peak abundance of Copepoda was in most cases during the premonsoon especially in April. Wide variations existed in their densities during different seasons (Fig. 21). At Cochin maximum abundance was observed in April (98,900/$10m^3$) and minimum (30/$10m^3$) in August. In other estuaries the number of species and their densities were much less compared to Cochin. Annual averages (Table 5) showed that Kallai and Korapuzha estuaries ranked next (maximum density - 21,929/ $10m^3$ at Kallai in April and 8,401/$10m^3$ at Korapuzha in May). Distribution of copepods was also similar in these two estuaries. During the peak of the monsoon period copepods were totally absent at Kallai (July and August) and Korapuzha (August and also in November). At Beypore this group was absent during the low saline months from July to September. The highest density observed here was in November (10,361/$10m^3$). Copepods were generally poor at Mahe estuary also (maximum density - 6,729/$10m^3$ in April) and were absent during monsoon period. The distribution of total Copepoda at Neendakara estuary had a different pattern (Fig. 21). During premonsoon period they occurred in low densities. During the monsoon there was a general increase (but lowest was recorded in September) and registered a maximum (2,342/$10m^3$) in December. At Veli higher abundance of copepods was noted during April/May (maximum density - 6,370/$10m^3$ in April). They were absent during August and September. Copepods were poorly represented and generally comprised of low saline species at Thottappilly except in April (maximum density in October - 963/$10m^3$).

Maximum number of copepod species was observed in Cochin (46) followed by Neendakara (29), Veli (27), Korapuzha (23), Kallai (20), Mahe (19), Thottappilly (19) and Beypore (17).

Three way analysis of variance (Table 4 B) was performed for the 13 common copepod species to find the significant variations in their abundance over months and areas of collections. *Acartia centrura* was significantly most abundant species followed by *A. spinicauda*, *Acrocalanus similis*, *Acartia bilobata* and *Pseudodiaptomus serricaudatus*. Minimum abundance was shown by the medium saline species like *Acartia plumosa*, *Acartiella keralensis*, the neritic copepod, *Acartia erythraea* and the low saline estuarine copepod *Acartiella gravelyi*. A true picture of the abundance of the medium and low saline forms do not emerge since the collections were made at the mouth of the estuaries. The seasonal collections made in the middle and upper reaches of the Cochin backwaters show that they dominate these areas for a long period in the annual cycle. However, at one time or another along with the rains and consequent salinity variations all these species shift to the mouth area of all estuaries giving a fairly good idea of their preferred habitats. The peak saline premonsoon month April showed maximum abundance of copepod followed by December and May and minimum was observed in August, September and July. Cochin backwaters again had highest copepod population and Thottappilly ranked lowest.

The distribution of common species of copepods in different estuaries is given in Figs. 23-47. Occurrence of other species and their abundance are listed in Table 6.

Family Acartiidae had the maximum diversity in these estuaries. Ten species belonging to this family were recorded. Family Pseudodiaptomidae ranked next by having eight species. Other families represented had lesser number of species and were more common during high salinity regime.

A total of 51 species of Copepoda belonging to 24 genera were observed in the estuaries. Calanoid copepods comprising of 43 species belonging to 13 families constituted the majority. Six species of cyclopoids belonging to 3 genera and 2 genera of harpacticoids represented by a species each constituted the remaining. About 30% of the species occurred sporadically or in small numbers.

Maximum species assemblage was observed in Cochin backwaters. Among Acartiidae, Acartia centrura, A. bilobata and A. spinicauda were the most abundant species during premonsoon and postmonsoon seasons and had more or less similar distribution (Fig. 22 A). They occurred in the middle reaches of the estuary in postmonsoon and early premonsoon period. By April these species penetrated into the interiors along with salinity recovery and could be traced upto the head (Fig. 22 B and C).

Acartia pacifica and A. southwelli were also predominantly high saline forms occurring in these seasons. But they were numerically not as abundant as the earlier group. Also, these two species showed a more or less restricted distribution and did not occur beyond the middle reaches. A. erythraea and A. negligens were recorded in few numbers during the peak salinity period. Their occurrences were restricted to the mouth area. Both are typically marine forms and while A. erythraea is neritic, A. negligens is an oceanic species.

The distribution of these high saline species of Acartiidae in other estuaries is more or less similar as that in Cochin backwaters. A. centrura, A. spinicauda and A. bilobata were the common species occurring during the high saline months. In general they were numerically less abundant than in Cochin backwaters. At Neendakara A. centrura was present throughout the year except in August. Higher numerical abundance was observed during the postmonsoon than premonsoon in this estuary. *A. spinicauda* occurred in comparatively lesser numbers and was absent during early premonsoon and postmonsoon (Fig. 23). *A. bilobata* did not show any consistent pattern in its distribution. These three species were abundant at Kallai and Korapuzha during the premonsoon and postmonsoon periods (Figs. 24 & 26). Higher abundance of these species was noted only in April at Mahe and in November at Beypore. Their population was poor especially at Mahe during other months.

Other high saline species like *Acartia pacifica* and *A. erythraea* occurred in low numbers in these estuaries in different months. *A. southwelli* occurred only at Mahe estuary in November.

Acartia plumosa and *Acartiella keralensis* were species that occurred in medium saline conditions and were absent at the mouth of the Cochin backwaters during the premonsoon period. They showed a similar distribution. During postmonsoon and early premonsoon months they were the dominant copepods in the middle reaches where salinity values were roughly between 10 and 20‰. As the premonsoon season progressed and salinity values in this region increased (Fig. 4 B - salinity distribution April) their population maxima shifted to the head region where the salinity was optimum. By July when salinity was near zero inside the estuary they were completely absent. However, during the monsoon period they were present at the mouth area where stratified waters with medium saline conditions occurred. It may be mentioned that during postmonsoon and early premonsoon seasons these two species formed the dominant copepods in the interior region of the backwater system.

Acartia plumosa and *Acartiella keralensis* were observed at Korapuzha during June and October. Both were more abundant in June (density 1791/10m^3 and 3982/10m^3 respectively). At Kallai *A. plumosa* was observed only in November (18/10m^3) and *A. keralensis* in June (851/10m^3). They were absent at Beypore and Mahe. At Neendakara these two species were encountered only during postmonsoon period. However, the observations at the mouth of these rivers do not necessarily reflect the distribution of the medium and low saline species towards the interiors.

Acartiella gravelyi is a low saline species and thrived in the estuary during the monsoon period. At Cochin this species thrived throughout the estuary during the monsoon period when the estuary became fresh water dominated (Fig. 22 C). They outnumbered other low saline species of families Diaptomidae (*Heliodiaptomus* cinctus and Allodiaptomus mirabilipes and Pseudodiaptomidae in this season. However copepod abundance is far less during low salinity regime compared to saline period.

A. gravelyi occurred at the mouth of Korapuzha and Kallai estuaries during the monsoon period. Maximum density recorded at Korapuzha was 1784/10m^3 in October and 748/10m^3 in June at Kallai. This species was not observed at Neendakara, Beypore and Mahe.

Family Pseudodiaptomidae had eight species in the estuarine waters. P. serricaudatus and P. jonesi were the common high saline forms. The two species occurred in higher abundance at Cochin and showed less tolerance to lower salinities. P. serricaudatus occurred in other estuaries also during the premonsoon and postmonsoon seasons. At Neendakara estuary they were less abundant during premonsoon and occurred in higher densities (391/10m^3 in December) during postmonsoon. At Korapuzha, Kallai and Beypore also they were observed during premonsoon and postmonsoon. Other high saline species of this genus that were found in these waters were P. mertoni and P. aurivilli. P. mertoni w a s recorded only once from Cochin backwaters. They occurred more frequently at Neendakara and Korapuzha while

P. aurivilli frequented Kallai and Beypore estuaries (maximum density - 1228/10m^3 in April at Kallai).

P. annandalei exhibited a wide range of salinity tolerance (0 - 33‰) but preferred stratified waters of the early premonsoon, monsoon and postmonsoon. At Cochin they occurred throughout the year at the mouth region with maximum abundance in July, when the monsoon was at its peak and the surface salinity fell to near zero values. But this species was absent in April when the water column was vertically homogeneous. In spite of the wide range of salinity tolerance exhibited, it did not occur towards the upper reaches where near fresh water conditions prevailed. At Korapuzha and Beypore this species was present only in June. At Mahe they were observed in March in high densities (945/10m^3) and also in postmonsoon. At Kallai they appeared in March and May and occurred in small numbers at Neendakara during early premonsoon, monsoon and postmonsoon months.

P. binghami malayalus, *P. tollingerae* and *Archidiaptomus aruensis* were the low saline species belonging to family Pseudodiaptomidae. *P. binghami malayalus* was observed at Cochin and Kallai estuaries during the monsoon period. Maximum density 213/10m^3 was noted at Kallai in June. *P. tollingerae* and *Archidiaptomus aruensis* were observed during September and October respectively in small numbers. These two species were not encountered in other estuaries except *A.* [illegible] which was recorded once from Thottappilly lake.

Four species belonging to Paracalanidae namely *Acrocalanus similis*, *A. gibber*, *Paracalanus crassirostris* and *P. aculeatus* were encountered in the estuaries. All but *A. gibber* were observed in high abundance in Cochin backwaters and thrived in the lower and middle reaches during the high saline months.

A. similis was common during high saline months at Neendakara, Kallai, Beypore and Mahe estuaries. At Neendakara and Beypore this species occurred more abundantly during the postmonsoon. *P. aculeatus* occurred more frequently at Beypore and Kallai estuaries and sparsely at Neendakara and Mahe. Both the species occurred only in December at Korapuzha estuary. *A. gibber* was observed in small numbers at Neendakara, Korapuzha and Mahe estuaries in December. Unlike families Acartiidae and Pseudodiaptomidae, family Paracalanidae has no low saline species occurring in the estuaries.

The other calanoid copepods which occurred in the estuaries were mostly euryhaline marine forms belonging to various families like Calanidae, Eucalanidae, Centropagidae, Pontellidae, Lucicutiidae and Temoridae.

while some of them occurred up to the middle reaches of the Cochin backwaters during high saline period, most occurred only at the mouth areas. Among them *Labidocera pectinata* and *Centropages alcocki* were the species which were common during the premonsoon in all the estuaries. They were less tolerant to lower salinities and hence were not observed beyond the middle reaches of Cochin backwater system. *Labidocera acuta* was recorded in small numbers at Cochin and Beypore estuaries during May and January respectively. Other species belonging to the genus *Centropages* namely *C. furcatus*, *C. tenuiremis* and *C. trispinosus* were also recorded from Cochin and Neendakara during high saline months. *C. tenuiremis* occurred in higher density ($342/10m^3$) at the mouth of the Cochin backwaters in March.

Species like *Eucalanus monachus*, *Canthocalanus pauper*, *Undinula vulgaris*, *Calanopia elliptica* which are common in coastal waters were observed at Cochin barmouth during high saline months. *E. monachus* and *E. subcrassus* were recorded at Neendakara during April and August in low numbers. *Lucicutia flavicornis*, was recorded from Neendakara in August. This is an oceanic bathypelagic species and is probably carried to the coastal waters during the upwelling period. *Temora turbinata* and

T. *stylifera* were encountered at Cochin and Narapuzha during January and November. T. *stylifera* occurred in higher densities (115/10m^3) in the Cochin backwaters in January. T. *turbinata* was present at Neendakara also in March. T. *turbinata* is known to form large swarms at times in the coastal waters (Haridas *et al.*, 1980).

The cyclopoid copepods in these waters included five species of the genus *Oithona* namely O. *nana*, O. *hebes*, O. *rigida*, O. *brevicornis* and O. *plumifera* and species of *Corycaeus*, *Oncaea* and *Sapphirina*. Among the genus *Oithona*, O. *nana* and O. *hebes* were more common and exhibited tolerance to lower salinities. O. *plumi-fera* and *Oncaea* sp. were observed at Neendakara during March. *Corycaeus* and *Sapphirina* spp. occurred at Cochin in small numbers during the high saline months. *Corycaeus* sp. was observed at Neendakara estuary also during pre-monsoon and postmonsoon period.

Two harpacticoid copepods namely [illegible] and *Euterpina acutifrons* were observed at Cochin and Neendakara estuaries. E. *acutifrons* is a coastal species. The other is estuarine and exhibit wide tolerance to salinity variations. *Macrosetella gracilis*, another neritic harpacticoid (Haridas and Rao, 1981) copepod of the coastal waters was once observed at Mahe estuary during April.

<u>Copepoda of Veli and [illegible] lakes</u>:

Copepoda which constituted 69.3% of the total counts of zooplankton at the Veli lake was the dominant group throughout the year except in July. Twenty seven species belonging to 13 genera were observed, of them, 23 belonged to Calanoida while Cyclopoida and harpacticoida shared two each.

Maximum density of copepoda in the Veli lake was noticed during April (6370/10m^3) which formed 81% of the total zooplankton counts. During the monsoon months the number of copepoda dwindled to 12.7% (in July) of the total numbers. Copepoda were absent in August and September.

During January and February when the surface salinity was around 2‰ and bottom salinity was 15‰, copepod fauna was a mixed assemblage. It comprised mainly of medium saline species like *Acartia plumosa* and *A. keralensis* and low saline species like *Acartiella gravelyi*, *Pseudodiaptomus binghami malayalus*, *Allodiaptomus mirabilipes* and *Heliodiaptomus cinctus*. High saline species like *Acartia centrura* and *A. spinicauda* also occurred only in small numbers. *A. gravelyi* showed maximum abundance during this period (358/10m^3

in January). *Pseudodiaptomus annandalei* and harpacticoid *Nitocra spinipes* were also observed.

The bottom salinity in this estuary was around 23‰ from March to May (the surface salinity was still low, between 0.7 to 3.2‰) and it fell to 2.8‰ in June. However, during this period high saline species like *Acartia centrura*, *A. spinicauda*, *A. erythraea*, *A. pacifica*, *A. bilobata*, *Acrocalanus similis*, *Paracalanus aculeatus*, *Centropages alcocki*, *Pseudodiaptomus serricaudatus*, *P. jonesi*, *P. aurivilli*, *Temora stylifera*, *Labidocera pectinata*, *Corycaeus* sp., *Oithona nana* and *Euterpina acutifrons* dominated the copepod fauna. Along with these a few low saline forms like *Pseudodiaptomus binghami malayalus* and *P. annandalei* were also observed. Of these, *A. centrura*, *A. spinicauda*, *A. pacifica* and *Acrocalanus similis* were the common species. These species occurred in high densities during April and May. In June and July the salinity of the water column was very low. But still high saline forms like *A. centrura*, *C. alcocki*, *P. aurivilli*, *P. serricaudatus*, *P. annandalei*, *L. pectinata* survived albiet scantly. The low saline species *P. binghami malayalus* was also present in July in small numbers.

In October and November only medium and low saline species like *Acartiella keralensis*, *A. gravelyi* and *Acartia plumosa* were present (Fig. 27). *A. keralensis* occurred in high density in October ($734/10m^3$). *Pseudodiaptomus annandalei* was also observed in October (salinity of the water column was 0.6‰). In December, the bottom salinity went up to 23.4‰ and the surface values remained at 2.6‰. But the copepod fauna included, in addition to all the high saline species present during premonsoon, some coastal species like, *Acartia spinicauda*, *Tortanus gracilis*, *Acrocalanus gibber* in few numbers. *Pseudodiaptomus binghami malayalus* was also present and showed the maximum density in this month ($21/10m^3$).

Salinity was very low at Thottappilly lake throughout the year (maximum value observed was only 1.8‰ at surface in June and 7.9‰ at the bottom in January). The copepod fauna was comprised of mainly low saline species belonging to families Acartiidae, Pseudodiaptomidae and Diaptomidae during most of the months except in April (Table 7). Maximum density of copepods was observed in October ($963/10m^3$). During January to March a mixed assemblage of species like *Acartia centrura*, *A. bilobata*, *A. plumosa*, *Acartiella keralensis*, *A. gravelyi* and *Pseudodiaptomus binghami malayalus* was observed.

Low saline species were more abundant among these during this period. *P. binghami malayalus* showed maximum density (214/10m^3) in February. In April higher saline species like *A. centrura*, *A. bilobata*, *A. spinicauda*, *Acrocalanus similis*, *Pseudodiaptomus serricaudatus*, *P. aurivilli*, *Centropages alcocki* and *Oithona nana* formed the bulk of the copepod fraction. *A. centrura* was comparatively more abundant in this month (34/10m^3).

During the other months, except in June, July and November when the copepods were absent in this lake, only the low saline species of the family Acartiidae and Pseudodiaptomidae and species like *Heliodiaptomus cinctus* and *Allodiaptomus mirabilipes* of Diaptomidae and some fresh water *Cyclops* sp. were observed. *H. cinctus* and *A. mirabilipes* were the common species having maximum densities in October (342/10m^3 and 382/10m^3 respectively). *Archidiaptomus aroorus*, a low saline Pseudodiaptomid was recorded from this lake in December. This species was present in the Cochin backwaters also during October.

The copepod fauna of the eight estuaries studied comprised of 18 families. Of these species belonging to families Acartiidae, Pseudodiaptomidae and Paracalanidae were the most common forms and formed the bulk of the copepod component of the zooplankton. Among these Acartiidae always dominated the counts. In the Cochin backwaters, the three families constituted 95.1% of the total copepoda (Acartiidae, 63.1%, Pseudodiaptomidae 12% and Paracalanidae 20%). At Korapuzha Acartiidae formed 80.4% followed by Pseudodiaptomidae (9%) and Paracalanidae (2.5%) together forming 91.9% of the total copepoda. At Kallai these families contributed to 88.6% of the total copepod counts, Acartiidae being 72.9%, Pseudodiaptomidae 7.1% and Paracalanidae 8.6%. At Beypore and Mahe Acartiidae constituted only 53.8% and 57.4% respectively. Pseudodiaptomidae showed a higher concentration at Mahe being 25.3% of the total copepoda. At Beypore it formed 9%. Family Paracalanidae constituted 20.5% and 8.9% in these two estuaries respectively. 89.8% of the total copepoda was constituted by these three families at Neendakara, Acartiidae contributing 67.6%, Pseudodiaptomidae 14.5% and Paracalanidae 7.7%. At Valli they formed 79.5%, 6.7% and 9.7% respectively, together constituting 95.9% of the total. At Thottappilly they constituted only 51% (Acartiidae 35%, Pseudodiaptomidae 15.5% and Paracalanidae 0.5%). The rest 49% was formed by species of the family Diaptomidae and some cyclopoids.

4.2.8. Amphipoda.

This group included mostly species belonging to family Gammaridae while a few hyperid amphipods occurred in small numbers in some months. Being mostly benthic, only part of the population which periodically migrate to the water column is normally represented in the plankton samples. They contribute significantly to the benthos of the estuary and have been found to occur in large numbers in muddy areas.

Three species, Corophium triaenonyx, Melita zeylanica and Photis digitata were commonly found in these estuaries. C. triaenonyx was the most abundant species and the other two species were met with only occasionally. In the Cochin backwaters, this group was present throughout the year and maximum density was recorded in July ($560/10m^3$). Of the eleven species in this backwater system, occurring C. triaenonyx is the commonest, exhibiting a wide range of salinity tolerance (from 0.1 to 27.7‰) with peak abundance attained in medium salinities (Nair, personal communication).

At Korapuzha, Mahe and Beypore they were found in all seasons. Highest density was observed at Mahe ($1000/10m^3$) in November. They occurred during pre-monsoon and monsoon periods only at Neendakara and at

Kallai during premonsoon and postmonsoon. They were observed only in small numbers at Thottappilly and Veli lakes. Murugan *et al.* (1980) have recorded 6 species from Veli where [illegible] *digitata* was the abundant species.

4.2.9. *Sergestidae*.

Lucifer hanseni was the common sergistid encountered in the estuaries. Higher abundance was always noted during the high saline months. At Cochin and Neendakara it occurred throughout the year except in one or two months during monsoon and postmonsoon period. Maximum density of this species at Cochin was $240/10m^3$ in May and $727/10m^3$ at Neendakara. Another species *L. typus* was also present in the Cochin backwaters. It was present only from May to June and maximum density was only $80/10m^3$ in April. This species was not recorded from other estuaries. During peak premonsoon period (April) *L. hanseni* were present upto the head of the Cochin backwaters. Another sergestid, *Acetes* sp. was also present during the premonsoon and monsoon months in small numbers. *L. hanseni* had a more or less similar distribution in the other estuaries with higher abundance during the high saline period. It was not observed in these waters during the peak monsoon period. Maximum abundance was observed at Beypore ($2886/10m^3$ in May) when they constituted 39.2% of the total zooplankton. At Kallai they occurred in higher abundance ($1228/10m^3$) in April. *Acetes* sp. was observed at Vali in small numbers in September. *L. hanseni* was observed at Thottappilly in various months.

4.2.10. *Mysidacea*.

Rhopalophthalmus indicus was present in very small numbers during the high saline months in the Cochin backwaters and once at Vali lake. They were not observed in the other estuaries. Like amphipods, the distribution pattern and abundance of Mysidacea cannot be gauged from their numbers in the present collections since they are actively migrating forms and usually come to the column only during night.

4.2.11. *Cumacea*.

Another benthic group, occasionally found in plankton collections, cumaceans were observed in all the estuaries in small numbers during different seasons. At Kallai, Nirapuzha and Mahe they were observed once during the premonsoon period. At Beypore they occurred during April, May and June with maximum density in May (144/10m^3). They were present at Veli and Cochin estuaries only during the monsoon season. Maximum density noticed at Cochin was 157/10m^3 in July. They occurred during premonsoon and monsoon periods at Neendakara - maximum density observed was 224/10m^3 in August.

4.2.12. [illegible]

These organisms occurred in very small numbers in the plankton samples collected from Cochin and Korapuzha estuaries. While they were observed more frequently at Cochin backwaters during monsoon and postmonsoon period (maximum density 12/10m^3 in May) they were present only in March at Korapuzha (9/10m^3).

4.2.13. Invertebrate larvae.

Decapod larvae constituted the majority of invertebrate larvae in these estuarine waters. They ranked next to copepods in overall abundance of zooplankton in the estuaries (9.4%). They formed 17.8% of the total annual counts at Mahe estuary followed by Veli (15.6%), Beypore (14.7%), Neendakara (11.4%), Kallai (9.2%), Thottappilly (8.6%), Cochin (7.9%) and Korapuzha (7.3%).

Zoea larvae were very common and occurred in all the seasons with peaks usually during the premonsoon months, except at Beypore and Neendakara estuary where maximum density was observed in December ($3216/10m^3$ and $260/10m^3$ respectively). At Kallai and Veli maximum density was in May ($1472/10m^3$ and $880/10m^3$ respectively) while it was in April at Korapuzha and Mahe. At Cochin they were observed throughout the year except in May and July with maximum density in February ($720/10m^3$). Zoea larvae were quite abundant in the middle and upper reaches of the Cochin backwaters in pre and post monsoon seasons. At Thottappilly zoea occurred in small numbers during the premonsoon months and also in August and December.

Larvae of penaeid and caridean decapods at various stages of development were present in these waters almost throughout the year. These included the larvae of the commercially important species like Penaeus indicus, Metapenaeus dobsoni, M. monoceros, M. affinis, Macrobrachium rosenbergii and M. idella. Higher abundance of these were noted during the premonsoon and postmonsoon periods. They were more abundant in the Cochin backwaters, and maximum density was recorded in December (4490/10m³). At Beypore also highest density was in this month (1604/10m³) (Figs. 13 & 15). Higher densities were observed during the premonsoon period at Neendakara, Korapuzha and Mahe. These larvae were observed in small numbers at Thottappilly also throughout the year except November).

Alima larvae of squilla were present in small numbers at Cochin, Neendakara and Mahe estuaries, during the premonsoon period. Megalopa larvae were observed in these waters during this period and also in slightly higher numbers in August at Neendakara (41/10m³). Phyllosoma larvae occurred at Neendakara estuary in April (32/10m³ - Table 7).

Cirripedia larvae were present in these estuaries except at Thottappilly. They were present throughout the year in Cochin backwaters except in July (maximum density - 360/10m³ in February). In the other estuaries these were observed only during the premonsoon months and June. Highest density was in Kallai estuary in April (1404/10m³). At Beypore, Neendakara and Vali they were poorly represented.

Polychaete larvae occurred in all the estuaries in various periods, in small numbers.

Cyphonautes larvae of Bryozoa and actinotrocha larvae of Phoronida occurred in low numbers at Cochin backwaters during April. Pluteus larvae of Echinodermata were observed at Kallai and Mahe estuaries during March. Lingula larvae of Brachiopoda were present at Neendakara and Mahe in May.

4.2.14. Fish eggs and larvae.

Fish eggs commonly occurred in the estuaries except at Thottappilly. They were usually sparse at the peak of the monsoon. In the Cochin backwaters fish eggs were observed throughout the year except in July and August. Maximum density was 420/10m^3 in November. At Kallai, Beypore and Mahe they were present in all seasons. Maximum density was observed at Kallai (386/10m^3) in March.

Larvae of fishes mainly belonging to the families Ambassidae, Mugillidae and Gobidae were common. They were observed throughout the year in the Cochin backwaters (maximum density 820/10m^3 in July). They were present at the middle reaches by November and at the head during the peak premonsoon months. At Korapuzha estuary also they occurred round the year with maximum density (207/10m^3) in December. The larvae were present during all seasons at Neendakara, Kallai, Beypore, Mahe, and Veli estuaries although period of peak density varied. They occurred in small numbers at Thottappilly lake.

4.2.15. Appendicularia.

Appendicularia showed higher abundance in the premonsoon and postmonsoon seasons. This group was absent at Veli and Thottappilly lake. At Cochin, their highest abundance was noticed in February (3410/10m^3). They were observed mostly during the premonsoon period at Kallai, Beypore, Mahe and Korapuzha. While they were more common in the Kallai estuary (maximum density 702/10m^3 in April), they occurred only in small numbers in others. They were also observed in low numbers at Neendakara during early premonsoon (January), monsoon and postmonsoon period (November-December).

4.2.16. Thaliacea.

Thaliacea which is common in marine zooplankton are usually sparse in the estuaries. The only *Thalia democratica* was noticed at the mouth of the Cochin backwaters in April. Thaliacea did not occur in other estuaries.

4.3. General discussion.

The zooplankton of the estuaries comprises of truly estuarine species, euryhaline marine forms and a few stenohaline marine and freshwater species. The latter two are only stragglers into the estuaries, carried by waves or currents, and never occur in large numbers. On the other hand many of the euryhaline marine species are able to thrive in appreciably large numbers near the lower reaches of the estuaries during the saline period. Nevertheless, there is no much evidence to suggest that they could breed in this area since their juvenile population is very low. The entire recruitment of this class is probably from the adjoining neritic waters through tidal currents.

Among the species which could be classified as true estuarine forms, three clines - high saline, medium saline and low saline can be recognised. This classification, especially regarding the high saline forms is somewhat arbitrary since most of them exhibit a wide range of salinity tolerance. However, this grouping is based on their observed abundance, and these species occur in larger numbers in higher salinities.

Some of these high saline forms which are classified as truly estuarine occur in the inshore waters, but in low numbers. The probable reason is competition. Grindley and Wooldridge (1974) found the salinity tolerance of Pseudodiaptomid species of Richards Bay, South Africa, ranged from near freshwater to 66‰, but peak survival was at around 35‰ salinity. They contend that it is not salinity but competition from marine organisms that prevent them from surviving in the sea. The adaptation of the estuarine fauna to tolerate extreme fluctuations in environment allow them to flourish in the estuary. Similarly, the euryhaline marine organisms which frequent these waters must be facing competition from the estuarine organisms restricting their abundance during the saline period.

One striking feature in the zooplankton abundance of the estuaries is its high standing stock, counts and thus the high turn over at secondary level in general, compared to the adjoining sea. The peak zooplankton standing crop and counts observed at Cochin backwaters in this study was 0.8 ml/m^3 and 10410/m^3 respectively. In other estuaries also zooplankton standing stock and counts were high during the saline period. Subbaraju and Krishnamurthy (1972) observed an average standing stock of 2 ml/m³ (maximum 4 ml/m³) and counts of 92,000/m³ (maximum 286,000/m³) from Vellar estuary during summer months. Grindley and Wooldridge (1974) recorded the density of a single estuarine copepod <u>Pseudodiaptomus hickmani</u> as high as 42,700/m³. In contrast, the coastal waters, let alone the open ocean, are far less productive. The annual range of zooplankton biomass was from 0.07 to 0.3 ml/m³ and counts were between 98 and 1091/m³ in a nearshore environment in the southeast coast of India (Haridas <u>et al</u>., 1980). Representative figures show that the average biomass ranged between 0.07 and 0.08 ml/m³ (Nair <u>et al</u>., 1977) and 0.09 and 0.3 ml/m³ (Nair <u>et al</u>., 1981) in the Bay of Bengal and 0.09 and 0.1 ml/m³ (Nair <u>et al</u>., 1978) in the Arabian Sea. In the Andaman Sea the range was from 0.02 to 0.1 ml/m³ and with counts of 7 to 14/m³ (Madhupratap <u>et al</u>., 1981).

The real reason for this enormous differences is not probably due to large scale variations in primary production between the two environments (the differences in primary productivity of coastal and estuarine waters is only marginal, and not consistent - see, Qasim <u>et al</u>., 1969; Radhakrishna <u>et al</u>., 1978 a,b; Bhattathiri <u>et al</u>., 1980), but because many of the estuarine organisms are omnivorous and feed on detritus and bacteria as well (see Chapter 3). Large quantities of detritus and associated bacterial flora are carried/produced into the estuaries and food is probably never a limiting factor for the estuarine zooplankton.

Clinal changes associated with seasons are much more apparent in the estuaries compared to neritic or oceanic environments. Zooplankton standing crop is high and high saline species are diverse during the saline period. In copepods, about 10 true estuarine species belonging to families Acartiidae and Pseudodiaptomidae abound in the estuaries during this season. As the salinity increases from mouth to head of the estuaries, these species are able to invade and propagate throughout the estuaries. A few species of the family Paracalanidae are also able to successfully compete with these species but are essentially neritic forms. The other species which occur during this period are euryhaline marine forms with limited distribution as mentioned earlier.

On the otherhand, species which preferred medium saline conditions were represented by only two form viz. _Acartia plumosa_ and _Acartiella keralensis_. Nevertheless, they occurred in large numbers during the saline period, but towards the middle and upper reaches, where the salinity was optimum.

When the monsoons reduce the salinity to near freshwater conditions, zooplankton standing crop and counts are very poor inside the estuaries. All the high saline and medium saline species are totally flushed out of them. About 6 low saline copepods represented by the families Diaptomidae, Pseudodiaptomidae and Acartiidae occur in the estuaries during the monsoon season. However, _Acartiella gravelyi_ is the only species which show some abundance in this period. But its peak densities are nowhere near the abundance showed by the high or medium saline species. Other low saline species such as _Heliodiaptomus cinctus_, _Allodiaptomus mirabilipes_, _Pseudodiaptomus binghami malayalus_, _P. tollingerae_ and _Archidiaptomus aroramus_ occur in very low numbers.

Thus monsoonal innundation, tidal incursion and associated changes in salinity are the main factors controlling the zooplankton of the estuaries. Other factors such as temperature, oxygen content and availability of food are apparently of secondary importance as far as tropical estuaries are concerned. The inability of the low saline zooplankton fauna to thrive in larger numbers during the low saline period is surprising. It is probably because they are not able to withstand the strong currents and these estuaries are left virtually unexploited at secondary level during this period.

Variations of wide nature, both seasonal and spatial, in zooplankton counts have been reported from other estuaries also. Secondary production is low in the low saline season compared to the premonsoon period in the Mandovi-Zuari estuarine system of Goa (Selvakumar et al., 1980). Peak population occur in summer months in Vellar estuary of Porto Novo (Subbaraju and Krishnamurthy, 1972) and they conclude that salinity and rainfall control the zooplankton abundance of these waters. Similar observations supporting lesser zooplankton abundance during low salinity have been made from mangrove environments of Porto Novo (Sundararaj and Krishnamurthy, 1981), Hooghly estuary of west Bengal (Sarkar and Choudhury, 1981) and Kali estuary of Karwar (Kumar et al., 1981).

The zooplankton counts of the Kali estuary were reported to vary from 2700/m^3 in July to 21,900/m^3 in October. Zooplankton counts ranged from 100/m^3 to 300,000/m^3 in the estuaries in Victoria, Australia (Neale and Bayly, 1974). In South Africa, Knysna estuary, where rainfall is more or less evenly distributed throughout the year, has an abundant fauna compared to St. Lucia estuary where rains flood the system during part of the year (Day, 1967).

Copepoda dominated the average zooplankton counts in all the estuaries presently studied. While this is so from data available from other estuaries of India, the dominant component has been reported to vary in different waters. Cirripede nauplii dominate the Southampton water (Raymont and Carrie, 1958) and York river, U.S.A. (Jeffries, 1964). Polychaete larvae form the major component in Raritan Bay and both polychaete larvae and lamellibranch larvae dominate in Narragansett Bay. (The absence of veliger larvae in the present collections is probably due to the larger mesh size used). Zoea larvae of Brachyura have been reported to dominate the zooplankton of Cochin backwaters (Madhupratap, 1978) in certain months. In the present collections decapod larvae dominated the counts in a few months at Neendakara and Beypore estuaries.

While the distribution of the zooplankton species in the estuaries with a perennial connection to the sea follows a conformed pattern, their distribution in the two lakes studied (Veli and Thottappilly) is perhaps a little tangential to the usual assumptions. There is no handy alibi to the occurrence of marine forms like Temora stylifera, Tortanus gracilis, Acartia negligens and several others at Veli in some months (March, April, December) when the lake has no free connection to the sea.

It has to be assumed that they might have come through the spill over of wave action and were able to survive although in low densities because of the higher saline bottom water.

A mixed assemblage of estuarine copepod species (consisting of low, medium and high saline forms) was often encountered in these estuaries. At Vali during January-February months when salinity was between 2‰. (surface) and 12‰. (bottom) medium and low saline species dominated with high saline forms occurring in small numbers. But from March to May high saline species were dominant forms (salinity 2 to 23‰.). But in June when salinity of water column was as low as 2‰., a few high saline forms were observed. Again in July when near fresh water conditions existed low saline species were found along with a few high saline forms (*Pseudodiaptomus serricaudatus* and *P. aurivilli* dominated; the latter *P. aurivilli* dominated copepods at Kallai in April when the salinity of the water column was around 32‰.). In October when salinity was 0.6‰, medium saline species like *Acartia plumosa* and *Acartiella keralensis* occurred although one would have expected low saline species like *A. gravelyi* to dominate. At Thottappilly lake, low saline forms were more abundant in most months as would be expected but a

5. COMMUNITY STRUCTURE.

Estuarine plankton, as mentioned earlier, form a class by themselves chiefly because they are adapted to the vagaries of this environment. The zooplankton element consists of both holoplankton and meroplankton. It is evident from the distribution and abundance (Chapter 4) that the holoplankton is dominated by a single group - Copepoda. The meroplankton may consist of larvae of many benthic invertebrates and fish. In the estuaries investigated in the present study, zoea larva of Brachyura was the dominant form. Other larvae of polychaetes, cirripedes, carideans and other decapods were also frequent.

The stenohaline marine forms and some fresh water organisms which enter accidently, do not have any role in the ecosystem of the estuaries. Records of these species from estuarine mouths or heads are of academic interest only. It could be seen that many groups of zooplankton like euphausids, ostracods, appendicularians, salps and doliolids which play an important role in the oceanic ecosystem are usually excluded in the estuarine plankton. Curiously, almost all of them are filter feeders and the absence of these groups in the estuarine habitat in interesting. Cladocera, another filter feeding group, also had a peculiar distribution in the estuaries (Chapter 4.2.5). Many of the groups which are diverse in the oceanic environment like hydromedusae, ctenophora and chaetognatha (all carnivores) have only a few representatives (mostly allochthonous forms entering the estuaries from the adjoining neritic waters during the saline period) in the estuary.

The zooplankton is thus dominated by true estuarine forms which have evolved adaptations to the fluctuations mainly salinity. The salinity ranges for the common species that occur in the estuary (Fig. 25 A & B) are, however, not their salinity tolerances, but only the recorded ranges in the present observations. Experimental studies have shown that many low saline species can be acclimatised slowly to readapt to sea water indicating that their low salinity adaptation was physiological than a fixed genetic change (Grindley, 1980).

As discussed earlier (4.3), estuaries sustain enormous standing stock of zooplankton compared to the sea. But the role of the zooplankton in the food chain is difficult to be pinpointed in the estuarine ecosystem as there is no shoaling fishery is in the shelf waters. Even larger estuarine fishes like _Mugil_ and _Chanos_ are mainly herbivorous or detritivorous (Hiatt, 1944). The coefficient of energy transfer from primary to secondary level was only 7.4% for Cochin backwaters and 6.6% for Mandovi-Zuari estuaries of Goa (Selvakumar _et al._, 1980) indicating excess phytoplankton production is also available for alternate pathways. Perhaps a large portion of phytoplankton and zooplankton production in estuaries contribute to the productivity of the coastal waters or forms a major source to the organic matter in bottom deposits. This could help the sustenance of a rich benthic life and in fact, high benthic biomass has been reported from several estuaries (Kurian, 1972; Ansari, 1974; Parulekar _et al._, 1980). The population of penaeid prawns which abound in the estuaries during the saline period may also be a major direct or indirect consumer.

Calanoid copepods play a pivotal role in the ecosystem of any aquatic environment. In the estuaries all over the world they are dominated by only a few genera or families. In the estuaries of India species of the families Acartiidae and Pseudodiaptomidae are dominant. A few species of the family Paracalanidae also occur in appreciable numbers. Species of the genera _Eurytemora_, *Acartia*, *Pseudodiaptomus* and *Tortanus* characterise the estuaries of South Africa (Grindley, 1980). Australian estuaries include a few other genera also like *Boeckella*, *Gladioferens* and *Sulcanus* (Taw and Ritz, 1978).

Heinrich (1962) recognises three 'types' of life cycles in the zooplankton in relation to feeding. Type 1 depends on the availability of food and breed only when food is plenty. Breeding in type 2 is independent of food supply and they usually store fat. These two types mainly occur inthe higher latitudes and bathypelagic systems. Type 3 occurs mostly in the tropics where the species are more or less continuous feeders and breeders. The estuarine copepods probably fall under this category since the copepodites of true estuarine forms are present in the collection althrough the saline premonsoon season. Bio-chemical studies on zooplankton from Cochin backwaters (Madhupratap *et al*., 1979) indicate that most species have a very low lipid storage indicating that they feed continuously. In such cases protein may function as an important food reserve (Conover and Corner, 1968; Raymont *et al*., 1969) which may be mobilised to meet the metabolic requirements.

The common carnivorous copepods of the pelagic realm belonging to the families Euchaetidae, Pontellidae and Candaciidae are not represented in these estuaries (but for the genus *Labidocera*). The few species of the family

Paracalanidae are probably herbivores whereas most of the species belonging to families Acartiidae and Pseudodiaptomidae are omnivores or detritivores. Only a few species like _Acartiella gravelyi_ and _A. keralensis_ appear to be carnivores (Tranter and Abraham, 1971).

The importance of detritus and associated bacterial load as a direct nutritional source to zooplankton especially copepods is now widely recognised (Heinle and Flemer, 1975; Heinle _et al._, 1977; Conover, 1979). Obviously there is no dearth of detrital material in the estuaries. Studies from Cochin backwaters reveal that phytoplankton production is in excess when compared to zooplankton grazing pressure (Qasim, 1970; Madhupratap _et al._, 1977). Hence availability of food is not the limiting factor for zooplankton survival in these estuaries.

In the higher latitudes there is usually a pulse of phytoplankton production in the spring. This is followed, after a lag, by an increase in zooplankton standing stock. In the tropics however, there is usually, no such sudden pulse and phyto- zoo- plankton production rates show a more or less an even curve. In contrast, in the coastal regions upwelling may cause sudden blooms of phytoplankton associated with large swarms of filter feeders like tunicates (Madhupratap _et al._, 1980).

The production trends of phytoplankton and zooplankton in the Cochin backwaters are not much varied, but the peak abundance attained by zooplankton in mid-summer (Fig. 29 A) is probably due to a relatively more stable environment (see Chapter 7) than the availability of food supply. Similarly salinity and currents must be affecting their survival in the monsoon period since phytoplankton production was fairly high during this period.

The carnivores of the zooplankton component (hydromedusae, ctenophora and chaetognatha) also show a close relation to increase in abundance of other zooplankton (Fig. 29 B). Naturally, their numbers are much less compared to secondary producers as in any ecosystem (say, terrestrial). All of them are high saline forms and apart from a low availability of food, salinity must be a major factor causing the decline of their population during the monsoon.

These estuaries are thus left unexploited at secondary level during the monsoons. The pathways of energy (derived from primary production and detritus etc.) transfer during this period is yet to be worked out.

The food chain in the estuaries are apparently simple compared to the more complex oceanic environment. The shallowness restricts vertical compartmentalisation, unlike the sea where vertical migration and depth range of zooplankton species are critically associated with distribution of food. The excess phytoplankton production and bacteria along with zooplankton and their faecal pellets contribute to the richness of the bottom deposits. The benthic community flourish and many of these estuaries are rich in clam beds, polychaets and amphipod communities. The benthic community is in turn exploited by an abundant population of prawns and other predators which feed on them.

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6. SPECIES DOMINANCE AND SUCCESSION.

In tropical estuaries, salinity is the key factor that controls the distribution and abundance of various zooplankton species. During the monsoon, because of heavy discharge of fresh water, the salinity is reduced to near fresh water conditions in the estuarine systems. Almost all the zooplankton organisms are wiped out with the exception of a few low saline species. Repopulation of these waters start during the postmonsoon period. Their intrusion and propagation towards the interiors of the estuaries depend largely on the salinity incursion. The successional pattern of various species could be deduced from the numerical abundance.

Compared to the low saline season the zooplankton numbers increase many fold during the favourable saline period. The estuarine species are r selected (Highly unpredictable or seasonal environments favour opportunistic species with high rate of increase - r selected - while the more constant environments do not - K selected, Mac Aruther, 1972). The succession shows that although many species appear in the sequence a few species among them tend to dominate numerically. The percentage of dominance may vary, but often a few species together constitute the major portion of the population.

Comparisons of species rich communities (like the open ocean) to species poor communities (like estuaries) have led to the generalisation that there are fewer numerically dominant species in the former (Mac Arthur, 1969). While there is an increasing gradient in species diversity from estuaries to open ocean, studies reveal that more often a few species tend to occur in greater abundance in the stable environments also (Haridas et al., 1980; Madhupratap et al., 1981; Nair et al., 1981). Birch (1981) analysing the marine benthic communities also came to the conclusion that Mac Arthur's theory need not always hold true.

In the estuaries Copepoda almost always showed the highest numerical dominance. Although 51 species belonging to this group were recorded only a few generally dominated the assemblage. Other groups/species predominated only rarely.

In the Cochin backwaters, *Paracalanus crassirostris* was the dominant species at the mouth area during the early postmonsoon period (November). This species was replaced by *Paracalanus aculeatus* during the late postmonsoon and early premonsoon months. *Acartia centrura* dominated all other species, all through the rest of the premonsoon period (Fig. 30 A). Other high saline species which are common in these waters like *Acrocalanus similis*, *Acartia bilobata*, *A. spinicauda*, *A. pacifica*, *Pseudodiaptomus serricaudatus*, *P. jonesi* and species of the family Centropagidae though occurred in considerable numbers are dwarfed by *A. centrura*. During the peak monsoon month (July) *Pseudodiaptomus annandalei* which preferred stratified waters is the dominant species. *Acartia plumosa*, a medium saline species was common during late monsoon. This species with *Acartiella keralensis* predominated in the middle reaches during the peak salinity regime. Though other high saline species of Acartiidae penetrated into these areas during this period they did not dominate. During the monsoon period *A. gravelyi* is the dominant species in the interior of the estuary.

Acartia centrura showed absolute dominance during most of the months of the year at Neendakara estuary. During the peak premonsoon period (April-May) *Lucifer*

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hanseni and Sagitta bedoti predominated (Fig. 30 A). At Kallai also A. centrura was the dominant species during the pre- and post- monsoon. But during low saline period, zoea larvae, Acartiella keralensis and A. gravelyi replaced the high saline species. Almost similar situation existed at Korapuzha estuary also (Fig. 30 B).

Similar to Cochin backwaters, various high saline species occurred in higher abundance during the pre-monsoon and postmonsoon months in these estuaries also. But Acartia centrura almost always outnumbered these species. The low saline species, Acartiella gravelyi was absent in Neendakara estuary, and species like A . keralensis and Acartia plumosa occurred in low numbers. This was because, very low saline condition did not exist at the mouth area of this estuary. Even at the peak of the monsoon salinity was 6.7‰ and 14.6‰ at the surface and bottom respectively.

In the estuaries of Mahe and Beypore dominance of copepods was not as high as in other estuaries (Fig. 30 B). Acartia centrura dominated only during peak premonsoon at Mahe while at Beypore it dominated during early premonsoon and postmonsoon, though Pseudodiaptomus annandalei was the dominant species

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Mahe and *Oithona nana* at Beypore. Brachyuran zoea and caridean larvae were dominant during early premonsoon and monsoon season and the amphipod *Corophium triangonyx* was abundant in postmonsoon at Mahe. *Eutima commensalis*, a hydromedusa and the sergestid *Lucifer hanseni* were the dominant species during the peak saline months at Beypore. Zoea, larvae of carideans and the cladoceran *Evadne tergestina* stemmed into dominance in some months during monsoon. The ctenophore *Pleurobrachia globosa* dominated in late postmonsoon.

Acartiella gravelyi was the dominant species during the early premonsoon at the Thottappilly and Veli lakes (Fig. 30 C). At Thottappilly it was replaced by medium saline species like *Acartia plumosa* and *Acartiella keralensis* during late premonsoon. Only some caridean larvae were present during the early monsoon period. Very low saline diaptomids like *Heliodiaptomus cinctus* and *Allodiaptomus mirabilipes* were dominating copepods during late monsoon and postmonsoon months. But in the Veli lake high saline species like *Acartia centrura*, *A. spinicauda* and *Pseudodiaptomus aurivilli* dominated during the premonsoon months. Though low saline copepods were present during the postmonsoon months, caridean larvae dominated.

Zooplankton populations in the estuaries are rich during the saline period. Most of the common species that occurred during this period were able to tolerate a considerable range of salinity variations and dominance is probably achieved at optimum salinity and when other environmental factors are also conducive.

Salinity recovery is faster at the mouth area of the estuaries during postmonsoon season and is slow towards the middle and upper reaches. Broadly, the successional pattern showed three zones, the low saline forms dominated the entire estuary (but in low numbers) during monsoon and the head region during postmonsoon. The high saline forms dominated the mouth area during postmonsoon and the middle reaches during premonsoon. The medium saline species were abundant in middle reaches during early premonsoon and at the upper reaches during later premonsoon. The medium saline species replaces the low saline forms towards the head as salinity recovers and later high saline species also invade this area in late premonsoon when salinity increases further.

In general *Acartia centrura* was the dominant species and this along with a few other species like *Acrocalanus similis*, *Paracalanus crassirostris*, *Acartia bilobata*, *A. spinicauda* and *Pseudodiaptomus serricaudatus* formed bulk of the population during saline period. Although the carnivorous groups like hydromedusae and ctenophora were not numerically dominant, the ecological dominance of these groups cannot be overlooked.

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7. SPECIES DIVERSITY.

The data most basic to the understanding of community structure are the number of species present and their relative abundance. In nature, we find that some communities are rich in the number of species (like perrenial forests of tropics, oceanic environment etc) while certain others (like estuaries) are relatively poor in this respect. Ecologists agree that there is a general increase in the number of species from higher latitudes towards the tropics. However, the reasons for variations are far from clear. Several theories with respect to this have been suggested, but no single explanation is sufficiently cogent to pinpoint the variations.

Within the tropical aquatic environment itself we find that there is a decreasing gradient in diversity from oceanic to neritic and to estuarine habitats. Mac Arthur (1965) stated that "the number of species within a habitat can be expected to increase with productivity (sometimes), with structural complexity of the habitat, lack of seasonality in resources and the degree of specialisation". Various theories involving time (older communities have more numbers of species), spatial heterogenity (more heterogenous physical environment supports more species), competition (leads to narrow niches), predation (reduces competition and allows more prey species), environmental stability (more species in stabler environments) and productivity (greater production results in greater diversity) have been put forward. However these theories, apart from lack of general stability of the environment do not explain the lower diversity in the estuaries.

Ecologists argue that negative feed back in ecosystems damps perturbations and the stability or the resilience of the environment contributes to higher diversity. The idea that ecosystems possess such stability was introduced by Mac Arthur (1955). Ecologists' subsequent efforts to verify this hypothesis became complicated by attempts to define stability and diversity in operational ways (Patten and Odum, 1981). "Increased stability with increased species is difficult to demonstrate.... Models reduce the intricate beauty and awesome complexity of a piece of living nature to what is by comparison a flat pallid image of reality. An ecosystem model, no matter how sophisticated or difficult to produce is but a shadow of its prototype" (Patten et al., 1975).

Environmental conditions in tropical estuaries are highly fluctuating unlike marine environment. A more or less stable condition in estuaries is attained only during the saline premonsoon months and zooplankton species are more diverse during this period compared to other seasons.

Two indices, 'D' (Margalef, 1968) and 'E' (Heip, 1974) were used to evaluate the diversity of zooplankton in the estuaries. The formula used for the index 'D' was,

$D = \frac{S-1}{\log_e N}$, where S is the number of species and N is the number of individuals of all species and for E was

$E = \frac{e^H - 1}{S-1}$, where S is the number of species.

The index 'D' is relatively stable compared to α (Fischer et al., 1943) but this index also possess the drawback that it is affected by the sample size. The evenness index is the ratio between the actual diversity and the maximum possible diversity which occurs when all species are equally abundant and ranges from 0 to 1. In short it gives the evenness in distribution of species within the sample. Evenness is the inverse of dominance.

The number of species and the indices 'E' and 'D' for the eight estuaries are given in Table 9. Diversity value, 'D', was higher during the salinity regime and lowest during the peak monsoon months. At Neendakara the values remained high throughout the year. In ranged between 3.2 and 7.0. Salinity was also high at the mouth of this estuary in most months. In the Cochin backwaters these values ranged between 2.2 and 5.3 comparatively higher values being observed during the time when salinity recovery started. Both marine and true estuarine forms occur at the mouth during this period. The values were comparatively lower in the Karapuzha estuary.

The index 'E' was highest at Thottappilly lake and to some extent at Vali also. In the other estuaries higher values were observed in certain months especially when the species number and zooplankton population were low. Thus during this period although the number of species was less, their distribution within the total numbers was more or less even.

The number of species which occurred showed more or less a direct correlation with salinity when the distribution in the upstream areas of Cochin backwaters was analysed (Fig. 31). There was a progressive decrease in the number of species along the salinity gradient towards the upper reaches. During July when the system was practically fresh water, only very few organisms tolerating low saline conditions thrived in the estuaries.

In almost all the estuaries, the greatest diversity occurs near the mouth where a wide range of neritic species also appear. Some of the higher values (D values) observed in some estuaries especially at Neendakara (7.0 in April, 6.1 in September) are because of stray occurrences of some of the coastal and neritic species. Thus if the estuarine and euryhaline species which are common in the estuaries only are taken into account and the less tolerant neritic species omited, the indices would be still low.

Species diversity in estuarine zooplankton was low compared to coastal or oceanic waters. The average diversity index 'D' ranged between 1.5 and 5.5 in these estuaries. It ranged from 3.1 to 7.7 in a nearshore environment (Haridas et al., 1980) from 8.2 to 12.9 in the coastal and oceanic waters of the Bay of Bengal (Nair *et al*., 1981) and from 3.2 to 8.1 in the Andaman Sea (Madhupratap *et al*., 1981). Thus there is a progressive gradient in the zooplankton diversity from estuarine environment to open ocean. A similar trend was observed for the tropical benthic communities by Sanders (1969). He maintains that estuaries are in principle physically controlled environment, unlike the open ocean which is more stable and develop biologically accommodated communities. The number of species present diminish continuously along the stress gradient from a stable environment to habitats where conditions are fluctuating and finally when the stress conditions become greater than the adaptive abilities of the organisms, an abiotic condition is reached.

Diversification has several important implications for the community. Ricklefs (1973) says that many species can exploit different kinds of resources more efficiently because the evolutionary independence of reproductively isolated populations allows specialisation. Further, diversity creates heterogenity in the environment which provides the basis for increased diversification of life forms. Whether species exploit more ecological roles in areas of high diversity in view of the greater variety of ecological opportunities or because species diversify to avoid competition, or both, is still open to question.

Productivity or spatial heterogenity are certainly not the factors affecting the species diversity in the estuaries. Analogous situations where diversity tend to decrease with higher standing population have been reported (Deevey, 1971; Nair _et al._, 1981). Phytoplankton diversity has been found to be high in oligotrophic areas compared to eutrophic areas (Peterson, 1975). It can only be speculated that lack of stability or time to diversify (only the intermonsoon period allows some diversification) and the constant physical changes of the environment lead to a lesser diversity in the estuaries.

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8. ZOOPLANKTON ASSEMBLAGES.

A variety of zooplankton organisms inhabit the estuarine environment competing or accommodating each other. The degree of coexistence and competition depends on the requirement and availability of food, space etc. in the habitat. Earlier informations on the coexistence of *Acartia* spp. and other copepods in the Cochin backwaters have come from Tranter and Abraham (1971); Madhupratap *et al.* (1975) and Madhupratap (1980). In this chapter the pattern of association of common groups and species of zooplankton in the eight estuaries are ~~attempted~~ discussed.

Correlation matrices for the groups and species were formed after converting their numbers to their respective logarithmic values. The formula used for obtaining the correlation coefficient was

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

The results are presented in Tables 10 and 11.

Correlation at group levels showed that most of the groups were positively correlated with each other in these estuaries except at Neendakara and Beypore.

The carnivorous forms like hydromedusae, ctenophores and chaetognaths were significantly positively correlated with each other in most of the estuaries. Highly significant relation between them ($P = < 0.001$) was observed at Mahe. At Neendakara, Cochin and Beypore, Copepoda showed significant positive correlation only with a few groups while in the other estuaries copepods occurred along with the other groups over the same period.

Cladocera in general did not show significant relationship with other taxa. They were negatively correlated with most of the groups at Veli, Cochin and Beypore. This is because of the rather peculiar distribution exhibited by this group being more common during certain months during the low salinity period. However, they exhibited significant positive correlations with sergestids, zoea and decapods at Karapuzha and Mahe.

With regard to the decapods and sergestids, they showed significant positive relations with other groups at varying levels in Veli, Karapuzha, Mahe and Kallai. But at Neendakara, Cochin and Beypore their association with other groups were not as significant as in other estuaries. Similar trends of associations were noticed for the meroplanktonic forms like zoea larvae, polychaete larvae and cirripede larvae.

Appendicularia showed significant positive correlations with other groups at Korapuzha, Mahe and Kallai and negative relations at Neendakara and Cochin. Fish eggs exhibited more positive relations compared to fish larvae in most of the estuaries.

Estuaries generally become rich in zooplankton population during the saline period and most groups thrive in this season. Thus it is natural that most of the groups were positively inter-related. However, the groups consist of species which have different ecological significance. Thus the pattern of associations observed at group level provide only limited information. The associations of the common copepod species is treated separately. The more or less consistent positive correlations for most groups confirm that the seasonal fluctuations of these groups are consistent in the estuaries studied.

Although 51 species of copepods were identified from these estuaries only the common species were taken to examine the pattern of associations. They included species preferring low, medium and high saline conditions.

In general, the various high saline species showed significant positive correlations with each other although variations existed in the level of signifience in different estuaries. Highly significant correlations were observed among *Acartia centrura*, *A. spinicauda*, *A. bilobata*, *A. erythraea*, *Centropages alcocki*, *Pseudodiaptomus aurivilli* and *Acrocalanus similis* in the Kallai estuary. Similar relations existed in the Mahe estuary also but *A. erythraea* was absent in these waters. In Cochin backwaters, *A. centrura*, the most common species, showed positive but not significant correlations with other species. However, it was correlated with *Pseudodiaptomus serricaudatus*, *P. aurivilli* ($P < 0.001$) and *Acrocalanus similis*.

At Korapuzha highly significant correlations were observed among *Acartia centrura*, *A. spinicauda*, *A. bilobata*, *Centropages alcocki*, *Pseudodiaptomus serricaudatus* and *P. aurivilli*. *Acartia pacifica* and *Acrocalanus similis* were negatively correlated with all other species.

Centropages alcocki showed significant correlations with higher saline species at Korapuzha, Kallai and Mahe but exhibited negative relations in other estuaries. Similarly *Pseudodiaptomus aurivilli* also showed significant correlations with high saline forms in some estuaries but negative relation in others.

Acrocalanus similis, another successful species in the estuarine waters were found to exist together with all the high saline forms in all the estuaries except at Karapuzha where they were associated with *Acartia pacifica* only.

Pseudodiaptomus annandalei a highly tolerant species to wide salinity fluctuations was found to associate with both high saline and medium saline species.

Acartia plumosa and *Acartiella keralensis*, the two medium saline species were significantly positively correlated ($P < 0.001$) with each other in all estuaries except at Kallai. They were also observed to associate at higher levels of significance with *A. bilobata* at Neendakara estuary. The common low saline species *Acartiella gravelyi* almost always stood separate from other species exhibiting negative correlations except at Veli lake.

The pattern of correlations among the common copepod species shows that the low saline species *Acartiella gravelyi* and the medium saline species *A. keralensis* and *Acartia plumosa* occupy niches which stand separate from the high saline forms. Since species in these two categories are few and the biotope is sufficiently heterogeneous no biological factors could be limiting their flourishing in the estuaries. They are separated both temporally and spatially from the high saline forms. Only physical forces like strong currents or chemical parameters such as salinity affect their survival.

On the other hand, the various high saline species exist in large abundance over the same span. These species in general showed significant positive correlations in most estuaries with minor variations. Spatially also they have similar distribution and this leads to either coexistence or competition among them. These results are in compliance with the earlier findings by Madhupratap (1980) from Cochin backwaters. Conceptually, if these species coexist, it would call for some degree of ecological differentiation between them to avoid niche overlap.

Earlier ecological theories, which are held valid to some extent even today, imply that competition cannot survive indefinitely. The competitive exclusion principle put forward by Gause (1934) is supported by Hardin (1960) who states that complete competitors cannot coexist. Slobodkin (1961) also holds the view that no two species can indefinitely continue to occupy the same ecological niche.

In aquatic communities, especially in microscopic zooplankton organisms, it is difficult to establish the nature of ecological differentiations since visual observations are virtually impossible. Tranter and Abraham (1971) had attempted to seek the differentiations among the coexisting copepod species of the family Acartiidae from the Cochin backwaters based on the structure of the mandibles. However, in their opinion "the differences which do exist are not sufficient to establish niche separation".

The absolute validity of competitive exclusion theory is, however, under criticism (Smith et al., 1975; Hayward, 1980). While niche overlap is difficult to establish in marine organisms, several studies from the land have proved to be of inconclusive results (Rusterholz, 1981). The concept of a guild (a guild is a group of species which uses the same environment resources in a similar fashion, Root, 1967) is attaining considerable impetus in recent studies. Among the guild subtle differences in feeding mechanisms can alleviate intense competition by harvesting a portion of the resource spectrum unavailable to other species. Hutchinson (1961, 1965) and Hulburt (1977) feel that species coexist, but not in equillibrium because equillibrium is attained only after the better competitors have excluded the poorer ones. Such equillibrium conditions are rarely met with in nature. In coral reef fish communities where the diversity is very high, there is considerable overlap in space and food requirements among the coexisting species (Sale, 1977). Recent experimental studies on several coexisting copepod species have shown that they feed upon the same size range of particles when presented with natural prey, and that the preferred size varies in response to particle size distribution in the habitat (Poulet, 1978). With our present knowledge, ecological differentiation among marine/estuarine zooplankton can perhaps only be defined emperically.

Studies (Cowey and Corner, 1963; Conover, 1966; Chervin, 1978; Rieper, 1978; Hayward, 1980) indicate that the spectrum of food used by copepods include detrius and bacteria as well, apart from the conventional phytoplankton-zooplankton link. The high primary production in the estuarine environments, availability of large amount of organic detritus and associated bacterial load provide the estuarine zooplankton with sufficient food resources. This also explains the large abundance of zooplankton in the estuaries compared to the marine environment. This availability of food and the probable variations that exist in feeding habits would allow the various high saline species to live as competitors or even allow coexistance. Moreover the peculiarity of the tropical estuaries allow them to expand their niches spatially as the salinity increases towards the interiors. Succession of the high saline species starts from the mouth areas of the estuaries at the cessation of the mônsoons and as salinity increases they invade the upper reaches utilising the resources available in these regions. Anyway, the periodical monsoons which washes out the high saline species out of the estuaries relieves them of the necessity to compete or co-exist for long, till the unlikely situation where resources would run out.

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9. SUMMARY.

1. Ecology of zooplankton of eight estuarine systems of Kerala spread over a stretch of 500 km of the coastline was studied based on year-round collections made during 1978. The hydrographic data and zooplankton samples were taken from one fixed station at the mouth of each estuary. The middle and upper reaches of the Cochin backwaters were sampled seasonally. Of the various estuaries studied, those at Veli and Thottappilly have only seasonal connection with the sea when the sand-bar breaks during the monsoon. Veli lake is situated near Trivandrum and Thottappilly is located north of Alleppey. The other estuaries studied have perenial connections with the Arabian Sea viz. Neenda-kara or Ashtamudi estuary at Quilon, Cochin back-waters at Cochin, Korapuzha, Kallai, and Beypore estuaries at Calicut, and Mahe estuary near Talli-cherry. The general environment of these estuarine systems and other major features are reviewed in the context of other estuarine studies.

2. Both the southwest and northeast monsoons exert their influence on these estuaries. Salinity, the single-most important factor in the biological process in estuaries showed wide variations over the year. Conditions at the mouths ranged from almost marine to near freshwater during the different seasons except at Neendakara where the water column remained slightly saline even during the peak monsoon period. The cold less oxygenated high saline water at the bottom layers at the Cochin backwaters during certain months could be identified as upwelled Arabian Sea water entering the channel.

3. The water column was well mixed during the premonsoon period (January-April) in these estuaries. Steep vertical gradients in salinity, temperature and oxygen were noticed in the Cochin backwaters during the monsoon period (May-October). Such vertical stratification of the water column was less pronounced in other estuaries, especially at Neendakara and Mahe.

4. Veli and Thottappilly lakes differed from the other estuaries in the general hydrobiological aspects. The system remained practically freshwater during most of the year at Thottappilly. At

Veli, the surface salinity was low but bottom salinity registered higher values during the premonsoon and postmonsoon seasons. The high saline water at the bottom in this lake in the absence of free connection with the sea could be explained partly by the dynamics of a coastal aquifer and also by spill over during intense wave action. The latter probably brings in the high saline fauna encountered in this lake.

5. Zooplankton biomass and total zooplankton counts varied significantly between seasons and estuaries. Highest biomass and total numbers of zooplankton were recorded from the Cochin backwaters; Korapuzha and Kallai estuaries ranked next. Maximum population was usually observed in April but the month when peak biomass was recorded differed from place to place showing total numbers and biomass were not always correlated. In general estuaries have a high standing stock and have higher turn over rates compared to the adjoining sea.

6. Seventy three species of zooplankton belonging to sixteen groups were identified from these estuaries. The species composition in the 8 estuaries studied were more or less similar.

However, some species did not occur in all the estuaries. Variations in the population of different species were also noticeable between estuaries. Maximum number of species was recorded from Cochin backwaters. Neendakara though poor in biomass and total numbers ranked second in species richness. Copepoda was usually the most abundant group followed by zoea larvae and Sergestidae.

7. Carnivorous forms like Hydromedusae, Ctenophora and Chaetognatha were present during the high saline period. The common hydromedusae occurring in these waters were essentially brackish water forms, whereas Ctenophora and Chaetognatha comprised only of marine species. Chaetognaths were more abundant at Cochin backwaters than in other estuaries. These three groups together constituted only 4.3% of the total numbers, but their feeding exerted profound influence on other zooplankton groups especially Copepoda.

Cladocerans which are common in the neritic and coastal waters were curiously absent in the estuaries during the high saline periods. They, on the other hand appeared during the low salinity regime. Higher primary production and lack of competition during the monsoon period seem to offer favourable conditions to them.

Copepoda was the dominant group in these estuaries constituting 67.7% of the total counts. Fifty one species belonging to 18 genera were identified. Families Acartiidae, Pseudodiaptomidae and Paracalanidae formed the bulk of the Copepod population. They together accounted for 85 to 95% of the total copepods in these estuaries except at Thottappilly lake. In this lake they formed only 51%, the rest being low saline species belonging to Diaptomidae and Cyclopida. *Acartia centrura*, *A. spinicauda*, *A. bilobata*, *Acrocalanus similis*, *Pseudodiaptomus serricaudatus*, *P. annandalei*, *Centropages alcocki* and *Labidocera pectinata* were the common high saline copepod species in the estuaries. *A. plumosa* and *Acartiella keralensis* preferred medium salinity and were the dominant forms in the middle and upper reaches of Cochin backwaters. *Acartiella gravelyi* thrived well during the low salinity regime. *Acartia centrura* emerged as the most abundant species in the three-way analysis of variance performed on the copepod species.

Unlike other estuaries a mixed assemblage of low, medium and high saline species of Copepods were observed at times at Thottappilly and Veli lakes. In the former where the salinity was low throughout the year, low saline species were relatively more abundant. The presence of marine species like _Temora stylifera_, _Tortanus gracilis_ and _Acartia negligens_ at Veli lake which lacks a permanent connection to the sea is a little intriguing. They might have come into this lake through the spill over during intense wave action and were able to survive because of the higher saline bottom water.

Decapod larvae constituted the majority of invertebrate larval forms ranking next to copepods in overall abundance. Zoea larvae were very common occurring in all seasons with peaks usually during the premonsoon months. Larvae of penaeid and caridean decapods at various stages of development including those of commercially important species were observed in all estuaries almost throughout the year. _Lucifer hanseni_ was the most common sergestid. Fish eggs and larvae were also common mostly belonging to families Ambassidae, Mugilidae and Gobidae.

Other groups like Siphonophora, Ostracoda, Cumacea, Mysidacea, Appendicularia etc. were observed during the higher saline months but are of less importance in the estuarine ecology.

8. The zooplankton of the estuaries comprise of truely estuarine, euryhaline marine, a few stenohaline marine and fresh water species. Among the true estuarine species three clines - high saline, medium saline and low saline - were recognised. The three obtain peak populations in different seasons depending on the environmental conditions.

9. The high saline species flourish during the premonsoon period. They are more abundant at the lower reaches but do invade the upper reaches along with salinity incursion. The medium saline species also flourish well during the saline period, but in the middle and upper reaches where salinity is optimum. Low saline species thrive at the upper reaches during postmonsoon months and throughout the estuary during monsoon period. Thus monsoonal innudation, tidal incursion and associated changes in salinity are the main factors controlling the zooplankton of the estuaries.

10. The occurrence of mixed assemblages of high and low saline copepod species in Veli and Thettappilly lakes which have limited connection to the sea, is very interesting. This debilitates the general idea that salinity is the factor controlling the occurrence of various species in the estuaries, though it does control the abundance of various estuarine species.

11. In these estuaries, phytoplankton, detritus and associated bacterial load form the main source of food for the zooplankton. The species of the families Acartiidae, Pseudodiaptomidae and Paracalanidae which contributed to the bulk of the copepod population are mainly herbivorous, omnivorous or detritivorous. In general, food is not a limiting factor for the survival of zooplankton in these estuaries. The coefficient of energy transfer from the primary and secondary trophic level is low in the Cochin backwaters. The underutilised excess production both at primary and secondary levels probably contribute to the richness of the bottom communities and productivity of coastal waters.

12. In the tropical estuaries heavy discharge of fresh water during monsoon season wipes out all but a few zooplankton organisms. Repopulation of the estuaries start with the salinity recovery. The successional sequence that follows could be seen from the relative numerical abundance culminating in high zooplankton population during the saline period before the following monsoon disrupts further progress. Among the numerous species that occur in the estuaries a few dominate the zooplankton assemblage. The pattern of succession showed three seres consisting of high saline, medium saline and low saline forms. The high saline forms dominated the mouth area during the premonsoon. The medium saline species were abundant at the middle reaches during early premonsoon and at the upper reaches during late premonsoon. The low saline species dominate during the monsoon period. Although the broad scheme of succession was similar individual variations did exist in different estuaries.

13. Species diversity of the estuaries was low compared to coastal and oceanic realms. Diversity increased in estuaries in the dry season when conditions tend to be more stable. The higher evenness of the species - population index observed at Thottappilly and Veli lakes was due to lesser numbers of

species corresponding to a thin population. Productivity and spatial heterogeneity being of little consequence, it is speculated that lack of stability leads to the lower diversity in estuaries.

14. Analysis of association of groups of zooplankton in the estuaries revealed that most of the groups exhibited significant correlations with each other. However, this is but natural since all the major groups occur in high numbers during the high saline months.

The common high saline copepod species showed high degree of correlations between themselves. The medium saline species like _Acartia plumosa_ and _Acartiella keralensis_ showed significant correlation between each other, but was negatively correlated with most of the high saline species. _Acartiella gravelyi_, the low saline species almost always stood separate exhibiting negative correlation with all other species.

Considerable niche overlap seems to occur between the common high saline species. The ecological differentiation between the species to allow coexistence is not lucid. Perhaps the availability of large amount of food provide the estuarine zooplankton sufficient resources to survive as competitors. The high saline species are eliminated by periodic monsoons before competition reaches the point where resources would run out.

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TABLES

Table 1: Annual river discharge from Indian Rivers (After Khosla, 1951).

	West Coast Rivers	Km^3/years
1.	Streams from Cape Comorin to Tadri (Excluding Tadri).	114.2
2.	Streams from Tadri to Tapti (excluding Tapti)	114.8
3.	Tapti	9.1
4.	Narmada	49.2
5.	Mahi	9.3
6.	Sabarmati	4.7
7.	Streams of Katin	4.8
8.	Luni	0.3
9.	Streams of Kutch	3.7
10.	Sutlej System	36.7
	East Coast Rivers	
1.	Rivers from Cape Comorin to Cauvery (excluding Cauvery).	7.9
2.	Cauvery	10.0
3.	Rivers between Cauvery and Pennar (excluding Pennar)	9.5
4.	Rivers between Pennar and Krishna	1.6
5.	Krishna System	44.9
6.	Godavari System	125.5

Table 1 (Contd.)

		Km^3/years
7.	Rivers between Godavari and Mahanadi (excluding Mahanadi)	16.1
8.	Mahanadi	92.8
9.	Brahmani and Baitarni	39.2
10.	Subarnarekha and streams from Subarnarekha to Baitarni	20.3
11.	Subarnarekha to Damodar (excluding Damodar)	14.0
12.	Damodar	13.0
13.	Hoogly	17.3
14.	Ganges System	489.8
15.	Brahmaputra System	381.1
	Total for West Coast Rivers	346.8
	Total for East Coast Rivers	1283.0

Table 2 A. Biomass (ml/10^3) in the estuarine mouths in the year 1978.

Months	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Premonsoon								
January	0.09	0.04	0.001	1.6	0.07	0.2	0.23	0.4
February	0.03	0.03	0.01	5.8	0.04	0.1	0.14	0.01
March	0.01	0.04	0.001	4.1	0.06	0.5	0.18	0.04
April	1.1	0.1	0.01	8.2	3.5	0.8	1.16	2.1
Monsoon								
May	0.25	0.03	0.001	7.0	1.9	0.5	1.3	0.001
June	0.001	0.05	0.001	0.9	0.2	0.2	0.3	0.03
July	0.02	0.03	0.001	5.1	-	-	0.001	0.01
August	0.01	0.2	0.01	0.8	0.4	0.001	0.001	0.001
September	0.001	0.01	0.001	0.2	0.8	0.001	0.07	0.001
October	0.2	0.04	0.01	1.4	0.2	0.001	0.4	0.001
Postmonsoon								
November	0.01	0.04	-	1.7	0.4	0.5	0.001	0.04
December	0.01	0.2	0.001	2.2	0.5	0.6	0.2	0.02
Annual mean	0.15	0.07	0.003	3.25	0.67	0.28	0.33	0.22
Seasonal average								
Premonsoon	0.31	0.05	0.005	4.9	0.96	0.4	0.42	0.64
Monsoon	0.08	0.06	0.003	2.6	0.60	0.11	0.34	0.007
Postmonsoon	0.01	1.2	0.0005	1.9	0.45	0.5	0.1	0.03

Table 2 B. Counts (No./$10m^3$) of zooplankton in the estuaries of Kerala coast during 1978.

Months	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Premonsoon								
January	843	405	25	10450	1838	1964	2447	6275
February	591	589	572	41260	611	1068	2075	636
March	82	577	32	37190	845	4603	3353	1414
April	7861	2167	169	104107	30297	10721	12805	11138
Monsoon								
May	8800	833	43	40270	15606	7376	12877	78
June	22	1436	43	6873	2957	1313	8402	948
July	1090	528	40	26890	-	-	76	200
August	246	2483	225	16012	28	162	180	30
September	7	155	78	2404	6560	27	285	63
October	2804	1384	1025	5804	810	289	4334	40
Postmonsoon								
November	672	1495	-	8047	1666	13490	9	1645
December	258	3139	27	15839	2926	6636	3503	336
Annual mean	1940	1272	23	26237	5345	3971	4195	1899
Seasonal average								
Premonsoon	2342	930	199	48291	8398	4589	5170	4863
Monsoon	2162	1136	239	16375	4326	1528	4359	226
Postmonsoon	465	2317	13	11793	2296	10063	1756	990

Table 2 C. Zooplankton biomass (ml/10m^3) and total counts (per 10m^3) from the mouth to head of Cochin backwaters - 1978 (Values in parenthesis are total counts).

	STATIONS						
Months	1	2	3	4	5	6	7
January	1.6 (10450)	1.3 (5730)	7.2 (4810)	2.9 (3362)	0.9 (2270)	9.6 (950)	0.7 (20)
April	8.2 (104107)	4.1 (12060)	20.0 (13960)	6.8 (46330)	2.0 (8160)	4.2 (1660)	1.1 (5320)
July	5.1 (26890)	0.06 (20)	0.04 (10)	0.05 (5)	0.06 (20)	0.02 (5)	0.02 (2)
November	1.7 (8047)	0.6 (940)	0.4 (290)	0.3 (160)	0.1 (10)	0.1 (3)	0.1 (10)

Table 3. Results of Analysis of Variance.

A. Biomass.

Source	SS	df	ms	F
Total	197.930	95		
Months	30.020	11	2.729	3.02**
Estuaries	98.434	7	14.062	15.59***
Error	69.476	77	0.902	

CD for months = 0.9307

CD for estuaries = 0.7599

** - $P < 0.01$

*** - $P < 0.001$

Table 3 (Contd.)

B. Total Numbers.

Source	SS	df	ms	F
Total	109.538	95		
Months	23.131	11	2.103	3.32**
Estuaries	37.671	7	5.381	8.5***
Error	48.736	77	0.632	

CD for months = 0.7794

CD for estuaries = 0.6365

** = $P < 0.01$

*** = $P < 0.001$

Table 4. Result of three way ANOVA.

A. Groups.

Source	SS	df	ms	F
Total	1467.69	1439		
Months	205.67	11	18.69	33.31**
Estuaries	13.44	7	1.92	3.99**
Groups	197.54	14	14.11	25.14**
Months x estuaries	181.56	77	2.35	4.90**
Months x groups	129.03	154	0.83	1.49**
Estuaries x groups	221.78	98	2.26	4.70**
Error	518.63	1078	0.48	

CD for months = 0.207

CD for groups = 0.2312

CD for estuaries = 0.1579

** Significant at 1% level.

Table 4 (Contd.)

B. Common Copepod species

Source	SS	df	ms	F
Total	855.36	1267		
Months	74.64	11	6.78	13.31**
Estuaries	13.96	7	1.99	5.60**
Species	152.91	12	12.74	24.99**
Months x estuaries	85.25	77	1.11	3.11*
Months x species	161.16	132	1.22	2.39*
Estuaries x species	30.81	84	0.36	1.03*
Error	336.59	944	0.35	

CD for months = 0.2287

CD for estuaries = 0.1617

CD for species = 0.2380

** Significant at 1% level

* Significant at 5% level.

Table 5. Seasonal distribution and annual mean (No./10m[3]) of various groups and their percentage to total counts in the estuaries - 1978.

VELI

6	Hydro-medusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapod larvae	Sergestidae	Other invertebrate larvae	Appendicularia	Fish eggs & Fish larvae
Premonsoon											
Jan - Apr.	68	-	109	117	7345	-	764	318	96	-	450
Monsoon											
May - June	301	-	200	-	5965	-	1300	375	153	-	525
July - Oct.	-	-	-	14	2494	66	1252	126	84	-	52
Postmonsoon											
Nov - Dec.	-	-	-	139	404	10	317	-	-	-	54
Annual mean.	30.7	-	25.7	22.5	1347.3	6.3	302.7	68.2	27.7	-	90.0
% to annual total	1.6	-	1.3	1.1	69.5	0.32	15.6	3.5	1.4	-	4.6

Table 5 (Contd.)

NEENDAKARA

	Hydro-medusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphiphoda	Decapod larvae	Sergestidae	Other Invertebrate larvae	Appendicularia	Fish eggs & Fish larvae
Premonsoon											
Jan - Apr.	97	13	53	22	1341	49	970	878	61	11	140
Monsoon											
May - June	222	90	159	-	1310	-	287	71	24	-	-
July - Oct.	31	4	218	491	2317	448	373	108	227	19	110
Postmonsoon											
Nov - Dec.	223	16	56	324	3452	-	112	68	25	22	74
Annual mean.	47.7	10.2	40.5	69.7	701.7	45.5	145.2	93.3	28.1	4.3	27.0
% to annual total	3.7	0.8	3.2	5.5	55.2	3.6	11.4	7.3	2.2	0.34	2.1

Table 5 (Contd.)

THOTTAPPILLY

6	Hydro-medusae	Ctenophore	Chaetognatha	Cladocera	Copepoda	Amphiphoda	Decapod larvae	Sergestidae	Other invertebrate larvae	Appendicularia	Fish eggs & Fish larvae
Premonsoon											
Jan - Apr.	20	-	-	-	579	2	97	25	5	-	70
Monsoon											
May - June	-	-	-	-	31	-	52	2	-	-	1
July - Oct.	-	-	-	84	1123	5	44	17	24	-	5
Postmonsoon											
Nov - Dec.	-	-	-	1	17	-	4	1	1	-	3
Annual mean	1.6	-	-	7.1	145.8	0.6	16.4	3.75	2.5	-	6.6
% to annual total	0.87	-	-	3.7	76.8	0.3	0.6	1.9	1.3	-	3.5

Table 5 (Contd.)

COCHIN

	Hydro-medusae	Cteno-phore	Chaeto-gnatha	Clado-cera	Cope-poda	Amphi-poda	Decapod larvae	Serge-stidae	Other inverte-brate larvae	Appendi-cularia	Fish eggs & Fish larvae
Premonsoon											
Jan - Apr.	230	390	290	-	174090	390	12300	410	480	2680	1110
Monsoon											
May - June	770	50	65	70	41130	100	3710	280	240	20	320
July - Oct.	-	-	20	150	27300	680	3125	213	90	20	1030
Postmonsoon											
Nov - Dec.	20	20	90	3440	12240	140	5620	20	220	920	110
Annual mean	76.7	37.5	38.7	305.0	21230	109.2	2062.9	76.9	85.8	303.3	214.2
% to annual total	0.29	0.14	0.15	1.2	80.9	0.41	7.9	0.29	0.33	1.1	0.81

Table 5 (Contd.)

KALLAI

	Hydro-medusae	Ctenophore	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapod larvae	Sergestidae	Other invertebrate larvae	Appendicularia	Fish eggs & Fish larvae
Premonsoon											
Jan - Apr.	905	391	9	-	23377	300	2319	1500	1530	862	600
Monsoon											
May - June	157	196	-	-	11044	-	2936	1261	2940	-	1265
July - Oct.	-	-	-	10	1004	4	52	70	23	-	223 (~~233~~)
Postmonsoon											
Nov - Dec.	205	-	263	-	3135	52	490	399	14	-	19
Annual mean	105.6	65.6	22.6	0.8	3212.5	29.7	483.1	269.2	375.6	71.8	175.6
% to annual total	2.0	1.26	0.43	0.02	61.7	0.57	9.3	5.2	7.2	1.4	3.4

Table 5 (Contd.)

BEYPORE

	Hydro-medusae	Ctenophore	Chaeto-gnatha	Cladocera	Copepoda	Amphipoda	Decapod larvae	Sergestidae	Other inverte-brate larvae	Appendicularia	Fish eggs & Fish larvae
Premonsoon											
Jan - Apr	4662	3952	258	-	5422	39	938	2810	380	64	73
Monsoon											
May - June	128	2080	112	-	1274	-	1633	2967	64	-	226
July - Oct.	3	-	-	312	9	1	144	2	-	-	5
Postmonsoon											
Nov - Dec.	495	713	289	4	11009	30	4312	1646	-	-	63
Annual mean	440.7	528.7	54.9	26.3	1478.7	5.8	585.6	618.7	37.0	5.3	30.6
% to annual total	11.1	13.3	1.4	0.7	37.2	0.15	14.7	15.6	0.93	0.13	0.77

Table 5 (Contd.)

MAHE

	Hydro-medusae	Cteno-phore	Chaeto-gnatha	Clado-cera	Cope-poda	Amphi-poda	Decapod larvae	Sergo-stidae	Other inverte-brate larvae	Appendi-cularia	Fish eggs & Fish larvae
Premonsoon											
Jan - Apr.	420	225	834	30	9718	371	3202	1342	792	775	455
Monsoon											
May - June	-	-	77	-	29	79	652	-	38	-	27
July - Oct.	-	-	-	-	36	36	135	3	-	-	3
Postmonsoon											
Nov - Dec.	34	-	-	30	222	1066	118	2	61	33	299
Annual mean	37.8	18.7	75.9	5	833.7	129.3	342.2	112.2	74.2	67.3	65.3
% to annual total	1.9	0.98	3.9	0.26	43.8	6.8	17.9	5.9	3.9	3.5	3.4

Table 6: Systematic list of species identified from the eight estuaries of Kerala.
(+ = Present; - = Absent).

Species	Veli	Thottappilly	Neendakara	Cochin	Korapuzha	Kallai	Beypore	Mahe
Phylum - Coelenterata								
Class - Hydrozoa								
Order - Hydroida								
Family - Companulariidae								
Obelia sp.	+	-	+	+	+	+	+	+
Blackfordia virginica Mayer	+	+	+	+	+	-	+	-
Family - Lovenellidae								
Eucheilota menoni Kramp	-	-	-	+	-	-	-	-
Family - Eirenidae								
Eirene ceylonensis Browne	+	+	+	+	+	+	+	+
Eirene menoni Kramp	-	-	-	+	-	-	+	-
Family - Eutimidae								
Eutima commensalis Santhakumari	+	+	+	+	+	+	+	+
Eutima neucaledonia Uchida	-	-	-	+	-	-	-	-

Table 6 (Contd.)

Species	Veli	Thottappilly	Neendakara	Cochin	Korapuzha	Kallai	Beypore	Mahe
Order - Siphonophora								
Family - Diphyidae								
Diphyes chamissonis Huxley	-	-	-	+	+	+	+	-
Lensia subtiloides (Lens & Van Riemsdijk)	-	-	+	+	+	+	-	+
Phylum - Ctenophora								
Class - Tentaculata								
Pleurobrachia globosa	-	-	+	+	+	+	+	+
Class - Nuda								
Beroe sp.	-	-	+	+	-	-	-	-
Phylum - Chaetognatha								
Sagitta bedoti Be'raneck	+	-	+	+	+	+	+	+
Sagitta enflata Grassi	+	-	+	+	+	-	+	+
Sagitta oceania Gray	-	-	+	+	-	-	-	-
Sagitta robusta Doncaster	-	-	-	+	-	-	-	-

Table 6 (Contd.)

Species	Veli	Thottappilly	Neendakara	Cochin	Korapuzha	Kallai	Beypore	Mahe
Phylum - Arthropoda								
Class - Crustacea								
Order - Cladocera								
Podon polyphemoides Leukart	+	-	-	-	-	+	+	-
Evadne tergestina Claus	+	+	+	+	+	-	+	-
Penilia avirostris Dana	-	+	+	+	-	-	+	-
Daphnia sp.	+	+	-	-	-	-	-	-
Order - Ostracoda								
Family - Halocyprididae								
Euconchoecia aculeata Th. Scott	-	-	+	+	-	-	-	-
Order - Copepoda								
Sub Order- Calanoida								
Family - Calanidae								
Canthocalanus pauper (Giesbrecht)	-	-	-	+	-	-	-	-
Undinula vulgaris (Dana)	-	-	-	+	-	-	-	-

Table 6 (Contd.)

Species	Veli	Thottappilly	Neendakara	Cochin	Korapuzha	Kallai	Beypore	Mahe
Family - Eucalanidae								
Eucalanus monachus Giesbrecht	-	-	+	+	-	-	-	-
Eucalanus attenuatus (Dana)	-	-	+	-	-	-	-	-
Family - Paracalanidae								
Paracalanus aculeatus Giesbrecht	+	+	+	+	+	+	+	+
Paracalanus crassirostris Dahl f. *cochinensis* Wellershaus	-	-	-	+	-	-	-	-
Acrocalanus similis Sewell	+	+	+	+	+	+	+	+
Acrocalanus gibber Giesbrecht	+	-	+	+	+	-	-	+
Family - Centropagidae								
Centropages alcocki Sewell	+	+	+	+	+	+	+	+
Centropages furcatus (Dana)	-	-	+	+	+	+	+	-
Centropages trispinosus Sewell	-	-	+	+	-	-	-	-
Centropages tenuiremis Thompson & Scott	-	-	+	+	+	-	-	-

Table 6 (Contd.)

Species	Veli	Thottappilly	Neendakara	Cochin	Korapuzha	Kallai	Beypore	Mahe
Family - Diaptomidae								
Heliodiaptomus cinctus Gurney	+	+	-	+	-	-	-	-
Allodiaptomus mirabilipes Kiefer	+	+	-	+	-	-	-	-
Family - Pseudodiaptomidae								
Archidiaptomus aroorus Madhuprotap & Haridas	-	+	-	+	-	-	-	-
Pseudodiaptomus annandalei Sewell	+	+	+	+	+	+	+	+
Pseudodiaptomus binghami malayalus Wellershaus	+	+	-	+	-	+	-	-
Pseudodiaptomus jonesi Pillai	+	-	+	+	+	+	+	+
Pseudodiaptomus aurivillii Cleve	+	+	+	+	+	+	+	+
Pseudodiaptomus mertoni Fruchtl	-	-	+	+	+	+	+	+
Pseudodiaptomus serricaudatus (T. Scott)	+	+	+	+	+	+	+	+
Pseudodiaptomus tollingerae Sewell	-	-	-	+	-	-	-	-

Table 6 (Contd.)

Species	Veli	Thottappilly	Neendakara	Cochin	Narapusha	Kallai	Beypore	Mahe
Family - Temoridae								
Temora turbinata (Dana)	-	-	+	+	+	-	-	-
Temora stylifera (Dana)	+	-	-	+	+	-	-	-
Family - Lucicutidae								
Lucicutia flavicornis (Claus)	-	-	+	-	-	-	-	-
Family - Candacidae								
Candacia bradyi A. Scott	-	-	-	+	-	-	-	-
Family - Pontellidae								
Calanopia elliptica (Dana)	-	-	-	+	-	-	-	-
Labidocera pectinata Thompson & Scott	+	-	+	+	+	+	+	+
Labidocera acuta (Dana)	-	-	-	+	-	-	+	-
Family - Acartiidae								
Acartia centrura Giesbrecht	+	+	+	+	+	+	+	+
Acartia spinicauda Giesbrecht	+	+	+	+	+	+	+	+
Acartia erythraea Giesbrecht	+	-	+	+	-	+	-	-

Table 6 (Contd.)

Species	Veli	Thettappilly	Neendakara	Cochin	Korapuzha	Kallai	Beypore	Mahe
Acartia bilobata Abraham	+	+	+	+	+	+	+	+
Acartia southwelli Sewell	-	-	-	+	-	-	-	+
Acartia negligens Dana	+	-	-	+	-	-	-	-
Acartia plumosa T. Scott	+	+	+	+	+	+	-	+
Acartia pacifica Steuer	+	+	+	+	+	-	+	+
Acartiella keralensis Wellershaus	+	+	+	+	+	+	-	-
Acartiella gravelyi Sewell	+	+	-	+	+	+	-	-
Tortanidae								
Family - Temoridae								
Tortanus gracilis (Brady)	+	-	-	-	-	-	-	-
Sub order - Harpacticoida								
Family - Tachidiidae								
Euterpina acutifrons (Dana)	+	-	+	+	-	-	-	-
Family - Canthocamptidae								
Mitocra spinipes Boeck	+	+	+	+	-	-	-	-

Table 6 (Contd.)

Species	Veli	Thottappilly	Neendakara	Cochin	Korapuzha	Kallai	Beypore	Mahe
Family - Macrosetellidae								
Macrosetella gracilis (Dana)	-	-	-	+	-	-	-	+
Sub Order - Cyclopoida								
Family - Oithonidae								
Oithona hebes Giesbrecht	-	-	+	+	+	+	+	+
Oithona nana Giesbrecht	+	+	+	+	+	+	+	+
Oithona rigida Giesbrecht	-	-	-	+	-	-	-	-
Oithona plumifera Baird	-	-	+	-	-	-	-	-
Oithona brevicornis Giesbrecht	-	-	-	+	-	-	-	-
Family - Corycaeus								
Corycaeus sp.	+	-	+	+	-	-	-	-
Family - Sapphirinidae								
Sapphirina sp.	-	-	-	+	-	-	-	-
Order - Mysidacea								
Family - Mysidae								
Rhopalophthalmus indicus Pillai	-	-	-	+	-	-	-	-

Table 6 (Contd.)

Species	Veli	Thottappilly	Neendakara	Cochin	Narakkal	Kallai	Beypore	Mahe
Order - Decapoda								
Family - Penaeidae								
Subfamily - Sergestidae								
Acetes sp.	+	-	-	+	-	-	-	-
Lucifer hanseni Nobili	+	+	+	+	+	+	+	+
Lucifer typus H.M. Edw.	-	-	-	+	-	-	-	-
Phylum - Chordata								
Subphylum - Urochordata								
Class - Thaliacea								
Family - Salpidae								
Thalia democratica Forskal	-	-	-	+	-	-	-	-
Class - Appendicularia								
Oikopleura sp.	-	-	+	+	+	+	+	+

Table 7: Distribution of Groups/Species (those not represented in diagrams) in the different estuaries in 1978 - Nos./10m^3 are given in parenthesis.

* Represented in diagrams; - absent.

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
HYDROMEDUSAE								
Blackfordia virginica	May (75)	*	Mar.(1); Apr.(3)	*	*	*	*	-
Eucheilota menoni	-	-	-	Dec.(17)	-	-	-	-
Eirene ceylonensis	Apr.(25) May (50)	*	Apr.(4)	*	*	*	*	*
Eirene menoni	-	-	-	*	-	Mar.(19)	-	-
Eutima commensalis	Apr.(45) May (175)	*	Apr.(5)	*	*	*	*	*
SIPHONOPHORA								
Diphyes chamissonis	-	-	-	Dec.(14)	Mar.(19); May(294)	Nov.(22)	Apr.(12)	-
Lensia subtiloides	-	Dec.(26)	-	Nov.(7)	Apr.(526)	-	Sept.(14)	May (9)

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
CTENOPHORA								
Pleurobrachia globosa	-	+	-	+	+	+	+	+
Beroe sp.	-	May (7)	-	Mar. (8) Apr. (3)	-	-	-	-
CHAETOGNATHA								
Sagitta bedoti	Apr. (82) May (200)	+	-	+	Jan. (9) Nov. (54) Dec. (209)	+	+	+
S. enflata	Apr. (27)	Jan. (3) Aug. (20) Oct. (5) Nov. (8) Dec. (30)	-	+	-	Jan. (2) Nov. (205)	+	Apr. (319)
S. oceania	-	Apr. (13)	-	+	-	-	-	-
S. robusta	-	-	-	Jan. (2) Dec. (18)	-	-	-	-
POLYCHAETE LARVAE	Feb. (8) Apr. (27) May (150) Jun. (3) Jul. (13) Aug. (71)	Jan. (5) May (14) Aug. (164) Dec. (30)	Apr. (4) Jul. (16) Sept. (8)	Jan. (10) Mar. (10) Jun. (190) Jul. (40) Sept. (10)	Mar. (13) Apr. (1053) May (98) Oct. (23)	Jan. (4) May (119)	Apr. (8) May (101) Oct. (171)	Jan. (411) Feb. (32) Apr. (53) Dec. (41)

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Karapuzha	Mahe
CIRREPEDE LARVAE	Jan. (3) Feb. (54) Mar. (4)	Jan. (34) Feb. (17) Mar. (3)	-	Jan. (40) Feb. (360) May (20) Aug. (10) Nov. (200) Dec. (20)	Jan. (21) Mar. (39) Apr. (1404) May (1078) Jun. (234)	Feb. (32) Mar. (169) Apr. (52) May (64)	Mar. (10) Apr. (333) May (808) Jun. (119)	Jan. (276) Mar. (11) Dec. (4)
DECAPOD LARVAE	*	*	*	*	*	*	*	*
OSTRACODA								
Euconchoecia aculeata	-	Apr. (7)	-	Apr. (12)	-	-	-	-
CUMACEA	-	Jan. (4) Feb. (2) Jul. (11) Aug. (226)	-	May (10) Jun. (15) Jul. (157) Nov. (6)	Apr. (8)	Mar. (38)	Mar. (9)	Mar. (3)
ISOPODA	-	-	-	May (12) Jun. (3) Oct. (4) Dec. (4)	-	-	Mar. (9)	-
MYSIDACEA	Jul. (13)	-	-	Jan. (10) Feb. (10) Mar. (20) Apr. (30)	-	-	-	-
SERGESTIDAE								
Lucifer hanseni	Feb. (15) Mar. (3) Apr. (301) May (375) Oct. (126)	*	Jan. (14) Feb. (8) Apr. (13) Sept. (12)	*	*	*	*	*

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Lucifer typus	-	-	-	*	-	-	-	-
COPEPODA								
Canthocalanus pauper	-	-	-	Feb.(3) Mar.(8)	-	-	-	-
Undinula vulgaris	-	-	-	Jan.(10)	-	-	-	-
Eucalanus monachus	-	Apr. (20)	-	Jan.(7) Apr.(13)	-	-	-	-
Eucalanus attenuatus	-	Aug. (20)	-	-	-	-	-	-
Paracalanus aculeatus	Mar.(200)	*	Apr.(2)	*	*	*	Dec.(149)	Nov.(8) Dec.(4)
Paracalanus crassirostris	-	-	-	*	-	-	-	-
Acrocalanus similis	Apr.(1110) May (250)	*	Apr.(8)	*	*	*	Dec.(587)	*
Acrocalanus gibber	Dec.(2)	Dec.(130)	-	Apr.(112)	-	-	Dec.(110)	Mar.(6)
Centropages alcocki	Mar.(329) Jul.(13)	*	Apr.(3)	*	*	Jan.(15) Nov.(183)	*	Apr.(691) Jan.(12)

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Centropages furcatus	-	Mar.(4) Dec.(33)	-	Jan.(16) Dec.(14)	Jan.(5)	Jan.(15)	Apr.(83)	-
C. trispinosus	-	Jan.(4) Mar.(2) May(14) Nov.(17)	-	Jan.(12) Dec.(22)	-	-	-	-
C. tenuiremis	-	Aug.(20)	-	Mar.(63)	-	-	Sept.(9)	-
Heliodiaptomus cinctus	Feb.(23)	-	Jan.(3) May(2) Aug.(6) Sept.(11) Oct.(342) Dec.(4)	Jul.(750) Aug.(60)	-	-	-	-
Allodiaptomus mirabilipes	Feb.(54)	-	Jan.(3) May(2) Aug.(10) Sept.(15) Oct.(552) Dec.(13)	Jul.(68)	-	-	-	-
Archidiaptomus aroorus	-	-	Dec.(2)	Oct.(16)	-	-	-	-
Pseudodiaptomus annandalei	*	*	Jan.(1) Aug.(8)	*	Mar.(26) May(137)	Jun.(69)	Jun.(795)	Mar.(548) Nov.(8) Dec.(4)

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Pseudodiaptomus binghami malayalus	Jan.(44) Mar.(2) Jul.(13) Dec.(25)	-	Feb.(214) Mar.(12) Aug.(12) Sept.(4)	Aug.(18)	Jun.(213) Oct.(11)	-	-	-
P. jonesi	Mar.(1) Dec.(19)	Jan.(2) Mar.(1)	-	*	Feb.(4)	Feb.(44) Dec.(20)	Feb.(260)	Jan.(69) Mar.(318)
P. aurivillii	Apr.(178) Jun.(10) Jul.(63)	Mar.(2) Apr.(247) Aug.(123) Sept.(6)	Apr.(4)	May(40)	Apr.(1228) May(39) Dec.(55)	Jan.(7) Feb.(48) Mar.(50) Apr.(765) May(64) Dec.(145)	Jan.(65) Feb.(109) Mar.(5) May(606) Sept.(9)	Feb.(27) Apr.(32)
P. mertoni	-	Mar.(8) May(14)	-	Jun.(75)	Apr.(702)	Mar.(215)	Mar.(75) Apr.(101) May(28)	Jan.(137) Mar.(4) Apr.(425)
P. serricaudatus	Jul.(25) Dec.(6)	*	Apr.(7)	*	*	Jan.(79) Nov.(411) Dec.(12)	*	Jan.(69) Feb.(48) Apr.(479) Nov.(16)
P. tollingerae	-	-	-	Sept.(5)	-	-	-	-
Temora turbinata	-	Mar.(2) Jul.(5) Sept.(1) Dec.(22)	-	Jan.(28) Nov.(5)	-	-	Nov.(3)	-
T. stylifera	Mar.(2) Apr.(55)	-	-	Jan.(38)	-	-	Mar.(15)	-

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Lucicutia flavicornis	-	Aug. (20)	-	-	-	-	-	-
Candacia bradyi	-	-	-	Apr.(3)	-	-	-	-
Calanopia elliptica	-	-	-	Jan.(6) Feb.(18) Mar.(25)	-	-	-	-
Labidocera pectinata	Jul.(12) Dec.(1)	*	-	*	*	*	*	*
L. acuta	-	-	-	May(30)	-	Jan.(15)	-	-
Acartia centrura	*	*	Feb.(73) Apr.(34)	*	*	*	*	*
A. spinicauda	*	*	Apr.(23)	*	*	*	*	*
A. erythraea	Mar.(12) Dec.(4)	Feb.(12) Mar.(61)	-	Apr.(740) Dec.(670)	Mar.(6) Apr.(1404)	-	-	-
A. bilobata	Mar.(1800)	*	Feb.(94) Apr.(19)	*	*	*	*	Apr.(1489)
A. southwelli	-	-	-	*	-	-	-	Nov.(32)
A. pacifica	Dec.(4)	-	-	Apr.(16)	-	-	-	-

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Acartia plumosa	*	Oct.(300) Nov.(128)	Feb.(107) Mar.(7) May(10) Aug.(42)	*	Nov.(10)	-	*	Dec.(22)
A. pacifica	Apr.(822) May(425)	Mar.(4) Aug.(390)	Apr.(2)	*	-	Jan.(7)	Dec.(207)	Nov.(4)
Acartiella keralensis	*	Oct.(65)	Jan.(2) Mar.(3) May(12) Aug.(15)	*	Jun.(850)	-	*	-
A. gravelyi	*	-	Jan.(6) Feb.(133) Mar.(3) May(6) Aug.(30)	*	Jun.(745) Oct.(280)	-	*	-
Tortanus gracilis	Dec.(2)	-	-	-	-	-	-	-
Euterpina acutifrons	Mar.(2)	Jan.(3) Nov.(6) Dec.(52)	-	May(40)	-	-	-	-
Nitocra spinipes	Feb.(31)	Jan.(1) Feb.(19)	Feb.(12)	Jan.(12) Jun.(67)	-	-	-	-
Macrosetella gracilis	-	-	-	Mar.(6)	-	-	-	Apr.(8)

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Oithona hebes	-	Jan.(6) Feb.(52) Apr.(27) Nov.(87)	-	Jan.(8) Feb.(16) Apr.(43) Sept.(14) Nov.(5)	Mar.(6) Apr.(970) May(130)	Jan.(19)	May(606)	Jan.(4)
O. nana	Apr.(110)	Feb.(9) Sept.(26) Nov.(21) Dec.(43)	Apr.(9)	Feb.(12) Apr.(24) Jan.(9) Aug.(7) Nov.(18)	Apr.(610) May(120) Oct.(11) Dec.(27)	Mar.(2354) Jun.(61) Oct.(8)	Jun.(448) Sept.(9) Oct.(113) Dec.(132)	Dec.(2)
O. rigida	-	-	-	Feb.(7) Apr.(32)	-	-	-	-
O. plumifera	-	Mar.(2)	-	-	-	-	-	-
O. brevicornis	-	-	-	Feb.(84) Jan.(10) Dec.(235)	-	-	-	-
Corycaeus sp.	Mar.(2)	Mar.(6) Nov.(8) Dec.(57)	-	Jan.(136) Feb.(4) Mar.(18)	-	-	-	-
Sapphirina sp.	-	-	-	Apr.(14)	-	-	-	-
AMPHIPODA	*	*	May(5) Aug.(5)	*	*	*	*	*

Table 7 (Contd.)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
GASTROPODA	Dec. (4)	Feb. (12) Mar. (3) Jun. (32)	Aug. (8)	Apr. (15) May (10) Jun. (180) Aug. (11670) Sept. (2140) Oct. (120)	-	Mar. (104)	Jan. (32) Oct. (34)	Mar. (32) Apr. (319) Jul. (70)
BIVALVES	Feb. (100) Mar. (5) Jun. (3) Aug. (14) Dec. (2)	Feb. (68) Mar. (17) Jun. (32) Dec. (28)	Jul. (20) Aug. (20) Sept. (4)	Apr. (20) Aug. (4010)	Dec. (27)	Apr. (61) May (144) Nov. (1530)	Apr. (333) May (505) Jun. (179) Oct. (285)	Jan. (685) Feb. (16) Apr. (159) Jul. (50) Nov. (71) Dec. (18)
THALIACEA								
Thalia democratica	-	-	-	+	-	-	-	-
APPENDICULARIA								
Oikopleura sp.	-	+	-	+	+	+	+	+
FISH EGGS	+	+	-	+	+	+	+	+
FISH LARVAE	+	+	+	+	+	+	+	+

Table 8 : Occurrence of species of Cladocera (Nos./$10m^3$) in different estuaries of Kerala in 1978.

(Months of occurrence are given in parenthesis)

Species	Veli	Neendakara	Thottappilly	Cochin	Kallai	Beypore	Korapuzha	Mahe
Evadne tergestina	10(Dec.)	10(Feb.) 70(Aug.) 10(Sept.) 320(Dec.)	30(Aug.)	20(Jun.) 1700(Aug.) 50(Sept.) 3(Oct.) 276(Nov.) 2(Dec.)	-	920(Aug.) 110(Oct.)	30(Jun.) 60(Aug.)	20(Nov.)
Penilia avirostris	-	350(Aug.) 70(Sept.)	-	2(Jun.) 29(Jul.) 1788(Aug.) 12(Oct.) 75(Nov.)	-	700(Aug.) 20(Oct.)	110(Aug.)	10(Nov.)
Podon polyphemoides	10(Jan.)	-	30(Oct.)	-	10(Oct.)	20(Oct.)	-	-

Table 9 : Number of species observed, evenness index ($E = \frac{e^{H} - 1}{S-1}$) and diversity index ($D = \frac{S - 1}{\log^{e} N}$) in the estuaries studied.

Months	Veli			Thottappilly			Neendakara			Cochin		
	No. of species	E	D	No. of species	E	D	No. of species	E	D	No. of species	E	D
January	9	0.49	1.8	8	0.99	3.4	26	0.62	4.7	23	0.21	3.6
February	18	0.71	4.1	12	0.61	2.8	19	0.72	4.4	22	0.22	3.1
March	15	0.92	4.9	8	0.99	3.4	31	0.38	7.0	14	0.11	2.3
April	18	0.47	2.5	17	0.91	5.2	22	0.35	3.9	22	0.11	2.5
May	16	0.64	2.2	9	0.99	3.6	18	0.62	3.8	13	0.13	2.3
June	6	0.69	1.6	-	-	-	17	0.53	3.2	22	0.44	3.9
July	10	0.18	1.9	3	0.98	1.2	17	0.71	3.9	4	0.99	2.2
August	10	0.71	2.9	15	0.86	4.3	21	0.64	3.6	17	0.19	2.6
September	-	-	-	10	0.96	3.7	21	0.92	6.1	9	0.94	3.3
October	9	0.70	1.4	9	0.29	1.7	21	0.39	4.0	18	0.86	5.3
November	6	0.65	1.2	-	-	-	25	0.45	4.8	23	0.69	4.9
December	21	0.71	5.4	11	0.99	4.2	25	0.45	4.2	27	0.09	4.3

Table 9 (Contd.)

Months	Korapuzha			Kallai			Beypore			Mahe		
	No. of species	E	D	No. of species	E	D	No. of species	E	D	No. of species	E	D
January	18	0.32	3.1	20	0.50	3.6	29	0.47	5.2	24	0.62	3.6
February	16	0.67	2.8	21	0.59	4.8	11	0.47	2.1	16	0.56	3.5
March	17	0.28	2.8	22	0.62	4.7	25	0.27	3.9	21	0.34	4.0
April	16	0.43	2.1	24	0.60	2.9	20	0.25	2.7	24	0.68	3.3
May	20	0.67	2.6	20	0.64	2.6	17	0.33	2.4	4	0.99	2.2
June	14	0.39	1.9	10	0.71	1.6	11	0.65	2.0	12	0.22	2.5
July	3	0.86	1.0	-	-	-	-	-	-	4	0.89	1.0
August	-	-	-	3	0.99	1.8	-	-	-	-	-	-
September	14	0.74	3.8	2	0.89	0.56	3	0.91	1.4	7	0.93	2.7
October	14	0.44	2.1	7	0.19	1.4	14	0.65	4.1	3	0.91	1.4
November	3	0.99	1.8	5	0.39	1.5	12	0.44	1.5	21	0.35	3.9
December	13	0.65	2.0	15	0.26	2.5	25	0.22	3.7	20	0.78	5.2

[illegible]
different estuaries – 1978.
(a, p < 0.1; b, p < 0.05; c, p < 0.02; d, p < 0.01; e, p < 0.001) **VELI**

	Hydromedusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapoda	Caridae	Sergestidae	Zoea	Polychaeta	Appendicularia	Fish eggs	Fish larvae	Cirripede larvae
Hydromedusae															
Ctenophora	0.00														
Chaetognatha	0.93^{e}	0.00													
Cladocera	-0.17	0.00	-0.20												
Copepoda	0.78^{e}	0.00	0.90^{e}	-0.23											
Amphipoda	-0.18	0.00	-0.21	-0.16	-0.28										
Decapoda	0.15	0.00	0.14	-0.12	0.07	0.72^{e}									
Caridae	0.58^{d}	0.00	0.61^{d}	0.40	0.61^{d}	-0.33	-0.06								
Sergestidae	0.85^{e}	0.00	0.94^{e}	-0.23	0.98^{e}	-0.27	0.09	0.62^{e}							
Zoea	0.93^{e}	0.00	0.96^{e}	-0.23	0.93^{e}	-0.25	0.11	0.62^{e}	0.97^{e}						
Polychaeta	0.89^{e}	0.00	0.82^{e}	-0.21	0.60^{e}	0.11	0.16	0.43^{e}	0.76^{d}	0.79^{e}					
Appendicularia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
Fish eggs	0.92^{e}	0.00	0.98^{e}	-0.21	0.89^{e}	-0.21	0.11	0.60^{e}	0.93^{e}	0.94^{e}	0.78^{e}	0.00			
Fish larvae	0.89^{e}	0.00	0.91^{e}	-0.14	0.81^{e}	-0.19	0.16	0.95^{e}	0.83^{e}	0.86^{e}	0.78^{e}	0.00	0.88^{e}		
Cirripede larvae	-0.12	0.00	-0.14	0.55^{e}	-0.16	-0.16	-0.14	-0.20	-0.14	-0.15	0.01	0.00	-0.13	-0.15	

Table 19 (Contd.) [illegible]

	Hydromedusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapoda	Caridea	Sergestidae	Zoea	Polychaeta	Appendicularia	Fish eggs	Fish larva	Cirripede larva
Hydromedusae															
Ctenophora	0.28														
Chaetognatha	-0.02	0.63^{a}													
Cladocera	-0.20	-0.18	0.51^{b}												
Copepoda	0.33^{b}	-0.14	0.01	0.04											
Amphipoda	-0.43^{a}	-0.21	0.54^{b}	0.64^{a}	0.05										
Decapoda	0.28	0.12	0.13	-0.08	-0.01	-0.02									
Caridea	0.31	-0.25	-0.41^{a}	0.00	0.49^{b}	-0.43^{a}	0.07								
Sergestidae	0.33	0.05	0.01	-0.11	0.01	-0.14	0.98^{a}	0.19							
Zoea	0.18	0.29	0.01	0.27	-0.38	-0.32	0.14	0.32	0.19						
Polychaeta	-0.24	-0.09	0.68^{a}	0.71^{a}	0.25	0.92^{a}	-0.01	-0.35	-0.13	-0.34					
Appendicularia	0.01	-0.11	-0.21	-0.19	-0.01	-0.01	-0.16	-0.23	-0.20	-0.11	-0.01				
Fish eggs	-0.14	-0.15	-0.30	-0.26	0.07	-0.03	-0.26	0.22	-0.18	-0.12	-0.21	0.12			
Fish larva	-0.10	-0.19	0.12	0.19	0.35	0.51^{b}	-0.02	0.04	-0.04	-0.21	0.41^{a}	0.28	0.65^{a}		
Cirripede larva	-0.35	-0.17	-0.29	-0.18	-0.39	0.04	-0.17	-0.20	-0.16	0.09	-0.20	0.18	0.15	0.19	

Table 10 (Contd.)

	Hydromedusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapoda	Caridea	Sergestidae	Zoea	Polychaeta	Appendicularia	Fish eggs	Fish larva	Cirripede larva
Hydromedusae															
Ctenophora	0.00														
Chaetognatha	0.00	0.00													
Cladocera	0.00	0.00	0.00												
Copepoda	-0.89*	0.00	0.00	0.17											
Amphipoda	0.00	0.00	0.00	0.00	0.95*										
Decapoda	0.00	0.00	0.00	0.00	0.00	0.00									
Caridea	-0.95*	0.00	0.00	0.95*	0.63*	0.98*	0.00								
Sergestidae	0.95*	0.00	0.00	-0.95*	0.40	0.00	0.00	0.49*							
Zoea	-0.95*	0.00	0.00	0.00	0.95*	0.00	0.00	0.93*	-0.95*						
Polychaeta	0.00	0.00	0.00	0.00	0.95*	0.00	0.00	-0.68*	0.00	0.00					
Appendicularia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
Fish eggs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Fish larvae	-0.95*	0.00	0.00	0.00	0.58*	0.00	0.00	0.84*	0.43*	0.95*	0.00	0.00	0.00		
Cirripede larva	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table 10 (Contd.) [illegible]

	Hydromedusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapoda	Caridea	Sergestida	Zoea	Polychaeta	Appendicularia	Fish eggs	Fish larvae	Cirripede larva
Hydromedusae															
Ctenophora	-0.61[a]														
Chaetognatha	0.65[a]	0.64													
Cladocera	-0.30	-0.47[b]	-0.26												
Copepoda	0.45[b]	0.61[a]	0.70[a]	-0.18											
Amphipoda	-0.25	0.14	-0.01	0.21	0.51[b]										
Decapoda	0.22	0.25	0.65[a]	-0.23	0.75[a]	0.30									
Caridea	-0.04	-0.02	-0.03	-0.17	0.22	0.53[b]	0.09								
Sergestida	0.48[b]	0.58[a]	0.34	-0.39	0.78[a]	0.34	0.61[a]	0.30							
Zoea	0.84	0.43[a]	0.72[a]	-0.14	0.62[a]	0.02	0.50[b]	-0.14	-0.01						
Polychaeta	0.26	0.18	-0.32	-0.12	0.13	0.32	-0.48[b]	0.17	0.14	-0.33					
Appendicularia	-0.04	0.03	0.37	0.03	0.17	-0.10	0.35	-0.50[b]	-0.21	0.68[a]	-0.12				
Fish eggs	0.26	0.38	0.77[a]	0.18	0.37	-0.07	0.47[b]	-0.43[a]	0.31	0.64[a]	-0.44[a]	0.52[b]			
Fish larva	0.04	0.09	0.05	-0.21	0.50[b]	0.47[b]	0.31	0.90[a]	0.54[b]	-0.02	0.22	-0.29	-0.36		
Cirripede larva	-0.09	0.06	0.19	0.07	-0.03	-0.05	0.19	-0.45[b]	-0.41[a]	0.57[a]	-0.04	0.62[a]	0.49[b]	-0.45[b]	

Table 10 (Contd.) [illegible]

	Hydromedusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapoda	Caridea	Sergestida	Zoea	Polychaeta	Appendicularia	Fish eggs	Fish larva	Cirripede larva
Hydromedusae															
Ctenophora	0.91														
Chaetognatha	0.19	-0.13													
Cladocera	0.00	0.00	0.00												
Copepoda	0.93	0.98	-0.08	0.00											
Amphipoda	-0.15	-0.14	-0.07	0.00	-0.11										
Decapoda	0.32	0.59	-0.14	0.00	0.50	-0.11									
Caridea	0.93	0.98	-0.11	0.00	0.98	-0.15	0.41								
Sergestida	0.84	0.92	0.09	0.00	0.89	-0.16	0.75	0.88							
Zoea	0.61	0.82	-0.13	0.00	0.75	-0.15	0.94	0.68	0.92						
Polychaeta	0.94	0.90	-0.09	0.00	0.94	-0.10	0.21	0.98	0.72	0.51					
Appendicularia	0.88	0.84	-0.11	0.00	0.89	0.06	0.11	0.92	0.64	0.41	0.97				
Fish eggs	0.35	0.62	-0.15	0.00	0.53	-0.12	0.99	0.43	0.78	0.93	0.25	0.14			
Fish larva	0.58	0.78	-0.18	0.00	0.75	-0.07	0.88	0.71	0.79	0.88	0.58	0.49	0.83		
Cirripede larva	0.84	0.97	-0.15	0.00	0.93	-0.14	0.73	0.91	0.94	0.91	0.81	0.74	0.78	0.87[c]	

	Hydromedusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapoda	Caridea	Zoea	Sergestidae	Polychaeta	Appendicularia	Fish eggs	Fish larvae	Cirripede larvae
Hydromedusae															
Ctenophora	0.69[a]														
Chaetognatha	-0.15	0.02													
Cladocera	-0.06	-0.06	0.84[a]												
Copepoda	0.53[a]	0.38	-0.26	0.12											
Amphipoda	0.98[c]	0.93[a]	0.10	0.00	0.17										
Decapoda	0.02	0.09	-0.09	-0.03	0.60[a]	-0.11									
Caridea	0.82[a]	0.55[a]	0.32	0.49[b]	0.44[a]	0.52[b]	0.04								
Zoea	0.02	0.09	-0.15	-0.09	0.60[a]	-0.09	0.98[a]	0.01							
Sergestidae	0.01	-0.12	-0.03	-0.12	-0.07	-0.14	-0.08	0.05	-0.09						
Polychaeta	0.01	-0.12	-0.04	-0.12	-0.07	-0.14	-0.07	0.05	-0.09	0.99[a]					
Appendicularia	0.25	0.45[a]	-0.09	-0.12	0.06	0.56[c]	0.04	0.16	0.19	-0.20	-0.20				
Fish eggs	0.00	0.40	0.06	-0.14	0.07	0.45[a]	0.29	-0.02	0.42[a]	-0.01	-0.01	0.89[a]			
Fish larvae	0.23	0.27	-0.03	-0.14	0.07	0.27	-0.16	0.25	-0.17	0.89[a]	0.89[a]	-0.01	0.12		
Cirripede larvae	-0.11	-0.15	-0.17	-0.05	0.44[a]	-0.15	-0.10	-0.11	-0.10	-0.09	-0.09	-0.01	-0.21	-0.02	

Table 10 (Contd.) [illegible]

	Hydromedusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapoda	Caridea	Sergestidae	Zoea	Polychaeta	Appendicularia	Fish eggs	Fish larva	Cirripede larva
Hydromedusae															
Ctenophora	0.01														
Chaetognatha	0.51[b]	0.27													
Cladocera	-0.15	0.98[a]	0.17												
Copepoda	0.29	0.51[b]	0.61[d]	0.44[a]											
Amphipoda	-0.14	-0.16	-0.22	-0.14	-0.15										
Decapoda	0.63[d]	0.02	0.76[a]	-0.11	0.68[d]	-0.17									
Caridea	0.13	0.38	0.21	0.38	0.09	-0.01	-0.27								
Sergestidae	0.48[b]	0.83[a]	0.96[a]	0.72[a]	0.72[d]	-0.24	0.44[a]	0.37							
Zoea	0.55[b]	0.71[d]	0.33	0.63[d]	0.49[b]	-0.20	0.18	0.66[d]	0.83[a]						
Polychaeta	0.46[a]	0.01	0.48[b]	-0.08	0.40	0.57[a]	0.67[d]	-0.23	0.22	0.04					
Appendicularia	0.51[b]	0.61[d]	0.86[e]	0.50[b]	0.77[a]	-0.22	0.76[a]	0.12	0.82[a]	0.53[b]	0.53[b]				
Fish eggs	0.27	0.49[b]	0.49[b]	0.41[a]	0.92[a]	-0.28	0.66[d]	-0.12	0.70[d]	0.42[a]	0.28	0.68[a]			
Fish larvae	0.19	-0.25	0.56[a]	-0.27	0.39	0.31	0.41[a]	0.31	0.00	-0.01	0.47[a]	0.27	0.12		
Cirripede larva	0.61[d]	0.42[a]	0.82[a]	0.29	0.88[a]	-0.22	0.91[a]	-0.09	0.72[a]	0.43[a]	0.62[d]	0.94[a]	0.76[a]	0.28	

Table 10 (Contd.) [illegible]

	Hydromedusae	Ctenophora	Chaetognatha	Cladocera	Copepoda	Amphipoda	Decapoda	Caridea	Sergestidae	Zoea	Polychaeta	Appendicularia	Fish eggs	Fish larvae	Cirripede larva
Hydromedusae															
Ctenophora	0.83														
Chaetognatha	0.82	0.97													
Cladocera	-0.08	-0.13	0.08												
Copepoda	0.83	0.93	0.97	0.17											
Amphipoda	0.09	0.14	0.13	0.40	0.13										
Decapoda	0.82	0.98	0.97	-0.14	0.92	0.14									
Caridea	0.71	0.82	0.91	0.36	0.98	0.08	0.82								
Sergestidae	0.56	0.60	0.73	0.61	0.83	0.04	0.58	0.94							
Zoea	0.41	0.42	0.60	0.61	0.86	0.03	0.46	0.80	0.87						
Polychaeta	0.06	0.00	0.19	0.86	0.34	-0.03	0.00	0.55	0.79	0.81					
Appendicularia	0.71	0.78	0.88	0.44	0.98	0.06	0.75	0.98	0.96	0.82	0.63				
Fish eggs	0.81	0.98	0.97	-0.15	0.91	0.13	0.99	0.81	0.57	0.47	-0.003	0.78			
Fish larvae	0.44	0.39	0.37	0.40	0.39	0.85	0.35	0.32	0.29	0.26	0.11	0.34	0.34		
Cirripede larva	-0.02	-0.10	0.09	0.87	0.24	-0.07	-0.11	0.47	0.73	0.72	0.98	0.53	-0.11	0.03	

Table 11 : Correlation matrix for the common copepod species in the different estuaries - 1978. **VELI**

(a, p < 0.1; b, p < 0.05; c, p < 0.02; d, p < 0.01; e, p < 0.001)

	Acartia centrura	A. spinicauda	A. bilobata	A. erythraea	A. pacifica	A. plumosa	A. keralensis	A. sewelli	Centropages alcocki	Pseudodiaptomus serricaudatus	P. annandalei	P. aurivilli	Acrocalanus similis
Acartia centrura													
A. spinicauda	0.97												
A. bilobata	0.99	0.00											
A. erythraea	0.99	0.00	0.00										
A. pacifica	-0.98	0.99 e	0.00	0.00									
A. plumosa	0.00	0.00	0.00	0.00	0.00								
A. keralensis	0.00	0.00	0.00	0.00	0.00	0.99							
A. sewelli	0.00	0.00	0.00	0.00	0.00	0.87	0.79						
Centropages alcocki	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
Pseudodiaptomus serricaudatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
P. annandalei	0.98	0.00	0.99	0.00	0.00	0.99	0.99	0.99	0.00	0.99			
P. aurivilli	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00		
Acrocalanus similis	0.95	0.99	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.99	0.00	

Table 11 (Contd.) NEENDAKARA

	Acartia centrura	A. spinicauda	A. bilobata	A. erythraea	A. pacifica	A. plumosa	A. keralensis	A. gravelyi	Centropages alcocki	Pseudodiaptomus serricaudatus	P. annandalei	P. aurivilli	Acrocalanus similis
Acartia centrura													
A. spinicauda	-0.13												
A. bilobata	0.41	0.15											
A. erythraea	0.73	-0.25	-0.21										
A. pacifica	-0.31	0.38	-0.20	-0.10									
A. plumosa	0.28	-0.32	0.78	-0.14	-0.13								
A. keralensis	0.14	-0.24	0.63	-0.10	-0.10	0.91							
A. gravelyi	-0.27	-0.13	-0.18	-0.10	-0.10	-0.12	0.09						
Centropages alcocki	-0.24	0.65	0.09	-0.27	0.81	-0.02	-0.04	0.24					
Pseudodiaptomus serricaudatus	0.78	0.07	0.03	0.90	0.01	-0.12	-0.12	-0.14	0.03				
P. annandalei	0.48	0.21	0.82	-0.18	-0.17	0.42	0.12	-0.15	0.13	0.10			
P. aurivilli	-0.30	0.23	-0.26	-0.15	0.36	-0.17	-0.13	-0.10	0.15	-0.13	-0.22		
Acrocalanus similis	0.74	-0.36	-0.09	0.94	-0.16	0.02	0.03	-0.12	-0.32	0.88	-0.11	-0.12	

	Acartia centrura	A. spinicauda	A. bilobata	A. erythraea	A. pacifica	A. plumosa	A. keralensis	A. sewelli	Centropages alcocki	Pseudodiaptomus serricaudatus	P. annandalei	P. aurivilli	P. binghami	Acrocalanus similis	Allodiaptomus mirabilipes	Heliodiaptomus cinctus
Acartia centrura																
A. spinicauda	0.00															
A. bilobata	0.95	0.00														
A. erythraea	0.00	0.00	0.00													
A. pacifica	0.00	0.00	0.00	0.00												
A. plumosa	0.00	0.00	0.00	0.00	0.00											
A. keralensis	0.00	0.00	0.00	0.00	0.00	0.74										
A. sewelli	0.00	0.00	0.00	0.00	0.00	0.95	0.68									
Centropages alcocki	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00								
Pseudodiaptomus serricaudatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00							
P. annandalei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
P. aurivilli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
P. binghami	0.00	0.00	0.00	0.00	0.00	0.74	-0.95	0.78	0.00	0.00	0.00	0.00				
Acrocalanus similis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Allodiaptomus mirabilipes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	-0.95	0.00		
Heliodiaptomus cinctus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	-0.95	0.00	0.95	

Table 11 (Contd.) COCHIN

	Acartia centrura	A. spinicauda	A. bilobata	A. erythraea	A. pacifica	A. plumosa	A. keralensis	A. sewelli	Centropages alcocki	Pseudodiaptomus serricaudatus	P. annandalei	P. aurivilli	Acrocalanus similis
Acartia centrura													
A. spinicauda	0.45[a]												
A. bilobata	0.41	0.64[a]											
A. erythraea	0.28	0.59[a]	0.94[a]										
A. pacifica	0.30	0.69[a]	0.98[a]	0.93[a]									
A. plumosa	0.19	-0.20	-0.12	-0.16	-0.05								
A. keralensis	-0.23	-0.21	-0.10	-0.13	-0.15	0.98[a]							
A. sewelli	-0.24	-0.23	-0.12	-0.13	-0.14	0.14	0.13						
Centropages alcocki	0.15	0.15	0.57[b]	-0.13	0.19	-0.11	-0.10	-0.12					
Pseudodiaptomus serricaudatus	0.88[a]	0.75[a]	0.79[a]	0.49[a]	0.18	-0.23	-0.10	-0.19	0.26				
P. annandalei	0.43	0.67[a]	-0.65[a]	-0.14	-0.04	0.65[a]	0.74[a]	-0.12	-0.03	0.47[a]			
P. aurivilli	0.89[a]	0.98[a]	0.76[a]	0.08	0.87[a]	0.00	-0.13	-0.13	0.46[a]	0.80[a]	-0.27		
Acrocalanus similis	0.58[b]	0.21	0.58[b]	0.95[a]	0.98[a]	-0.12	-0.11	0.11	0.09	0.80[a]	0.09	0.31[b]	

Table 11 (Contd.) KALLAI

	Acartia centrura	A. spinicauda	A. bilobata	A. erythraea	A. pacifica	A. plumosa	A. keralensis	A. sewelli	Centropages alcocki	Pseudodiaptomus serricaudatus	P. annandalei	P. aurivillii	Acrocalanus similis
Acartia centrura													
A. spinicauda	0.98												
A. bilobata	0.95	0.93											
A. erythraea	0.88	0.87	0.87										
A. pacifica	0.00	0.00	0.00	0.00									
A. plumosa	-0.16	-0.13	-0.12	-0.09	0.00								
A. keralensis	-0.16	-0.13	-0.12	-0.09	0.00	-0.09							
A. sewelli	-0.16	-0.13	-0.12	-0.09	0.00	-0.09	0.99						
Centropages alcocki	0.62	0.74	0.74	0.33	0.00	-0.12	-0.12	-0.12					
Pseudodiaptomus serricaudatus	0.29	0.36	0.35	-0.11	0.00	-0.11	-0.11	-0.11	0.88				
P. annandalei	0.24	0.37	0.37	-0.11	0.00	-0.10	-0.10	-0.10	0.89	0.95			
P. aurivillii	0.90	0.89	0.89	0.95	0.00	-0.09	-0.09	-0.09	0.36	-0.08	-0.07		
Acrocalanus similis	0.90	0.87	0.87	0.95	0.00	-0.09	-0.09	-0.09	0.32	-0.11	-0.11	0.99	

Table 11 (Contd.) BEYPORE

	Acartia centrura	A. spinicauda	A. bilobata	A. erythraea	A. pacifica	A. plumosa	A. bengalensis	A. sewelli	Centropages alcocki	Pseudodiaptomus serricaudatus	P. annandalei	P. aurivilli	Acrocalanus similis
Acartia centrura													
A. spinicauda	0.98												
A. bilobata	-0.12	-0.07											
A. erythraea	0.00	0.00	0.00										
A. pacifica	-0.06	-0.07	-0.15	0.00									
A. plumosa	0.00	0.00	0.00	0.00	0.00								
A. bengalensis	0.00	0.00	0.00	0.00	0.00	0.00							
A. sewelli	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
Centropages alcocki	-0.06	-0.07	-0.15	0.00	0.99	0.00	0.00	0.00					
Pseudodiaptomus serricaudatus	0.98	0.99	-0.18	0.00	0.09	0.00	0.00	0.00	0.09				
P. annandalei	-0.08	-0.13	0.31	0.00	-0.09	0.00	0.00	0.00	-0.09	-0.11			
P. aurivilli	-0.12	-0.09	0.12	0.00	-0.12	0.00	0.00	0.00	-0.12	-0.15	-0.12		
Acrocalanus similis	0.99	0.98	-0.13	0.00	-0.01	0.00	0.00	0.00	-0.01	0.99	-0.09	-0.13	

Table 11 (Contd.) [illegible]

	Acartia centrura	A. spinicauda	A. bilobata	A. erythraea	A. pacifica	A. plumosa	A. bengalensis	A. sewelli	Centropages alcocki	Pseudodiaptomus serricaudatus	P. annandalei	P. aurivilli	Acrocalanus similis
Acartia centrura													
A. spinicauda	0.80												
A. bilobata	0.78	0.54											
A. erythraea	0.00	0.00	0.00										
A. pacifica	0.18	-0.13	-0.13	0.00									
A. plumosa	-0.22	-0.14	-0.01	0.00	-0.09								
A. bengalensis	-0.26	-0.16	-0.02	0.00	-0.11	0.99							
A. sewelli	-0.20	-0.13	-0.14	0.00	-0.09	-0.01	0.12						
Centropages alcocki	0.68	0.97	0.40	0.00	-0.11	-0.11	-0.12	-0.10					
Pseudodiaptomus serricaudatus	0.67	0.93	0.24	0.00	-0.11	-0.14	-0.15	-0.13	0.93				
P. annandalei	-0.22	-0.13	0.01	0.00	-0.09	0.99	0.97	-0.09	-0.10	-0.13			
P. aurivilli	0.63	0.98	0.26	0.00	-0.12	-0.13	-0.14	-0.12	0.97	0.98	-0.12		
Acrocalanus similis	0.18	-0.14	-0.15	0.00	0.99	-0.12	-0.12	-0.10	-0.11	-0.10	-0.09	-0.11	

G3420

Table 11 (Contd.) MAHE

	Acartia centrura	A. spinicauda	A. bilobata	A. erythraea	A. pacifica	A. plumosa	A. keralensis	A. sewelli	Centropages alcocki	Pseudodiaptomus serricaudatus	P. annandalei	P. aurivilli	Acrocalanus similis
Acartia centrura													
A. spinicauda	0.85												
A. bilobata	0.88	0.95											
A. erythraea	0.00	0.00	0.00										
A. pacifica	-0.12	0.19	-0.09	0.00									
A. plumosa	-0.12	-0.12	-0.09	0.00	-0.09								
A. keralensis	0.00	0.00	0.00	0.00	0.00	0.00							
A. sewelli	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
Centropages alcocki	0.88	0.95	0.95	0.00	-0.09	-0.09	0.00	0.00					
Pseudodiaptomus serricaudatus	0.95	0.95	0.98	0.00	-0.08	-0.11	0.00	0.00	0.98				
P. annandalei	-0.13	-0.11	-0.11	0.00	0.02	0.02	0.00	0.00	-0.11	-0.14			
P. aurivilli	-0.13	-0.12	-0.09	0.00	-0.09	-0.09	0.00	0.00	-0.09	.0.01	-0.11		
Acrocalanus similis	0.95	0.64	0.68	0.00	-0.13	.0.06	0.00	0.00	0.65	0.78	-0.16	-0.13	

Fig. 1. Map showing the estuaries along the east and west coast of India.

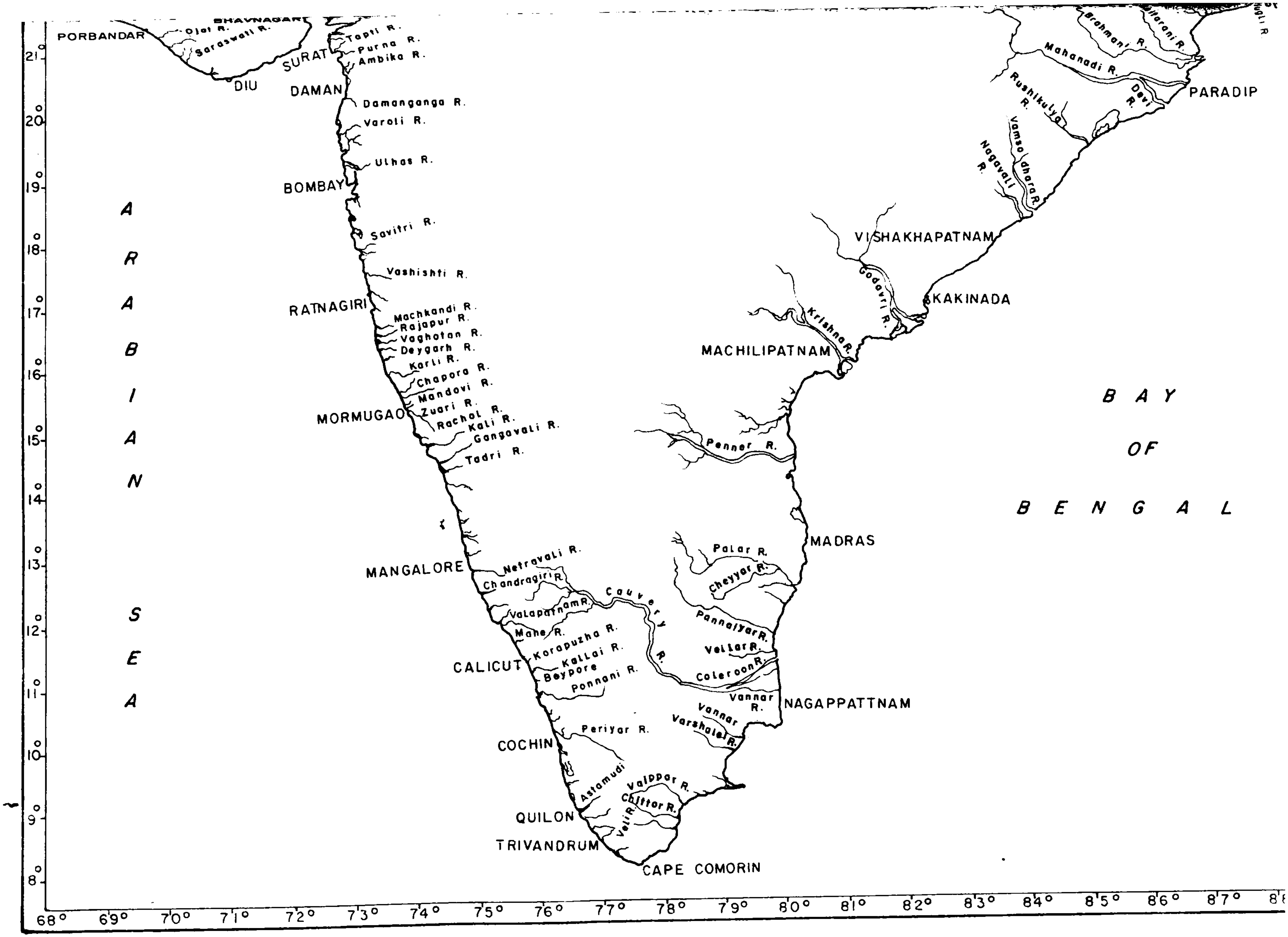

PORBANDAR
BHAVNAGAR
Ojat R.
Saraswati R.
DIU
SURAT
DAMAN
Tapti R.
Purna R.
Ambika R.
Damanganga R.
Varoli R.
Ulhas R.
BOMBAY
Savitri R.
Vashishti R.
RATNAGIRI
Machkandi R.
Rajapur R.
Vaghotan R.
Deygarh R.
Karli R.
Chapora R.
Mandovi R.
Zuari R.
Rachol R.
Kali R.
Gangavali R.
Tadri R.
MORMUGAO
MANGALORE
Netravali R.
Chandragiri R.
Valapatnam R.
Mahe R.
Korapuzha R.
Kallai R.
Beypore
Ponnani R.
CALICUT
Periyar R.
COCHIN
Astamudi
QUILON
TRIVANDRUM
Vali R.
Chittor R.
Valppar R.
CAPE COMORIN
Varshalai R.
Vannar
Vannar R.
NAGAPPATTNAM
Coleroon R.
Vellar R.
Pannaiyar R.
Cauvery R.
Cheyyar R.
Palar R.
MADRAS
Penner R.
MACHILIPATNAM
Krishna R.
Godavri R.
KAKINADA
VISHAKHAPATNAM
Nagavali R.
Vamsa dhara R.
Rushikulya R.
Mahanadi R.
Devi R.
PARADIP
Brahmani R.
Baitarani R.
Hugli R
A R A B I A N
S E A
B A Y
O F
B E N G A L
21° 20° 19° 18° 17° 16° 15° 14° 13° 12° 11° 10° 9° 8°
68° 69° 70° 71° 72° 73° 74° 75° 76° 77° 78° 79° 80° 81° 82° 83° 84° 85° 86° 87°

Fig. 2. Map showing the location of the Stations (indicated by arrows) at the mouth of the estuaries where collections were made.

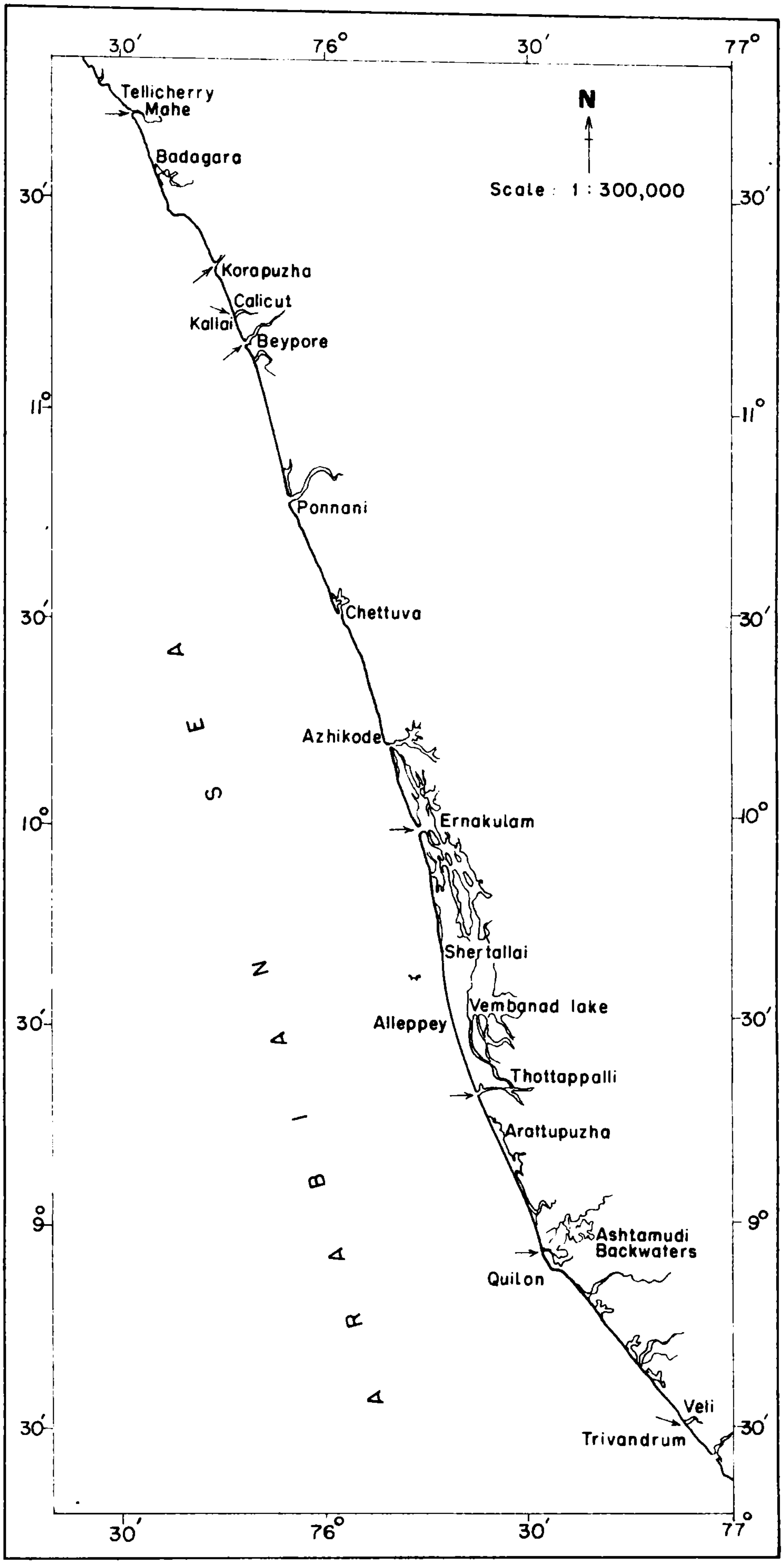

30′
76°
30′
77°
N
Scale : 1 : 300,000
Tellicherry
Mahe
Badagara
Korapuzha
Calicut
Kallai
Beypore
Ponnani
Chettuva
Azhikode
Ernakulam
Shertallai
Vembanad lake
Alleppey
Thottappalli
Arattupuzha
Ashtamudi
Backwaters
Quilon
Veli
Trivandrum
A R A B I A N S E A
30′
11°
30′
10°
30′
9°
30′

Fig. 2

Fig. 3. Map of Cochin backwaters showing 7 Stations.

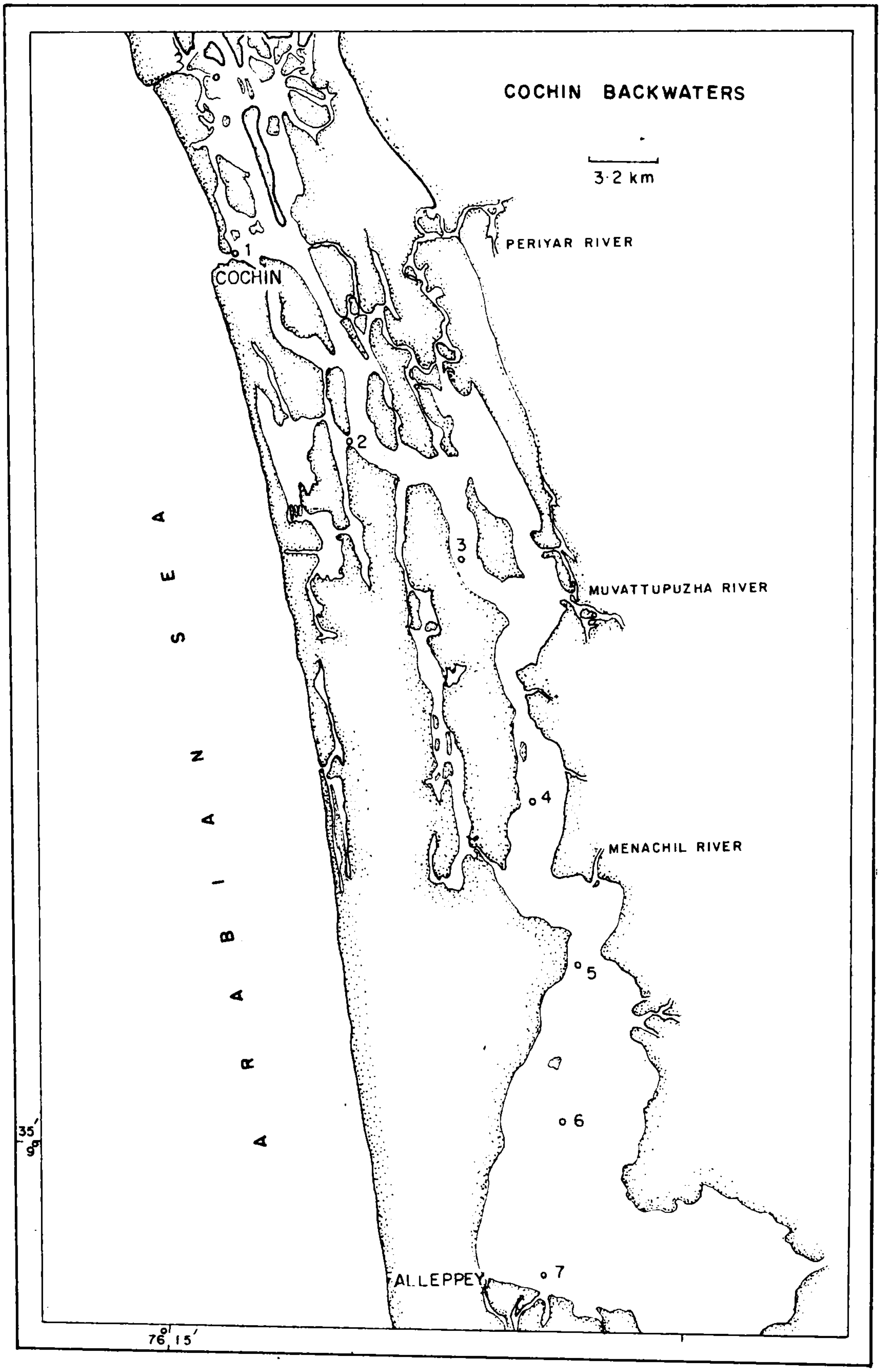
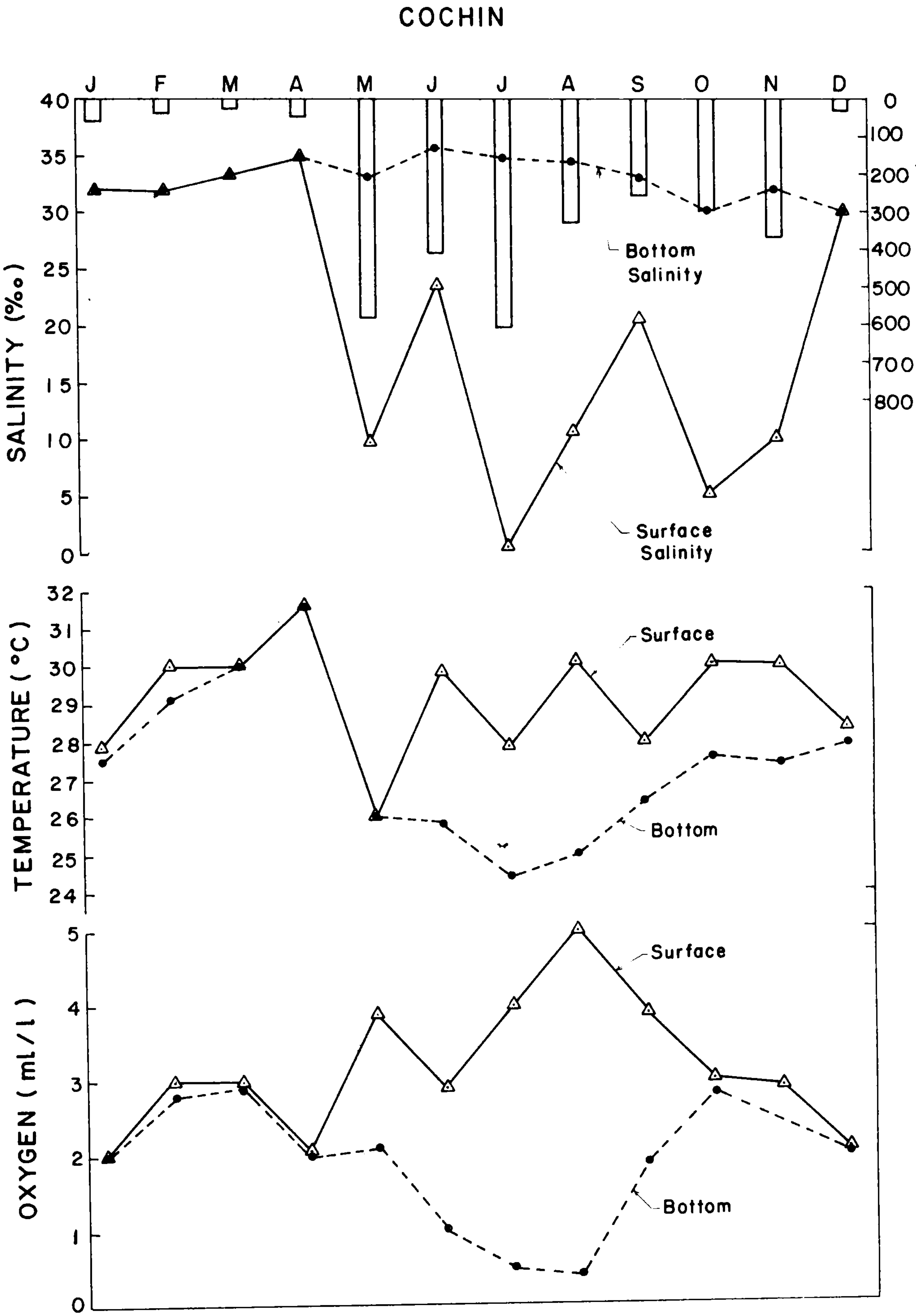

COCHIN BACKWATERS
3·2 km
PERIYAR RIVER
COCHIN
1
2
3
MUVATTUPUZHA RIVER
4
MENACHIL RIVER
5
6
7
ALLEPPEY
ARABIAN SEA
9°35′
76°15′

Fig. 3

Fig. 4 A . Salinity, temperature, oxygen distribution and rainfall at the mouth of Cochin backwaters during 1978.



COCHIN
J F M A M J J A S O N D
SALINITY (‰)
RAINFALL (mm)
0 100 200 300 400 500 600 700 800
40 35 30 25 20 15 10 5 0
Bottom Salinity
Surface Salinity
TEMPERATURE (°C)
32 31 30 29 28 27 26 25 24
Surface
Bottom
OXYGEN (ml/l)
5 4 3 2 1 0
Surface
Bottom

Fig. 4A

Fig. 4 B. Salinity distribution to the upper reaches of Cochin backwaters.

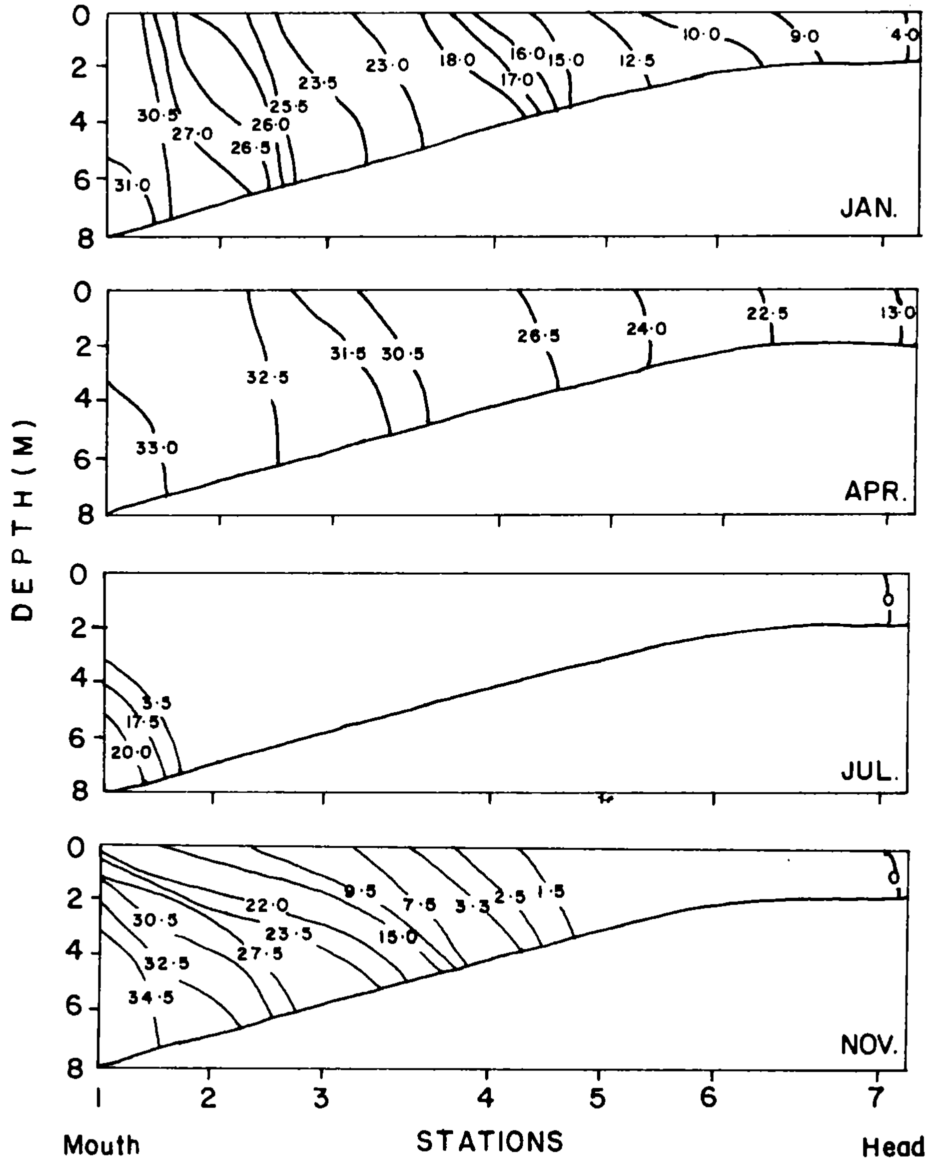

DEPTH (M)
0
2
4
6
8
10·0
9·0
4·0
23·0
18·0
16·0
15·0
12·5
17·0
23·5
30·5
25·5
26·0
27·0
26·5
31·0
JAN.
22·5
13·0
26·5
24·0
31·5
30·5
32·5
33·0
APR.
3·5
17·5
20·0
JUL.
9·5
7·5
3·3
2·5
1·5
22·0
30·5
23·5
15·0
27·5
32·5
34·5
NOV.
1
2
3
4
5
6
7
Mouth
STATIONS
Head

Fig. 4B

Fig. 5. Salinity, temperature, oxygen distribution and rainfall during 1978 at Neendakara.

Description of lines in Figures 5 to 11 as in Fig. 4 A.

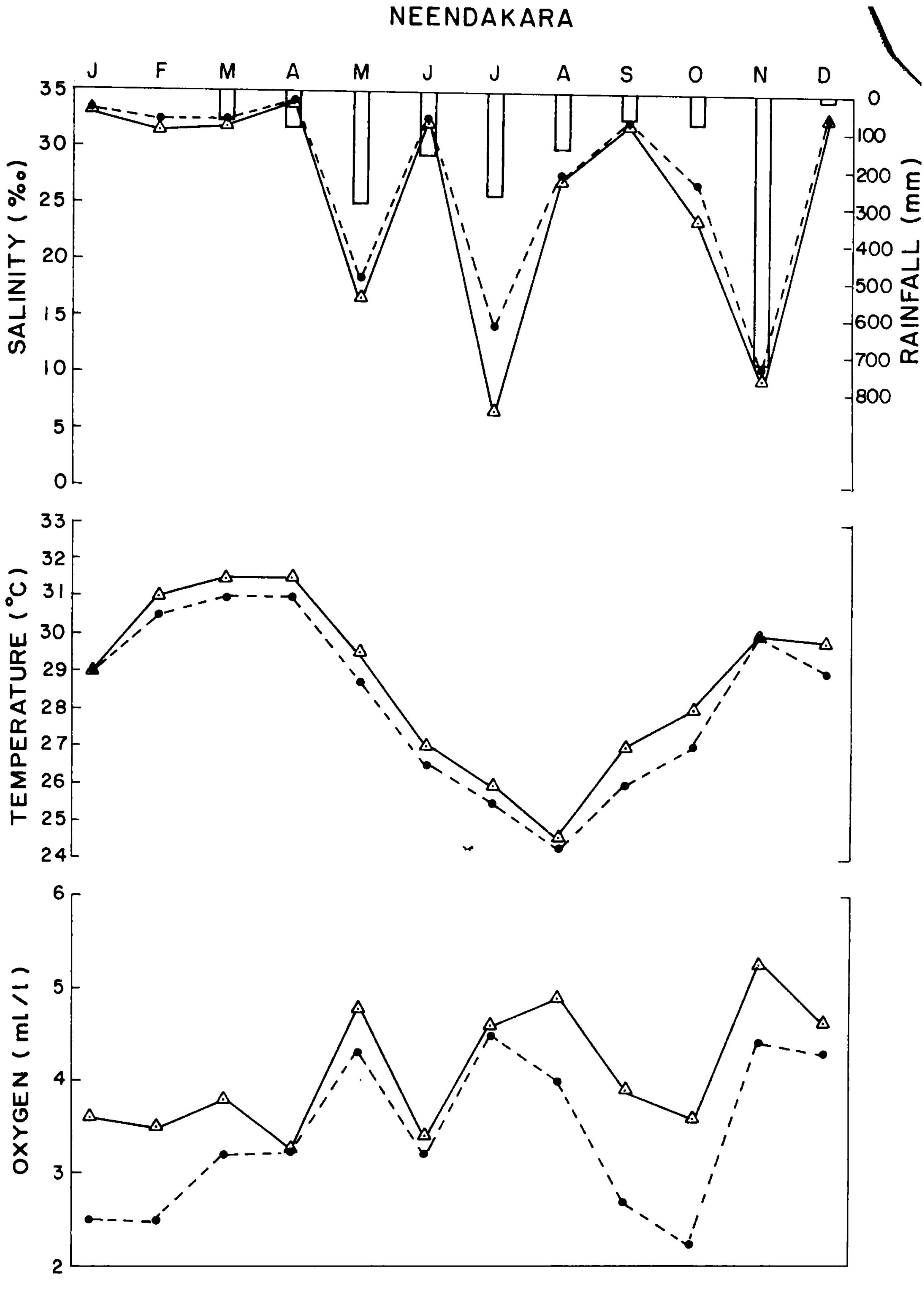

NEENDAKARA
J F M A M J J A S O N D
SALINITY (‰)
RAINFALL (mm)
35 30 25 20 15 10 5 0
0 100 200 300 400 500 600 700 800
TEMPERATURE (°C)
33 32 31 30 29 28 27 26 25 24
OXYGEN (ml/l)
6 5 4 3 2

Fig. 5

Fig. 6 : Salinity, temperature, oxygen distribution and rainfall during 1978 at Kallai.

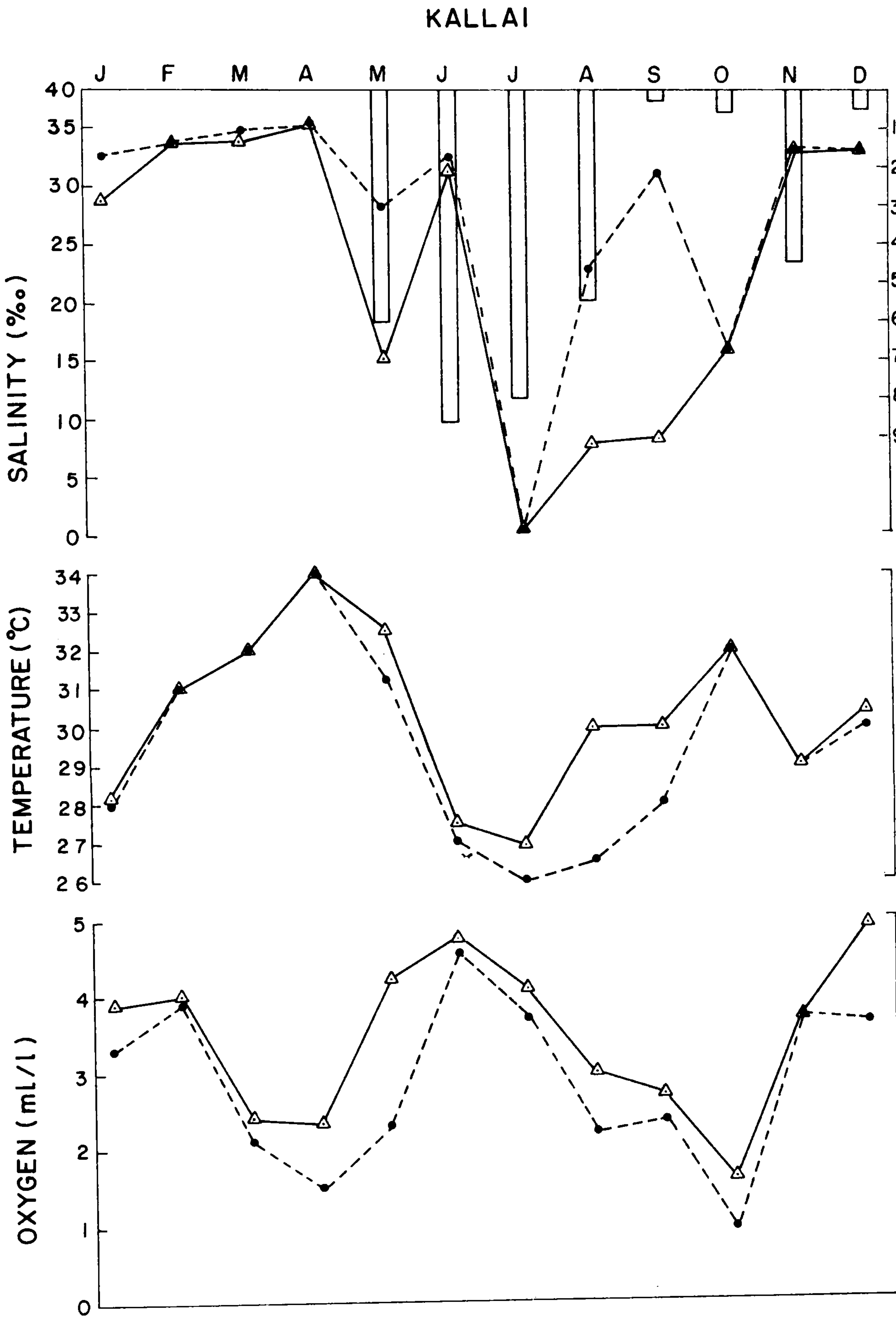

KALLAI
J F M A M J J A S O N D
SALINITY (‰)
40 35 30 25 20 15 10 5 0
0 100 200 300 400 500 600 700 800 900
TEMPERATURE (°C)
34 33 32 31 30 29 28 27 26
OXYGEN (ml/l)
5 4 3 2 1 0

Fig. 6

Fig. 7 : Salinity, temperature, oxygen distribution and rainfall during 1978 at Beypore.

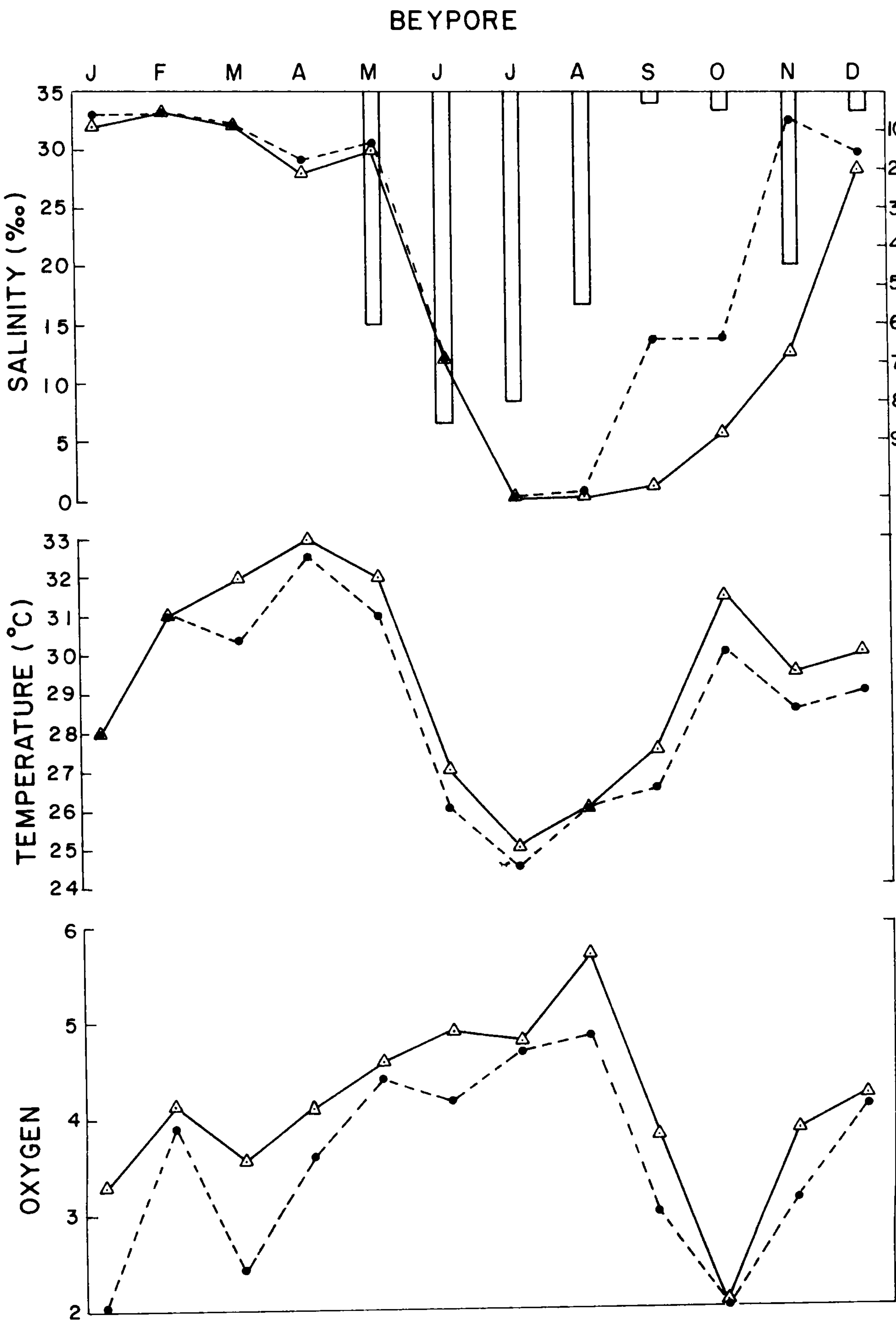

BEYPORE
J
F
M
A
M
J
J
A
S
O
N
D
SALINITY (‰)
35
30
25
20
15
10
5
0
RAINFALL (mm)
0
100
200
300
400
500
600
700
800
900
TEMPERATURE (°C)
33
32
31
30
29
28
27
26
25
24
OXYGEN
6
5
4
3
2

Fig. 7

Fig. 8: Salinity, temperature, oxygen distribution and rainfall during 1978 at Korapuzha.

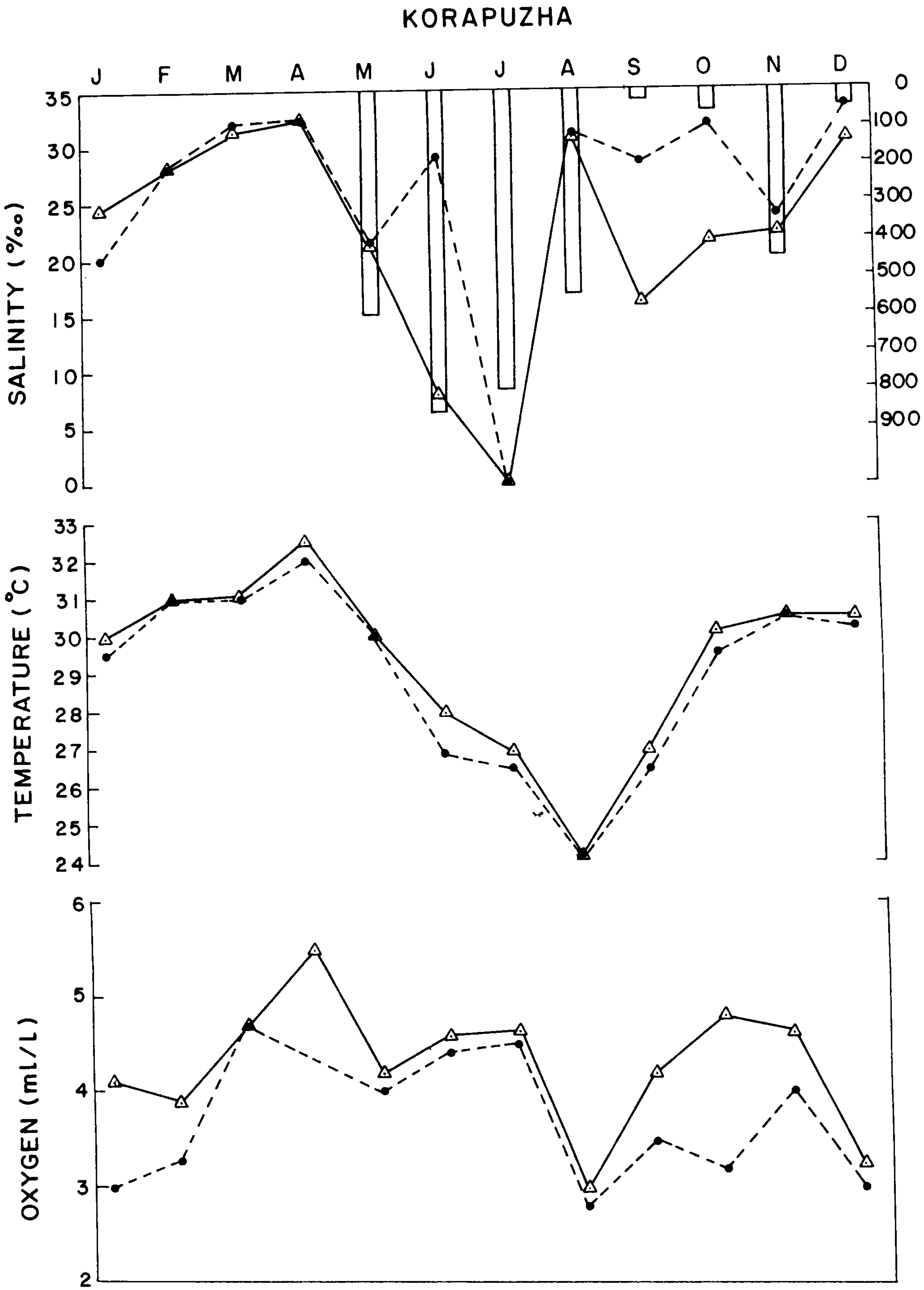

KORAPUZHA
J F M A M J J A S O N D
SALINITY (‰)
RAINFALL (mm)
0
100
200
300
400
500
600
700
800
900
35
30
25
20
15
10
5
0
TEMPERATURE (°C)
33
32
31
30
29
28
27
26
25
24
OXYGEN (ml/L)
6
5
4
3
2

Fig. 8

Fig. 9. Salinity, temperature, oxygen distribution and rainfall during 1970 at Mahe.

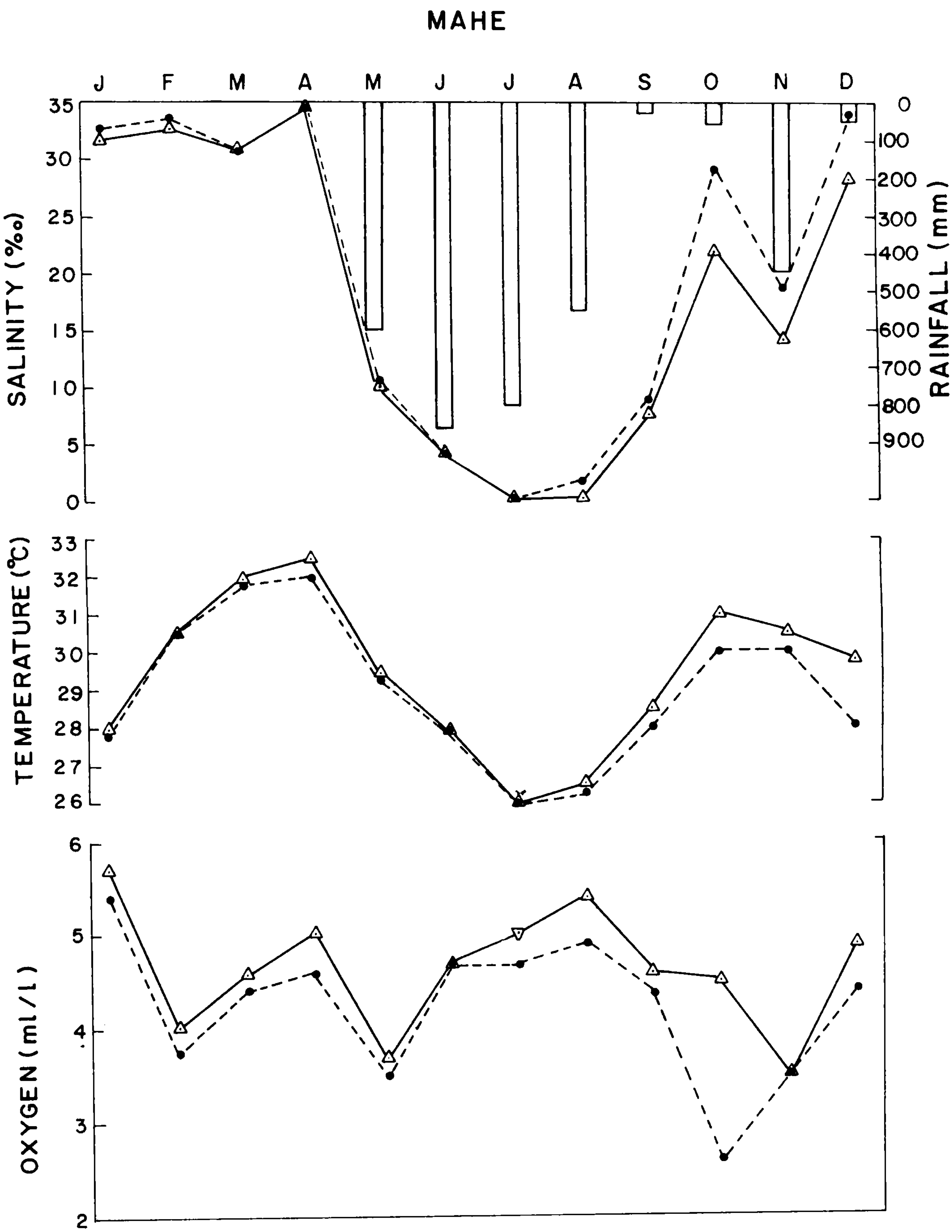

MAHE
J F M A M J J A S O N D
SALINITY (‰)
RAINFALL (mm)
TEMPERATURE (°C)
OXYGEN (ml/l)

Fig. 9

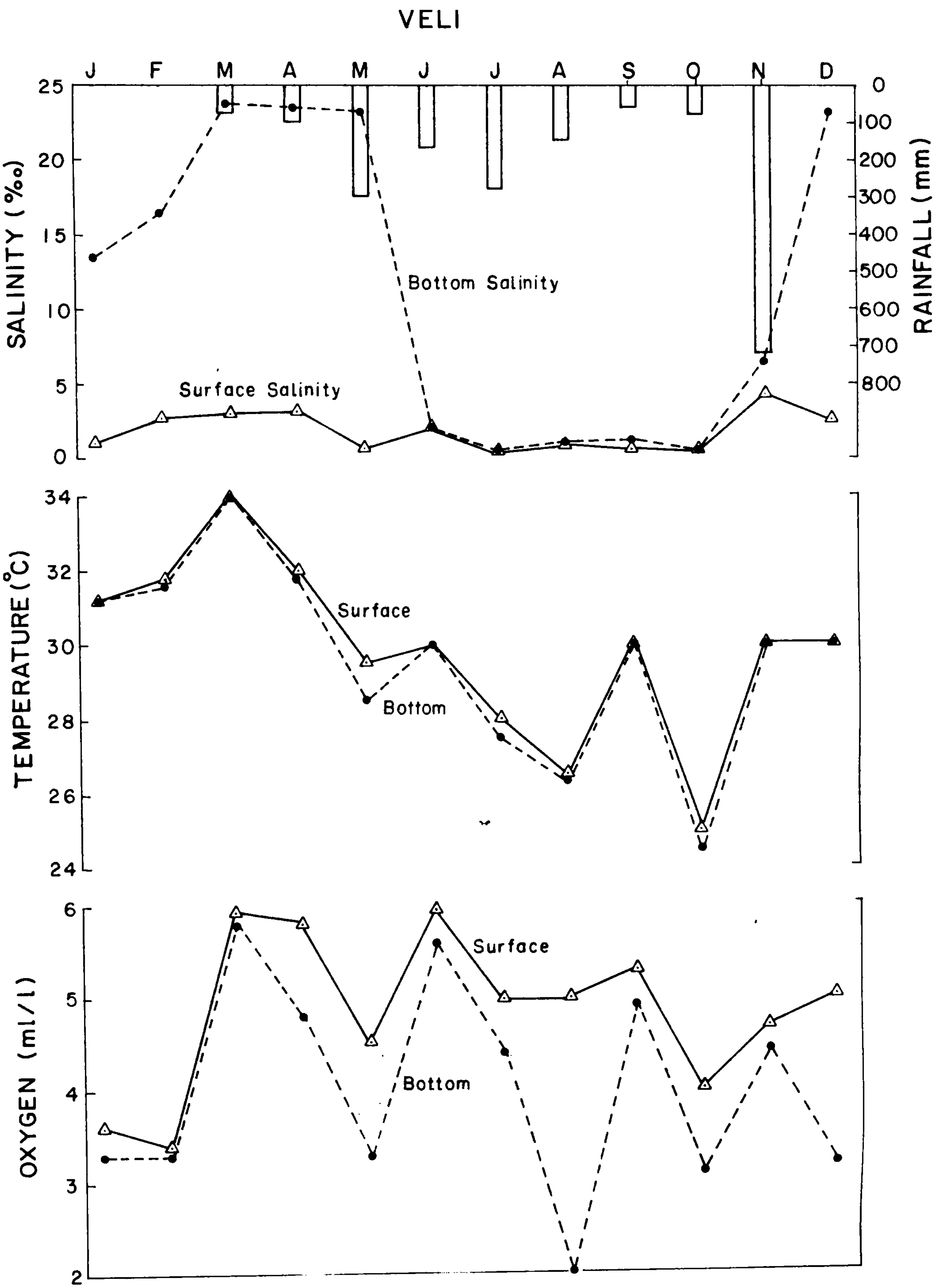

VELI
J F M A M J J A S O N D
SALINITY (‰)
RAINFALL (mm)
Bottom Salinity
Surface Salinity
TEMPERATURE (°C)
Surface
Bottom
OXYGEN (ml/l)
Surface
Bottom

Fig. 10

Fig. 11. Salinity, temperature, oxygen distribution and rainfall during 1978 at Thottappilly.

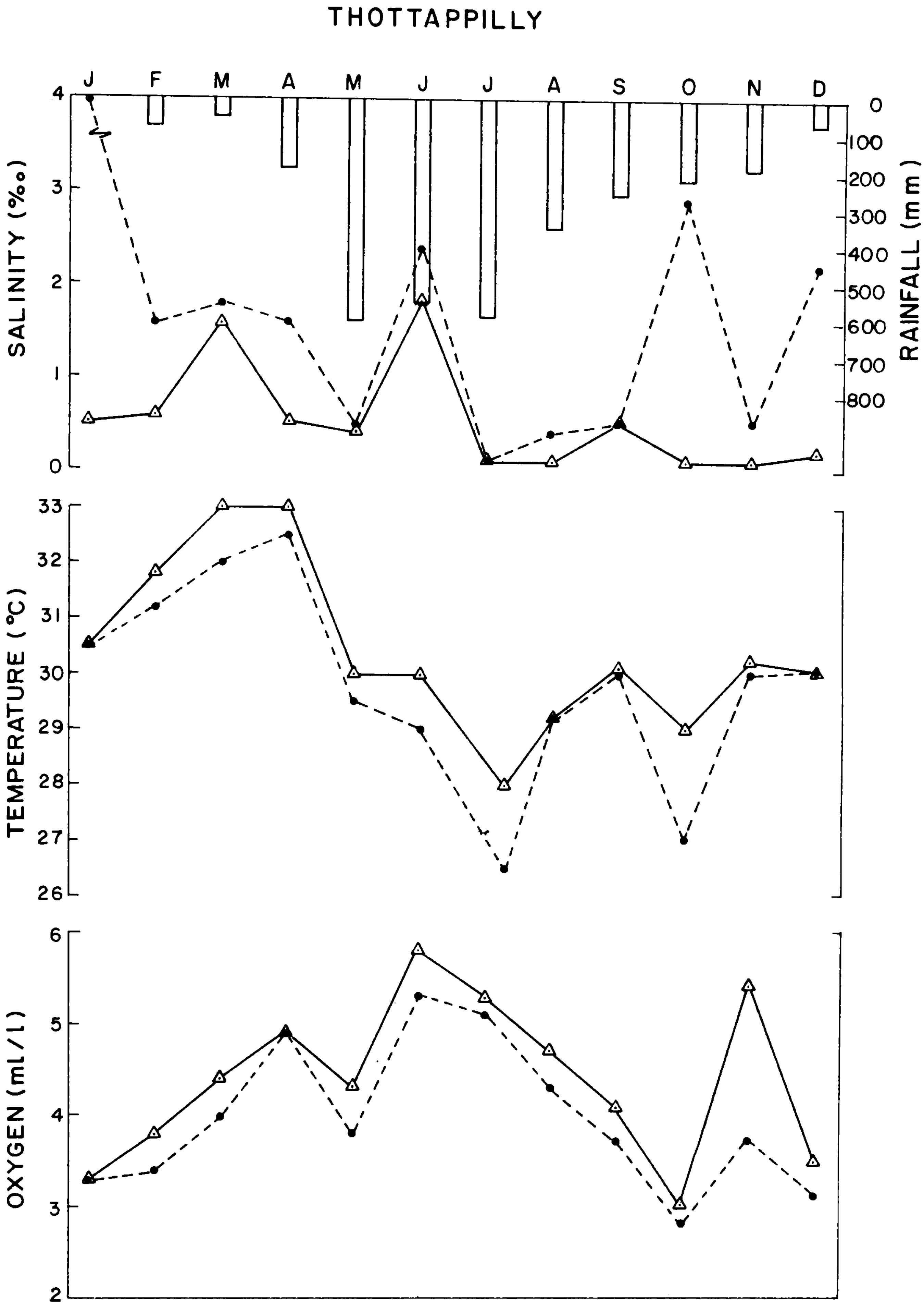

THOTTAPPILLY
J F M A M J J A S O N D
SALINITY (‰)
RAINFALL (mm)
0
100
200
300
400
500
600
700
800
4
3
2
1
0
TEMPERATURE (°C)
33
32
31
30
29
28
27
26
OXYGEN (ml/l)
6
5
4
3
2

Fig. 11

Fig. 12. Distribution of zooplankton counts (No./10m^3) in the estuaries during 1978.

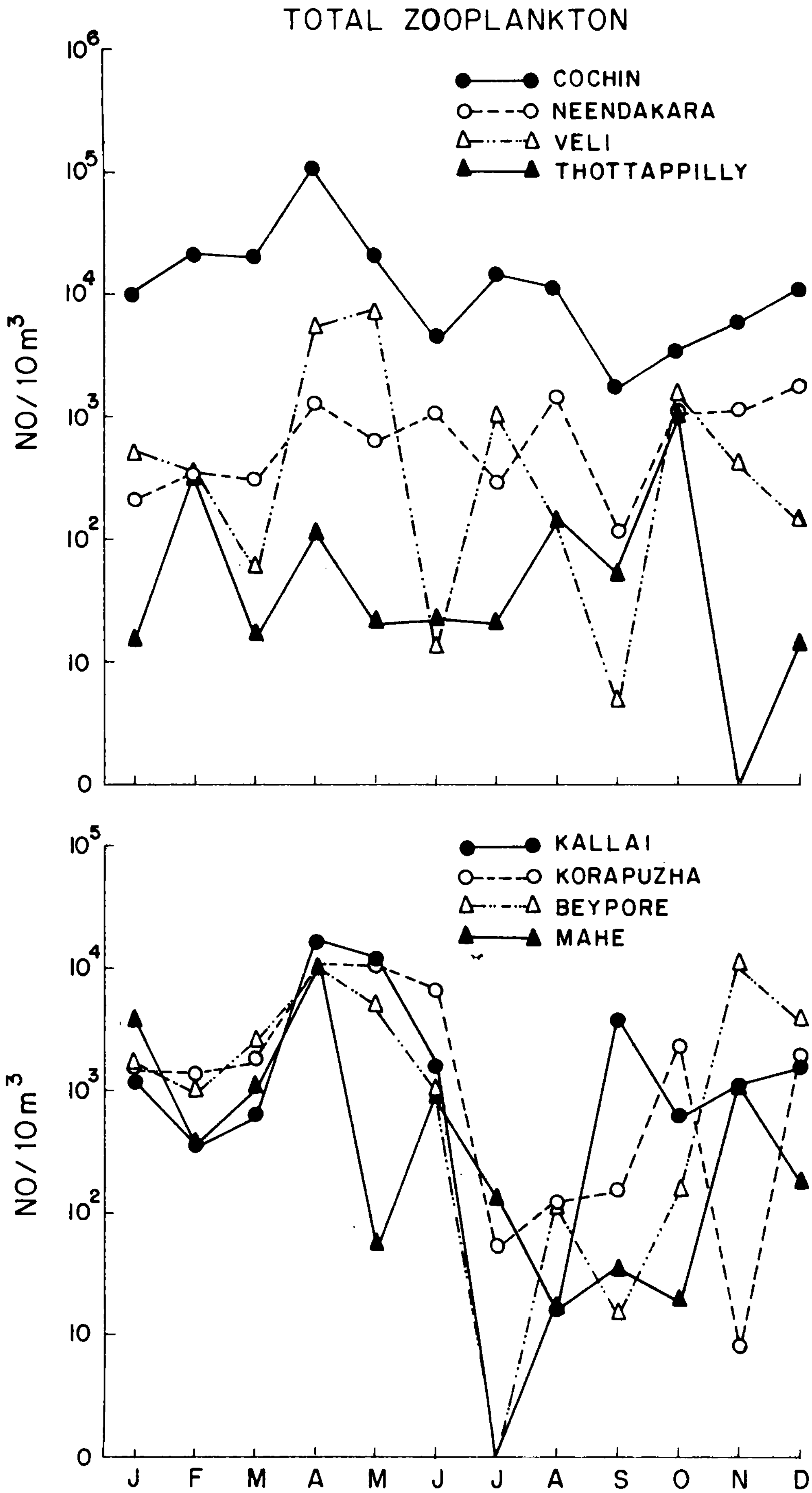

TOTAL ZOOPLANKTON
COCHIN
NEENDAKARA
VELI
THOTTAPPILLY
KALLAI
KORAPUZHA
BEYPORE
MAHE
NO/10 m3
10^6
10^5
10^4
10^3
10^2
10
0
J F M A M J J A S O N D

Fig. 12

Fig. 13. Distribution of common groups at Cochin and Neendakara estuaries.

Description of lines in the bottom figures of Figs. 13 to 16 as in the upper figures.

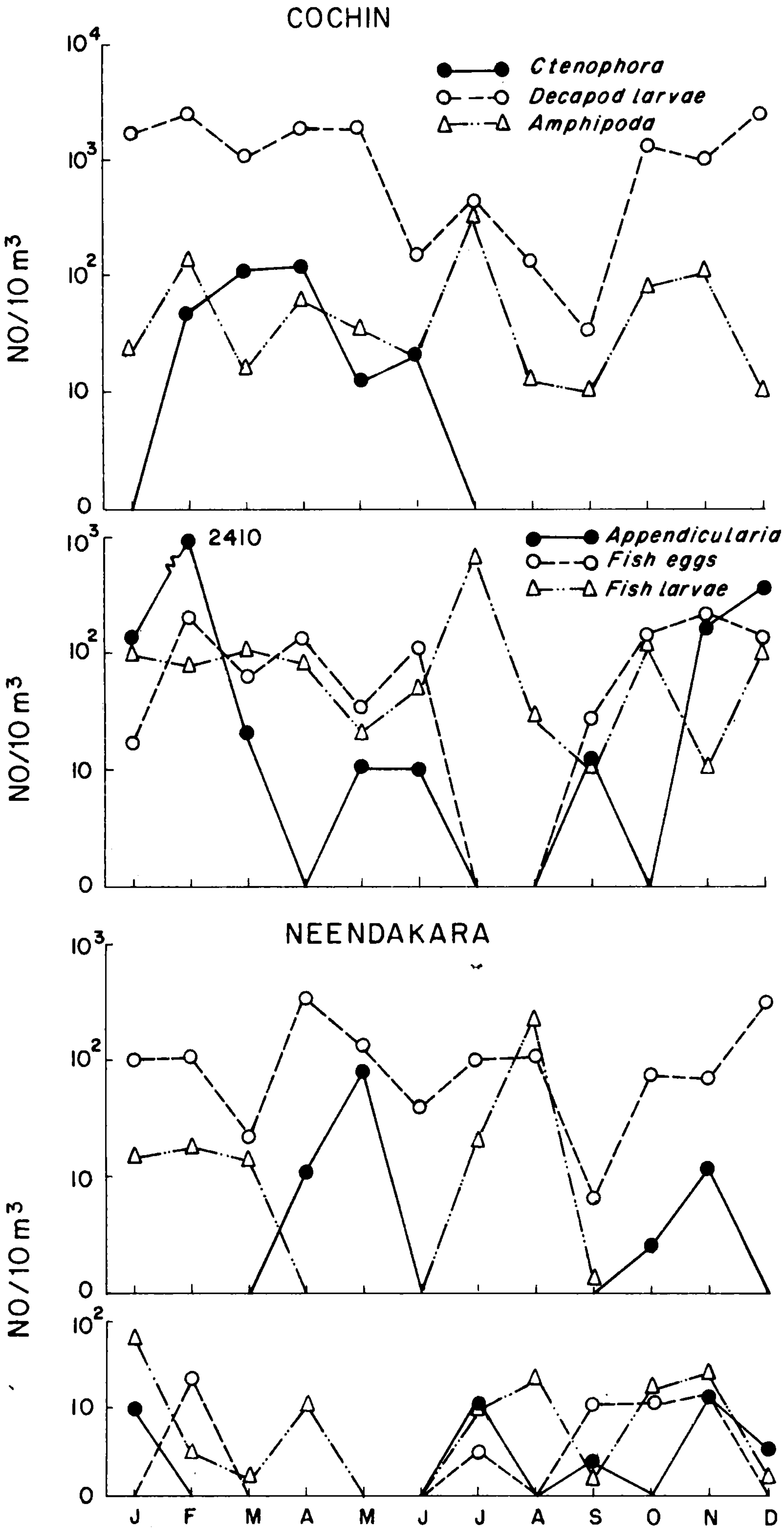

COCHIN
Ctenophora
Decapod larvae
Amphipoda
Appendicularia
Fish eggs
Fish larvae
2410
NEENDAKARA
NO/10 m3
10
0
J F M A M J J A S O N D

Fig. 13

Fig. 14. Distribution of common groups at Kallai and Korapuzha estuaries.

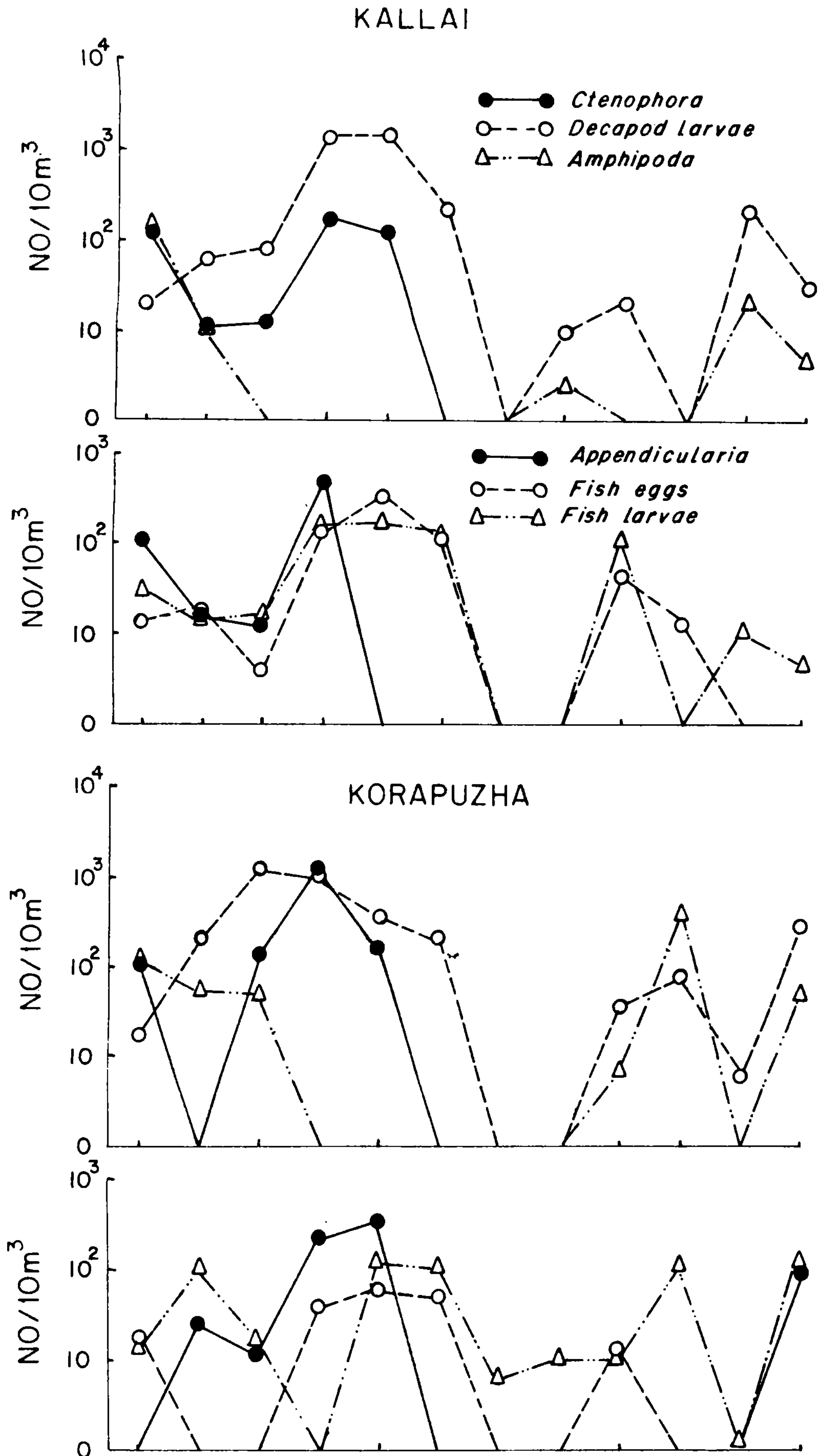

KALLAI
KORAPUZHA
NO/10m^3
Ctenophora
Decapod larvae
Amphipoda
Appendicularia
Fish eggs
Fish larvae
10^4
10^3
10^2
10
0
J
F
M
A
M
J
J
A
S
O
N
D

Fig. 14

Fig. 15. Distribution of common groups at Beypore and Mahe estuaries.

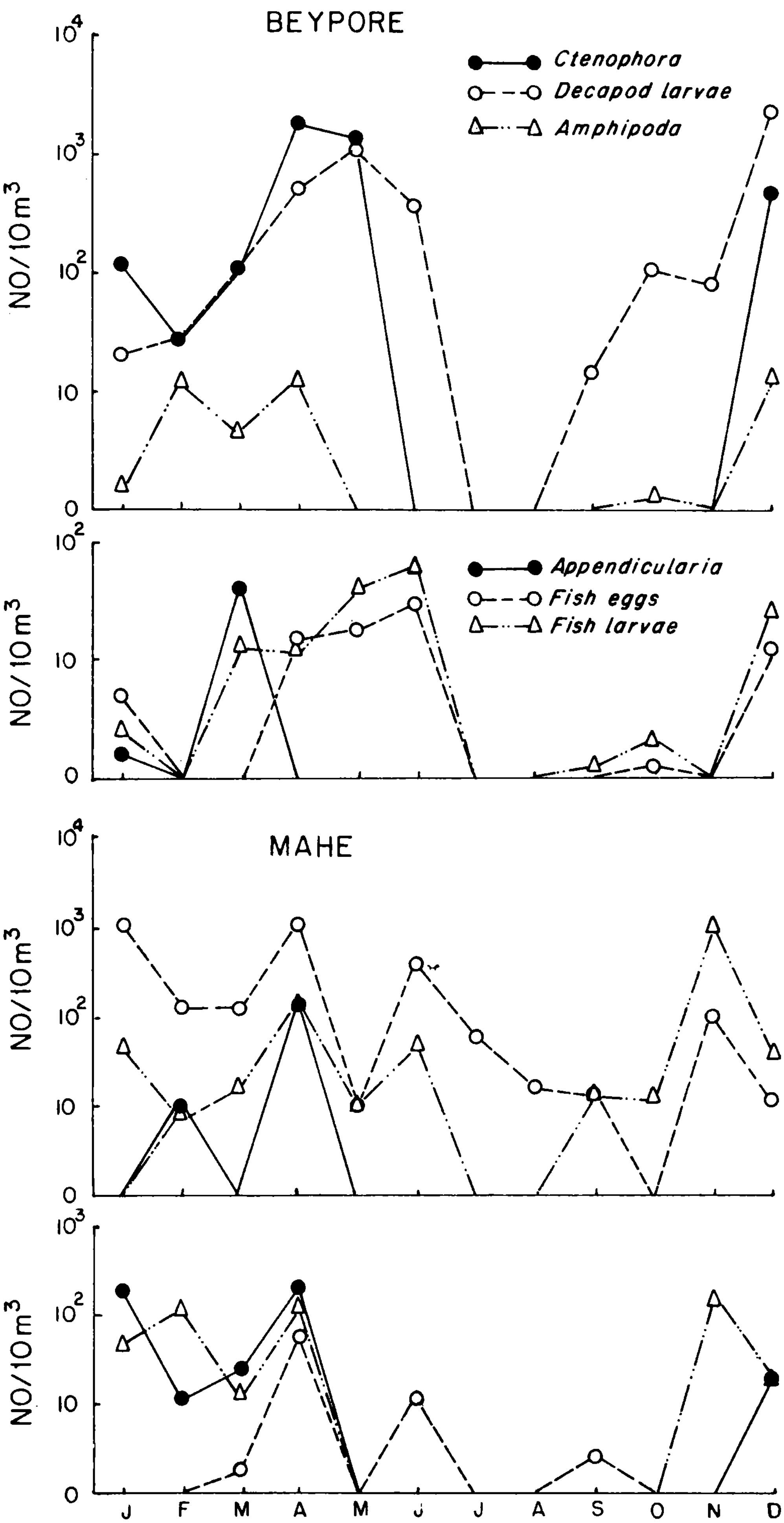

BEYPORE
Ctenophora
Decapod larvae
Amphipoda
Appendicularia
Fish eggs
Fish larvae
MAHE
NO/10m³
J F M A M J J A S O N D

Fig. 15

Fig. 16. Distribution of common groups at Veli and Thottappilly lakes.

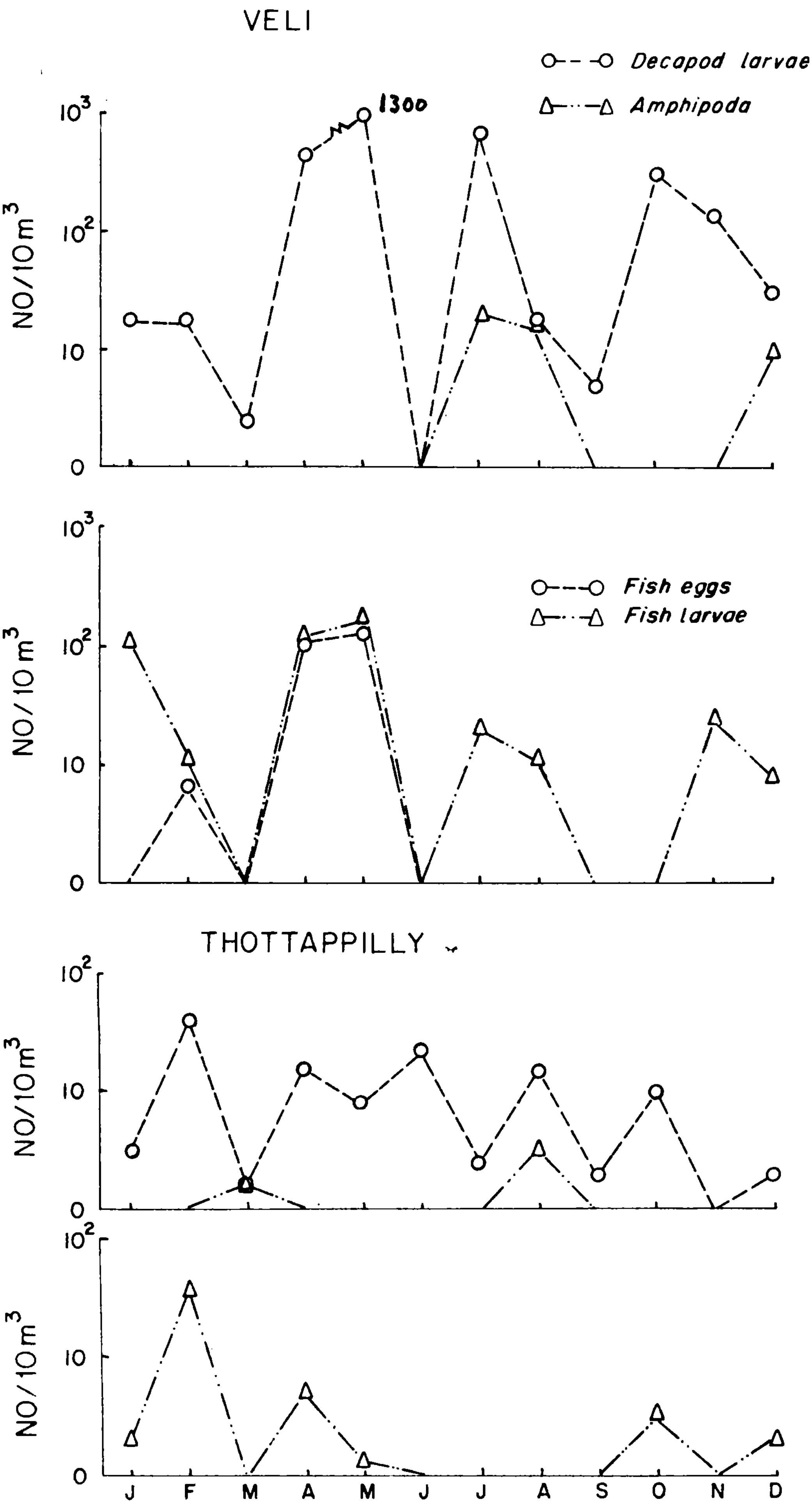

VELI
Decapod larvae
Amphipoda
1300
Fish eggs
Fish larvae
THOTTAPPILLY
NO/10m³
10³
10²
10
0
J F M A M J J A S O N D

Fig. 16

Fig. 17. Distribution of common groups towards the interior of Cochin backwaters.

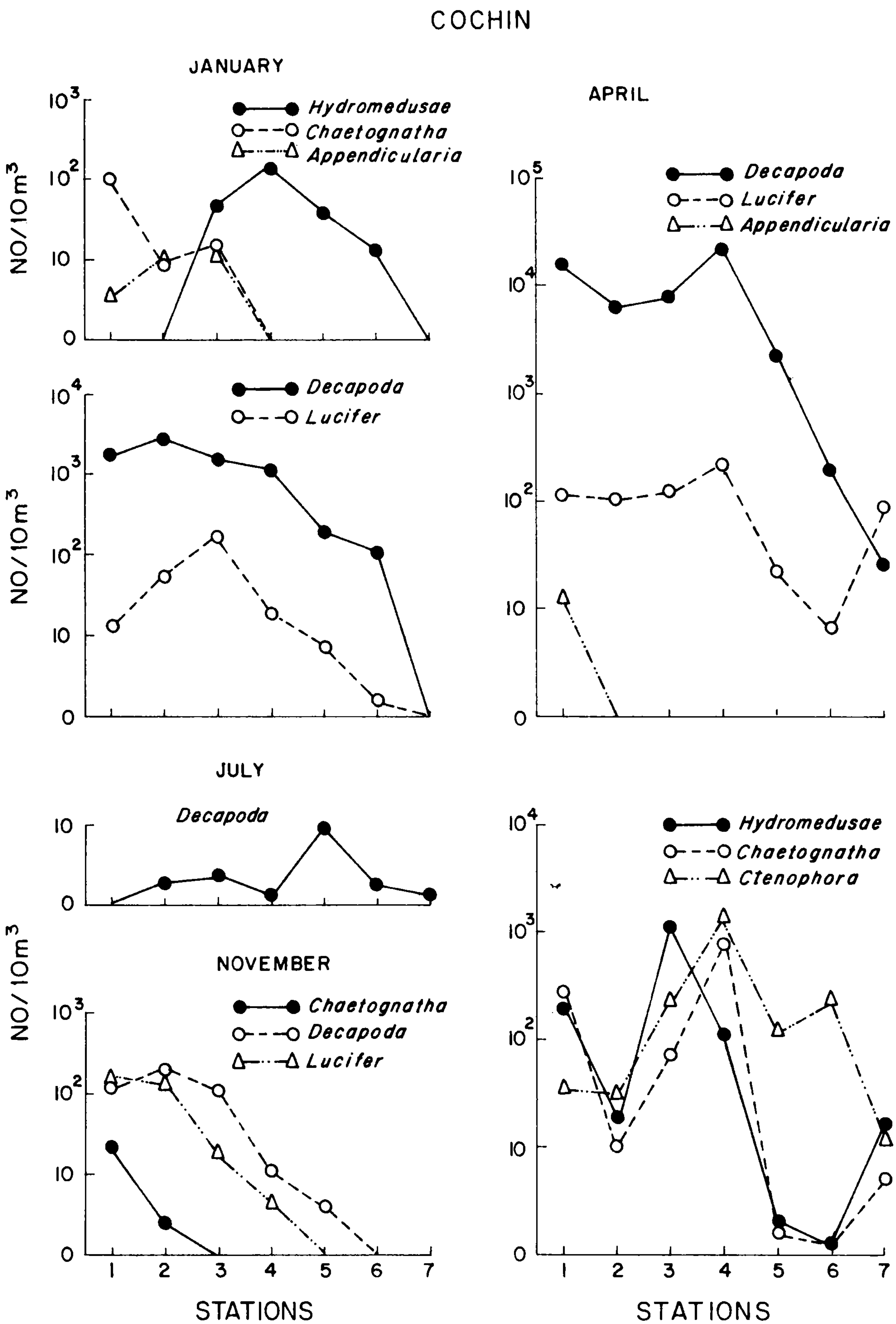

COCHIN
JANUARY
Hydromedusae
Chaetognatha
Appendicularia
Decapoda
Lucifer
APRIL
Decapoda
Lucifer
Appendicularia
JULY
Decapoda
NOVEMBER
Chaetognatha
Decapoda
Lucifer
Hydromedusae
Chaetognatha
Ctenophora
NO/10m³
STATIONS
STATIONS

Fig. 17

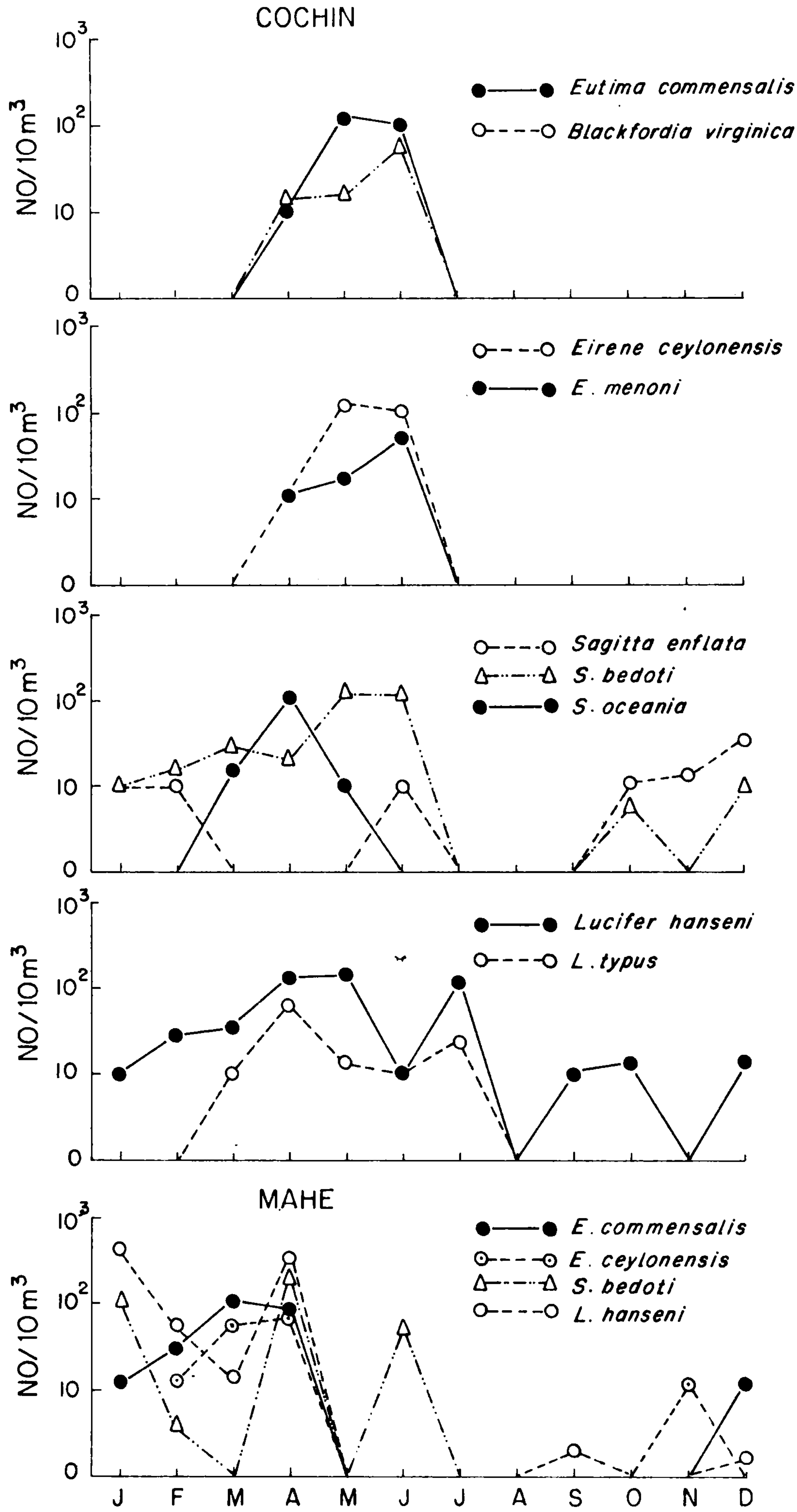

COCHIN
NO/10m^3
10^3
10^2
10
0
Eutima commensalis
Blackfordia virginica
Eirene ceylonensis
E. menoni
Sagitta enflata
S. bedoti
S. oceania
Lucifer hanseni
L. typus
MAHE
E. commensalis
E. ceylonensis
S. bedoti
L. hanseni
J
F
M
A
M
J
J
A
S
O
N
D

Fig. 18

Fig. 19. Distribution of common species other than copepods at Korapuzha and Kallai estuaries.

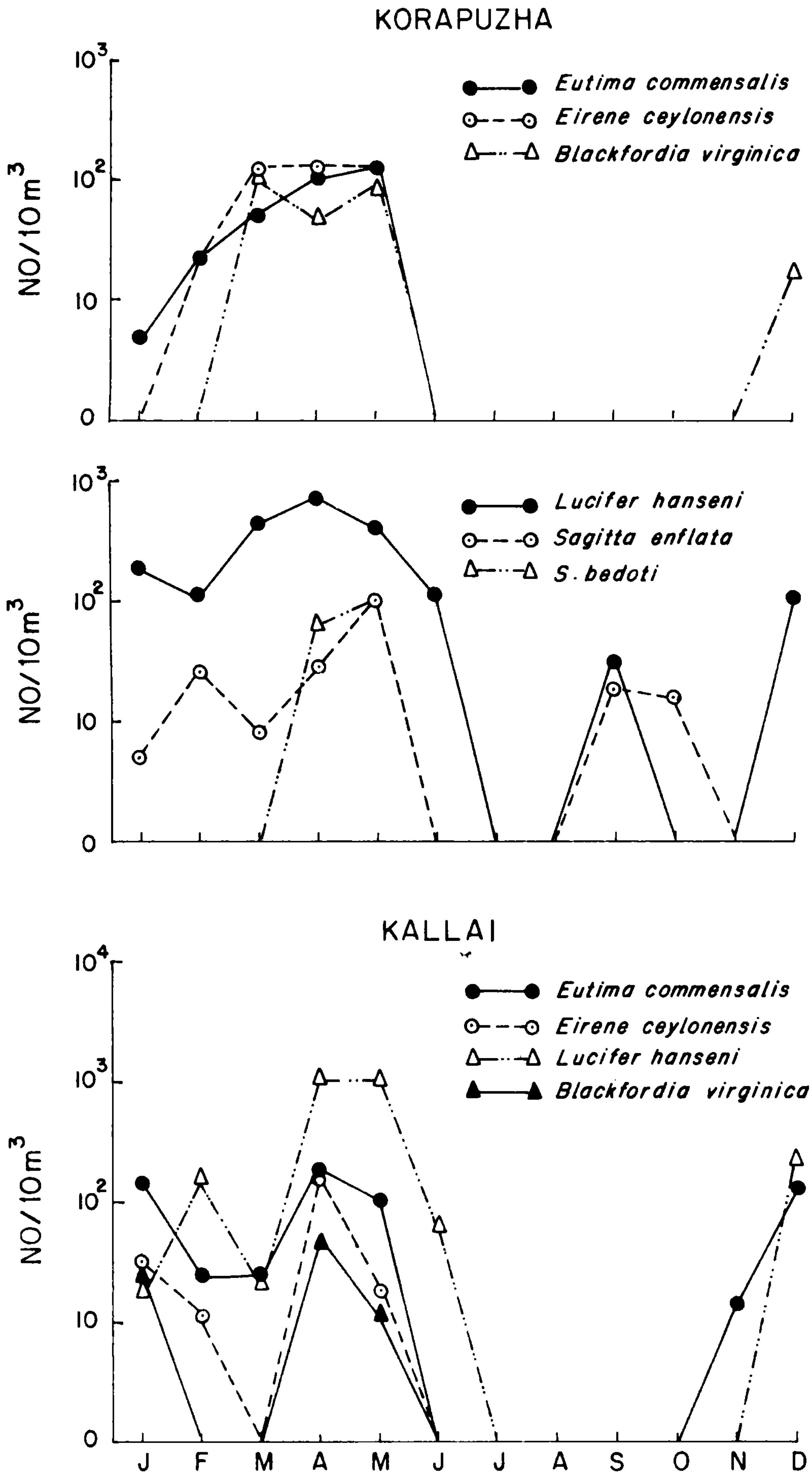

KORAPUZHA
Eutima commensalis
Eirene ceylonensis
Blackfordia virginica
NO/10m³
Lucifer hanseni
Sagitta enflata
S. bedoti
KALLAI
Eutima commensalis
Eirene ceylonensis
Lucifer hanseni
Blackfordia virginica
J F M A M J J A S O N D

Fig. 19

Fig. 20. Distribution of common species other than copepods at Beypore and Neendakara estuaries.

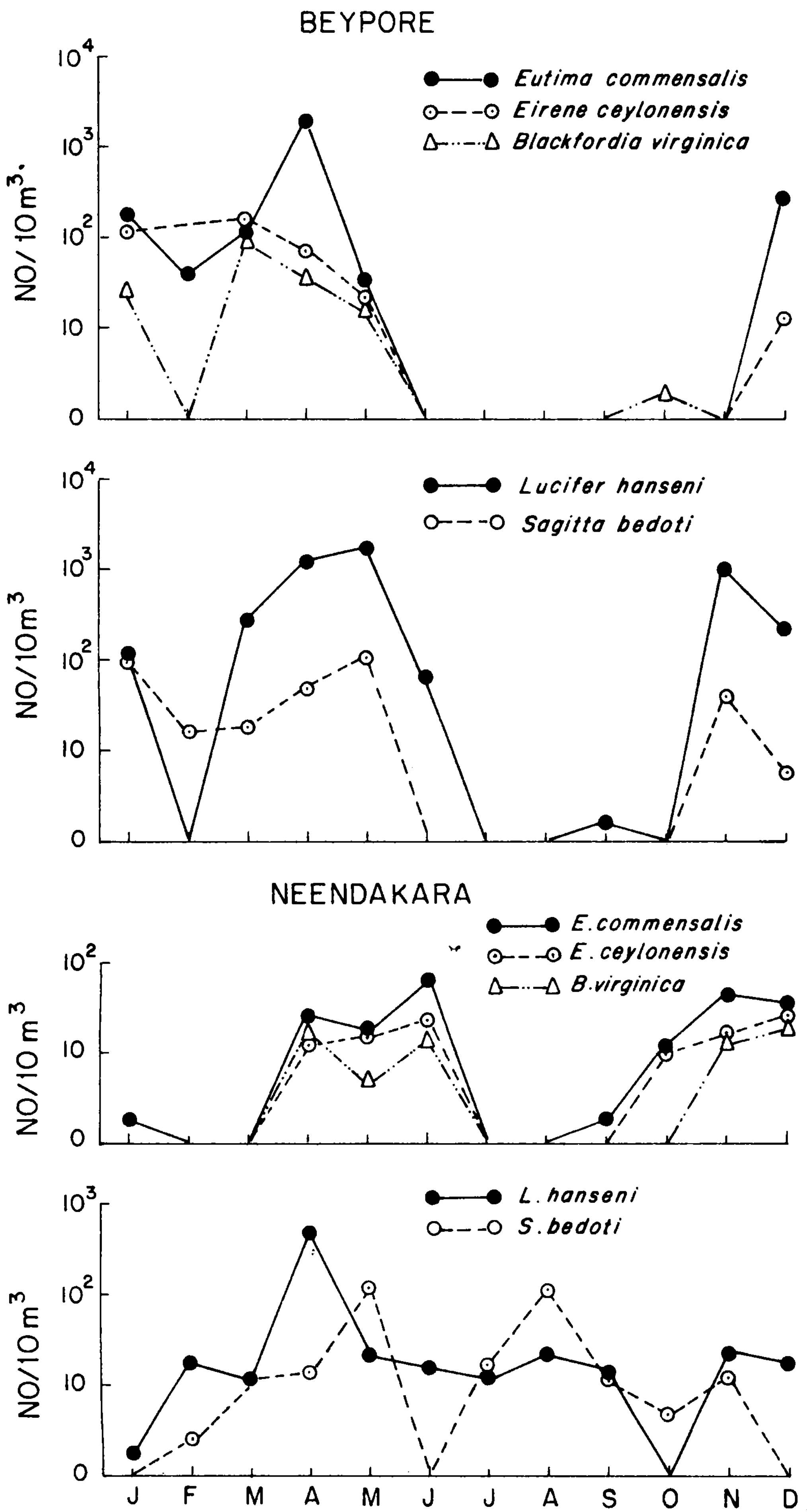
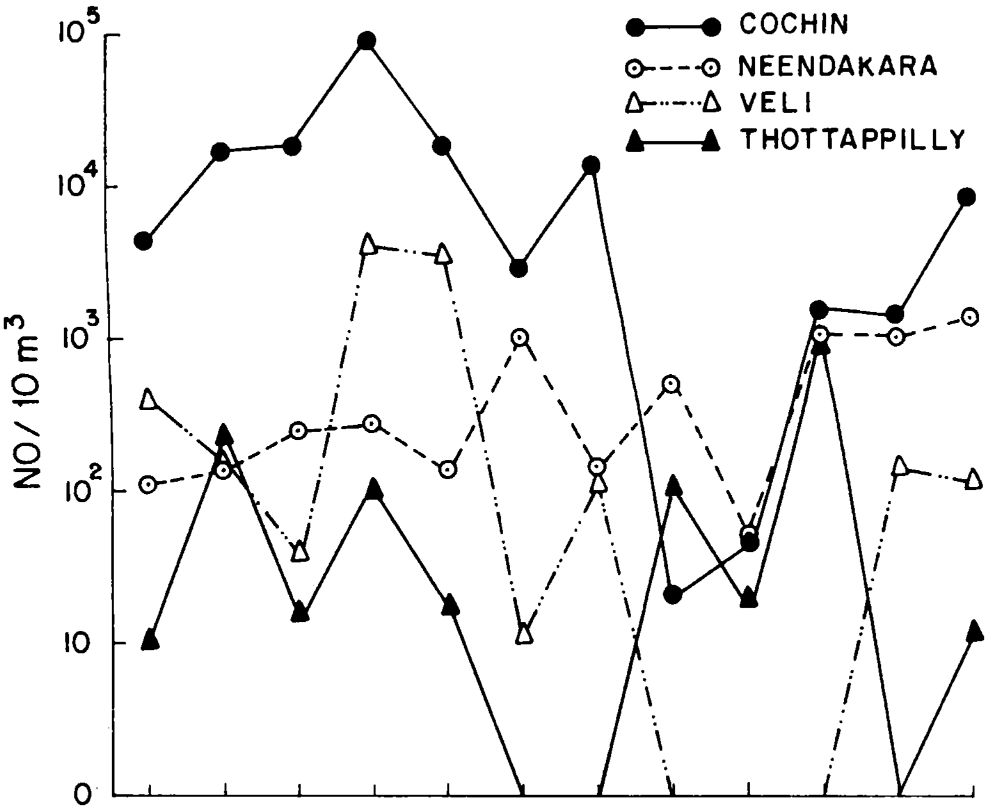

BEYPORE
Eutima commensalis
Eirene ceylonensis
Blackfordia virginica
Lucifer hanseni
Sagitta bedoti
NEENDAKARA
E. commensalis
E. ceylonensis
B. virginica
L. hanseni
S. bedoti
NO/10m³
J F M A M J J A S O N D

Fig. 20

Fig. 21. Distribution of total Copepoda in the eight estuaries during 1978.

TOTAL COPEPODA



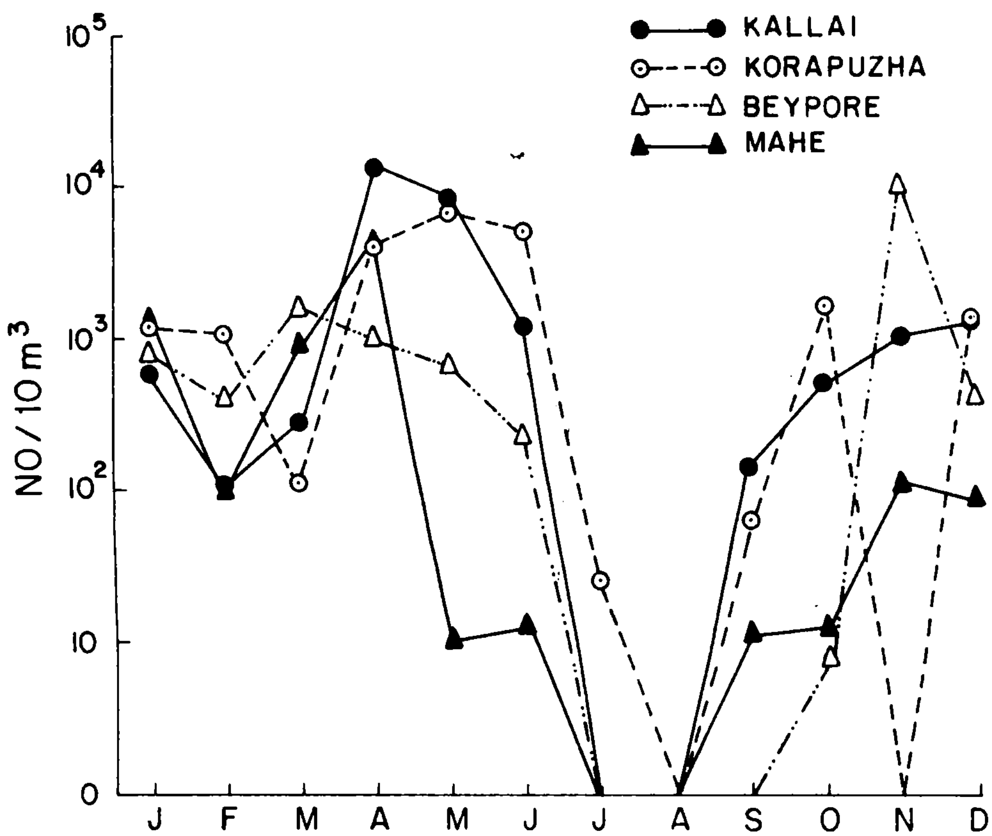


Fig. 21

Fig. 22A. Distribution of common copepod species at the mouth of Cochin backwaters.

COCHIN

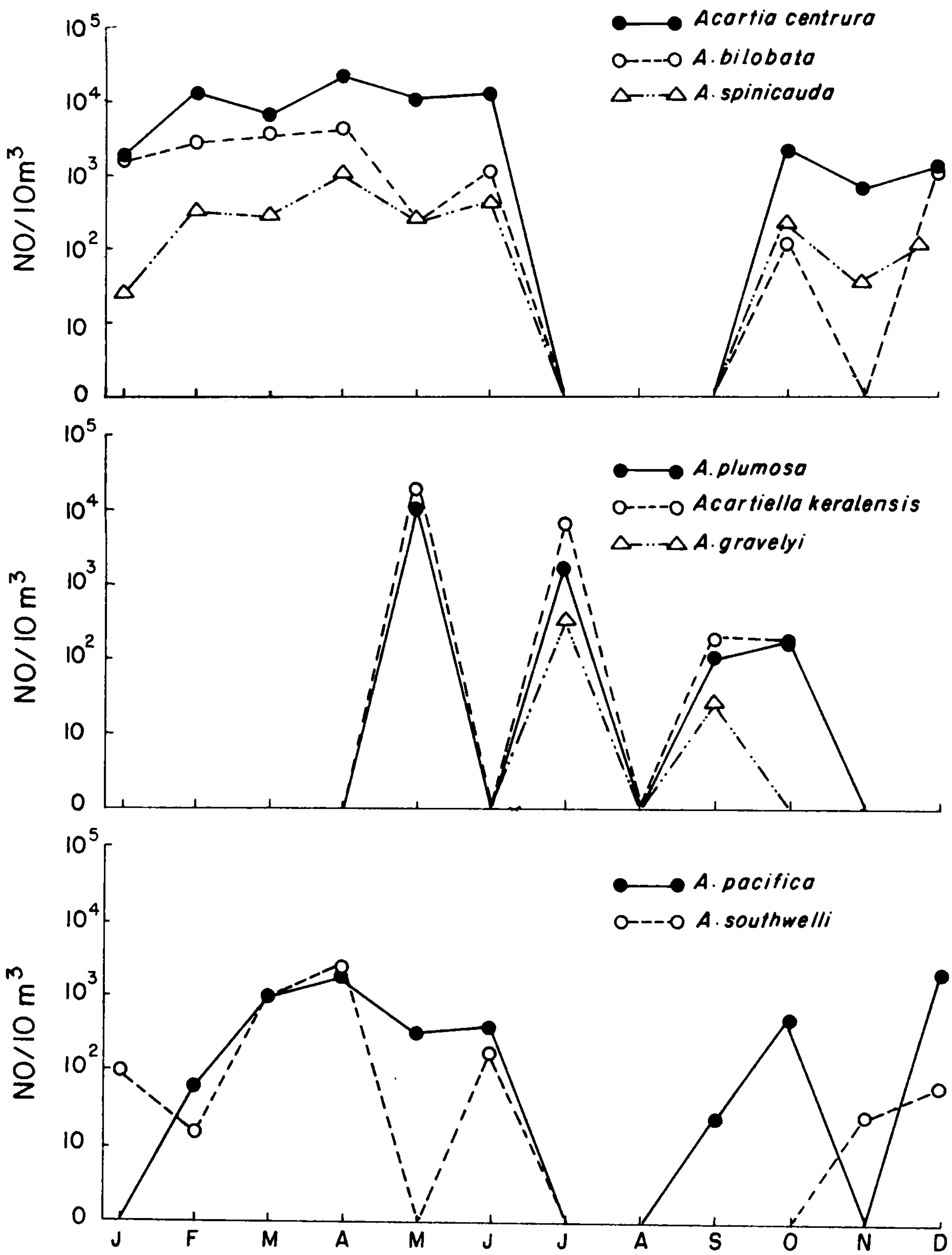


Fig. 22 A

COCHIN

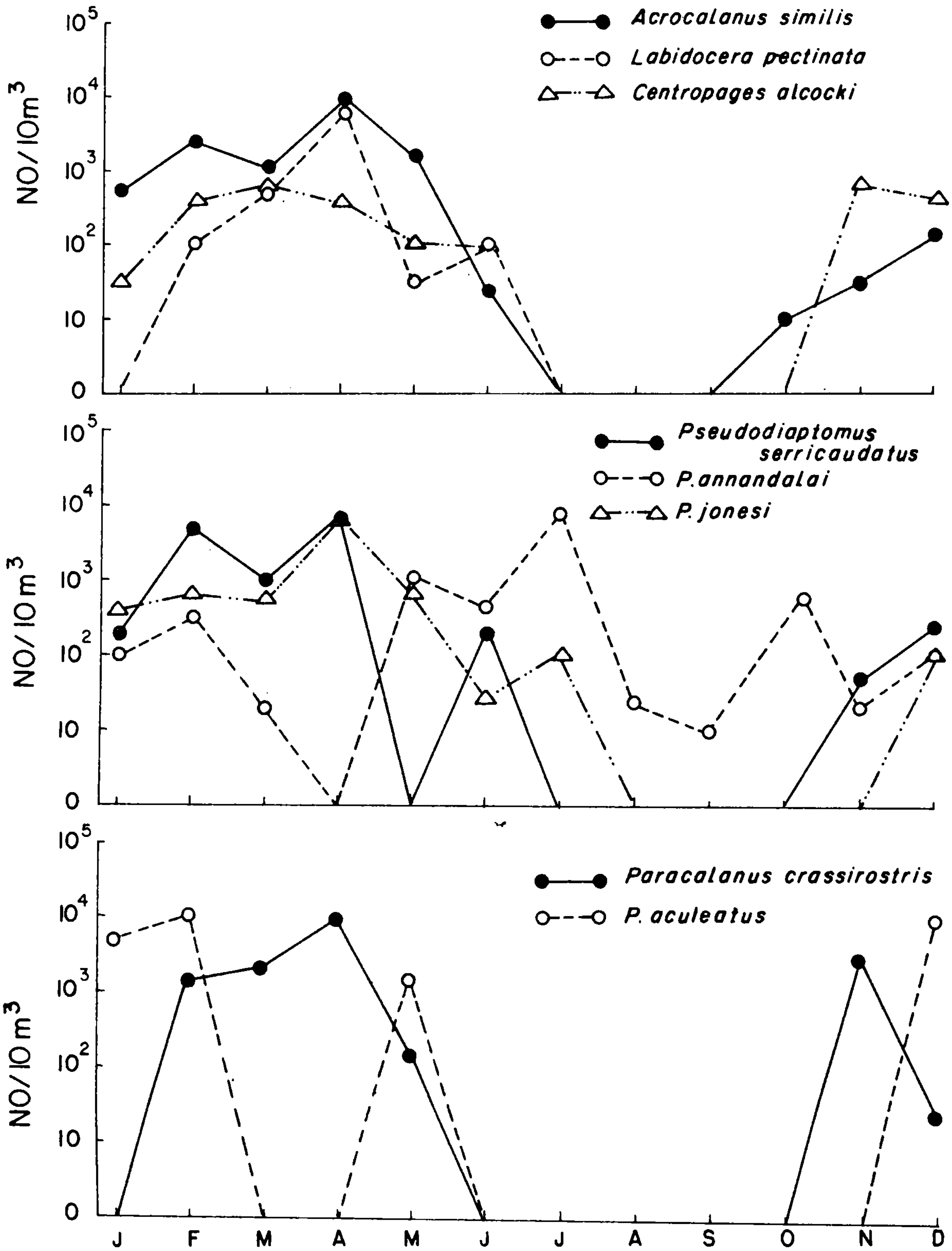


Fig. 22 A

Fig. 22 B. Distribution of common copepod species towards the upper reaches of Cochin backwaters.

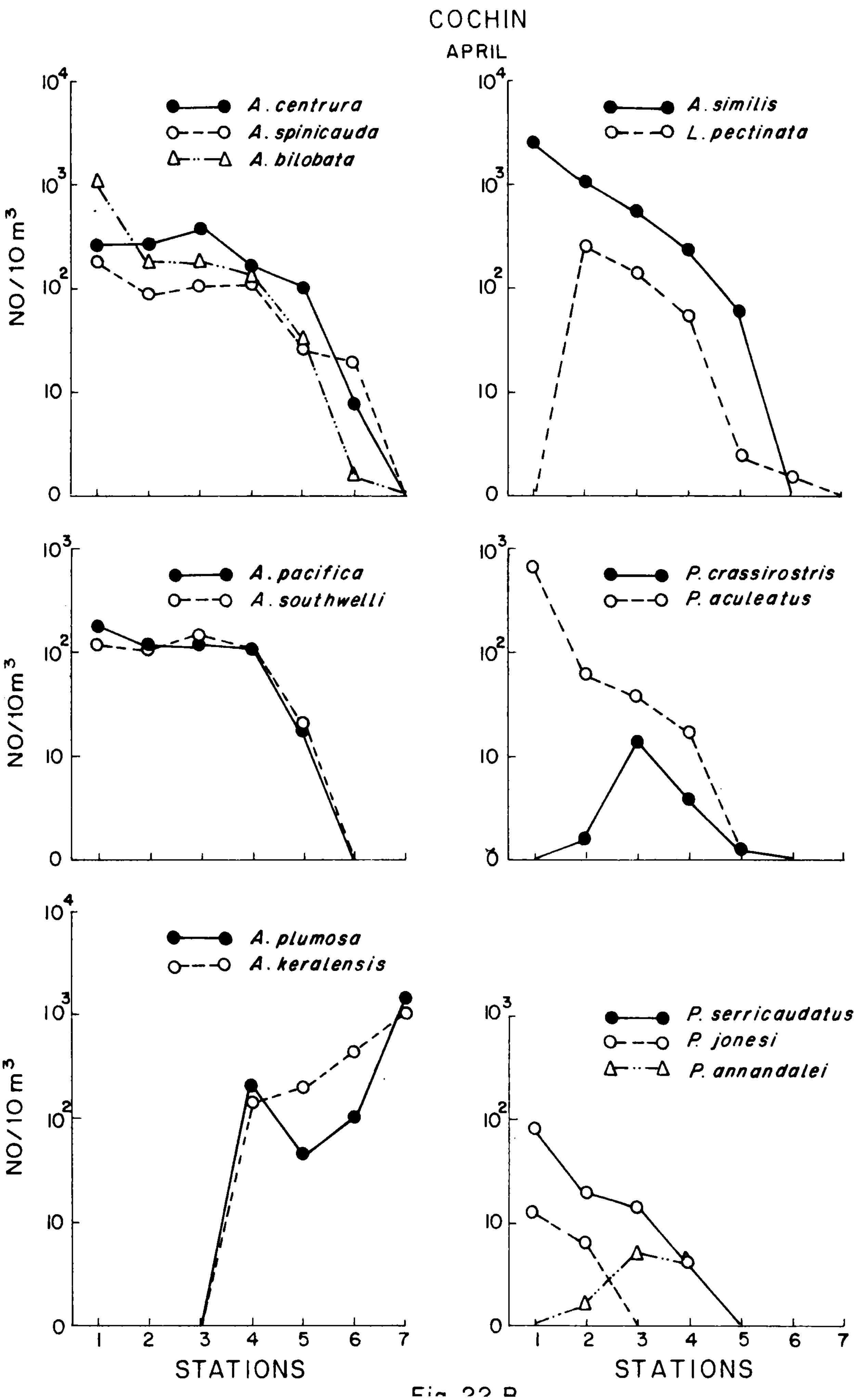
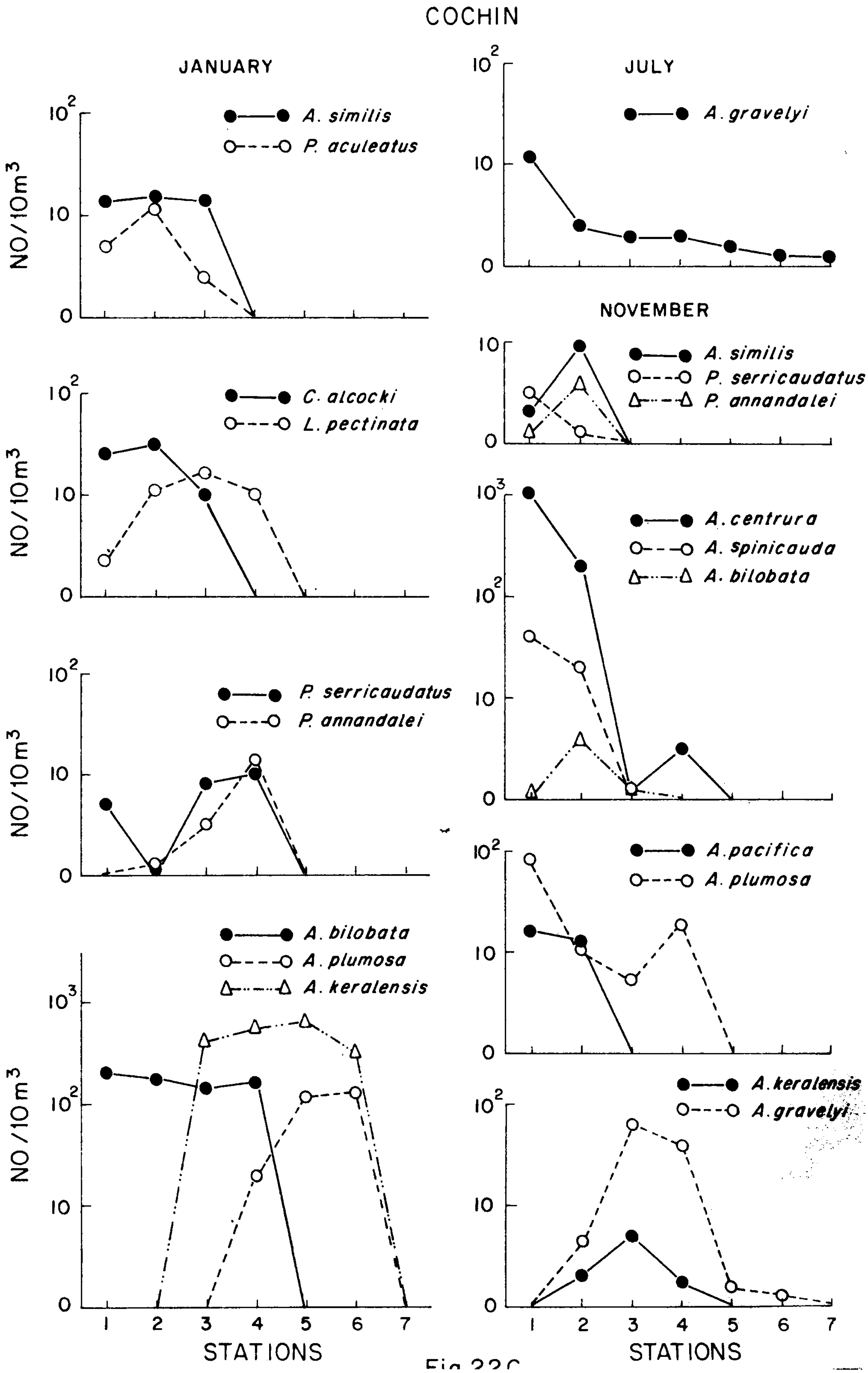

COCHIN
APRIL
A. centrura
A. spinicauda
A. bilobata
A. similis
L. pectinata
A. pacifica
A. southwelli
P. crassirostris
P. aculeatus
A. plumosa
A. keralensis
P. serricaudatus
P. jonesi
P. annandalei
NO/10m³
STATIONS

Fig. 22 B

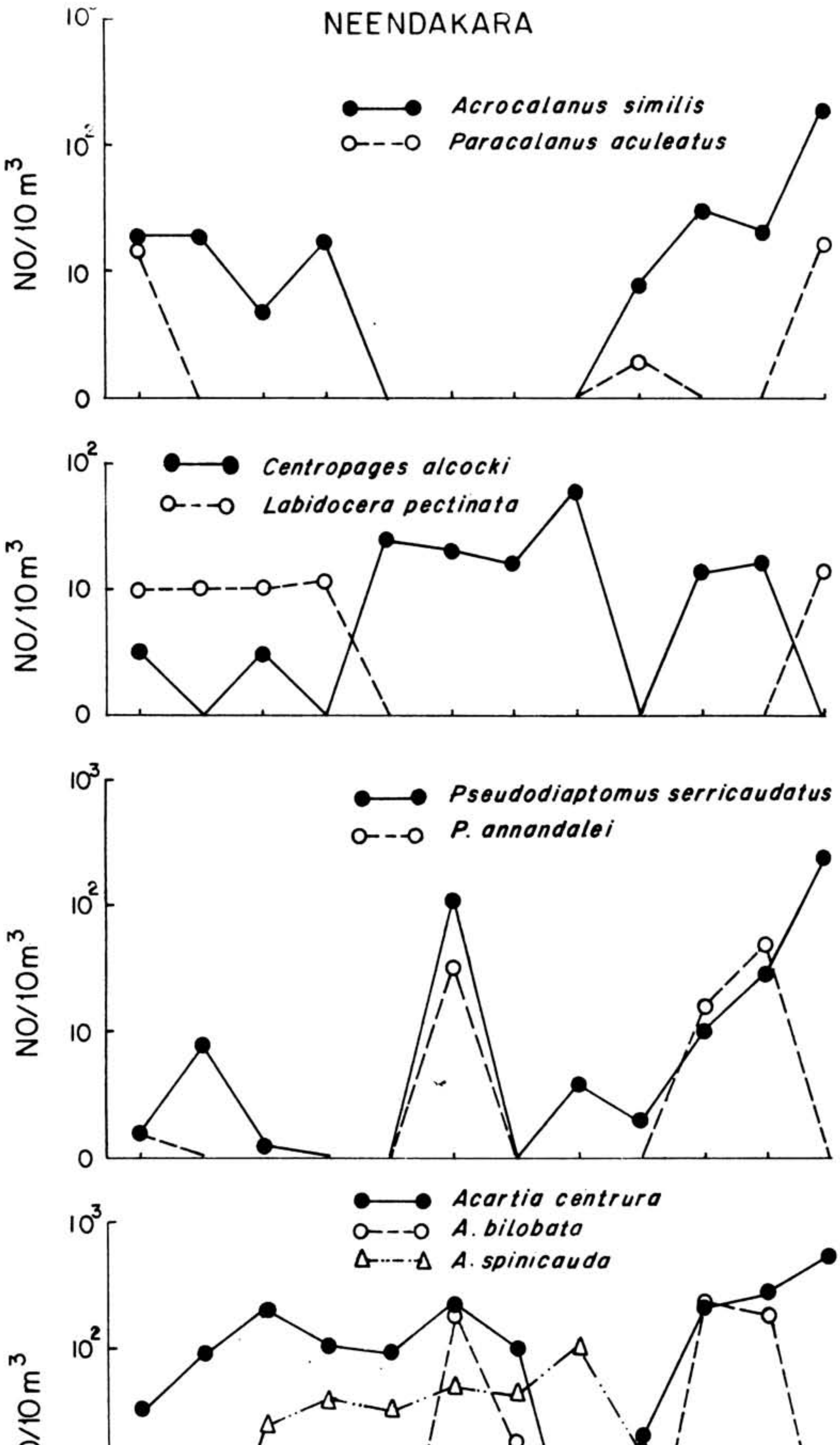
Fig. 22 C. Distribution of common copepod species towards the upper reaches of Cochin backwaters.



COCHIN
JANUARY
JULY
NOVEMBER
A. similis
P. aculeatus
C. alcocki
L. pectinata
P. serricaudatus
P. annandalei
A. bilobata
A. plumosa
A. keralensis
A. gravelyi
A. similis
P. serricaudatus
P. annandalei
A. centrura
A. spinicauda
A. bilobata
A. pacifica
A. plumosa
A. keralensis
A. gravelyi
NO/10m³
STATIONS

Fig. 22C

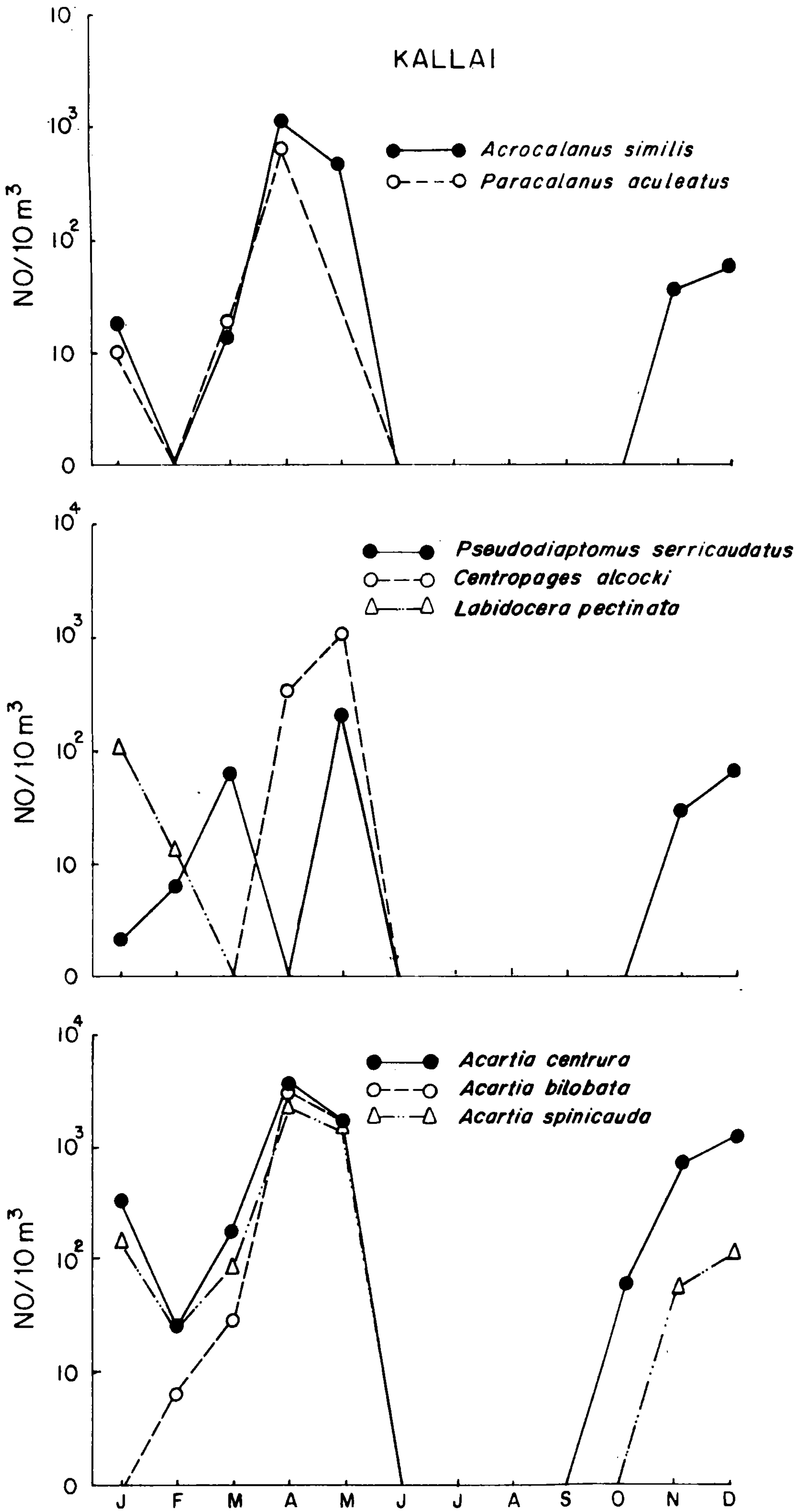
Fig. 23. Distribution of common copepod species at Neendakara.



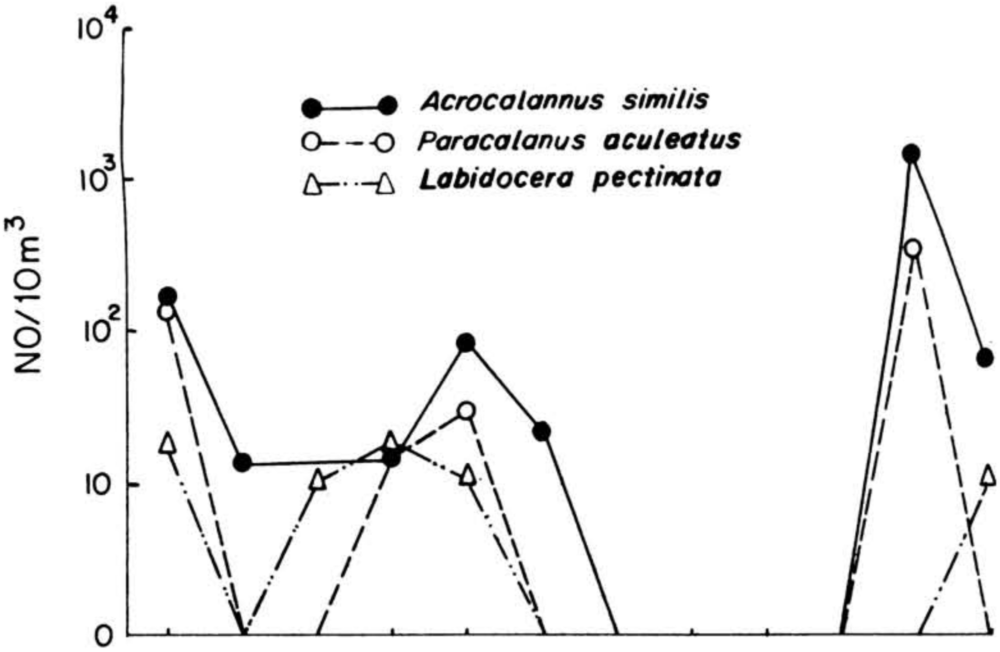
NEENDAKARA
Acrocalanus similis
Paracalanus aculeatus
Centropages alcocki
Labidocera pectinata
Pseudodiaptomus serricaudatus
P. annandalei
Acartia centrura
A. bilobata
A. spinicauda
NO/10 m3
J F M A M J J A S O N D

Fig. 23

Fig. 24. Distribution of common copepod species at Kallai.


KALLAI
Acrocalanus similis
Paracalanus aculeatus
Pseudodiaptomus serricaudatus
Centropages alcocki
Labidocera pectinata
Acartia centrura
Acartia bilobata
Acartia spinicauda
NO/10 m3
J F M A M J J A S O N D

BEYPORE



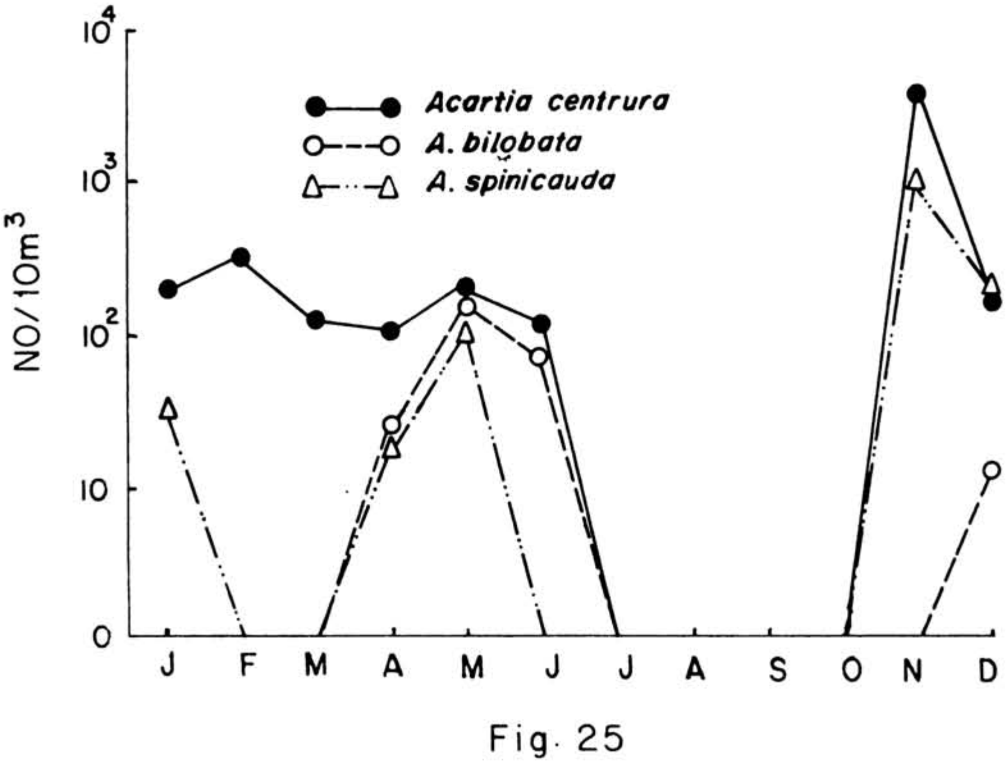


Fig. 25

Fig. 26. Distribution of common copepod species at Korapuzha.

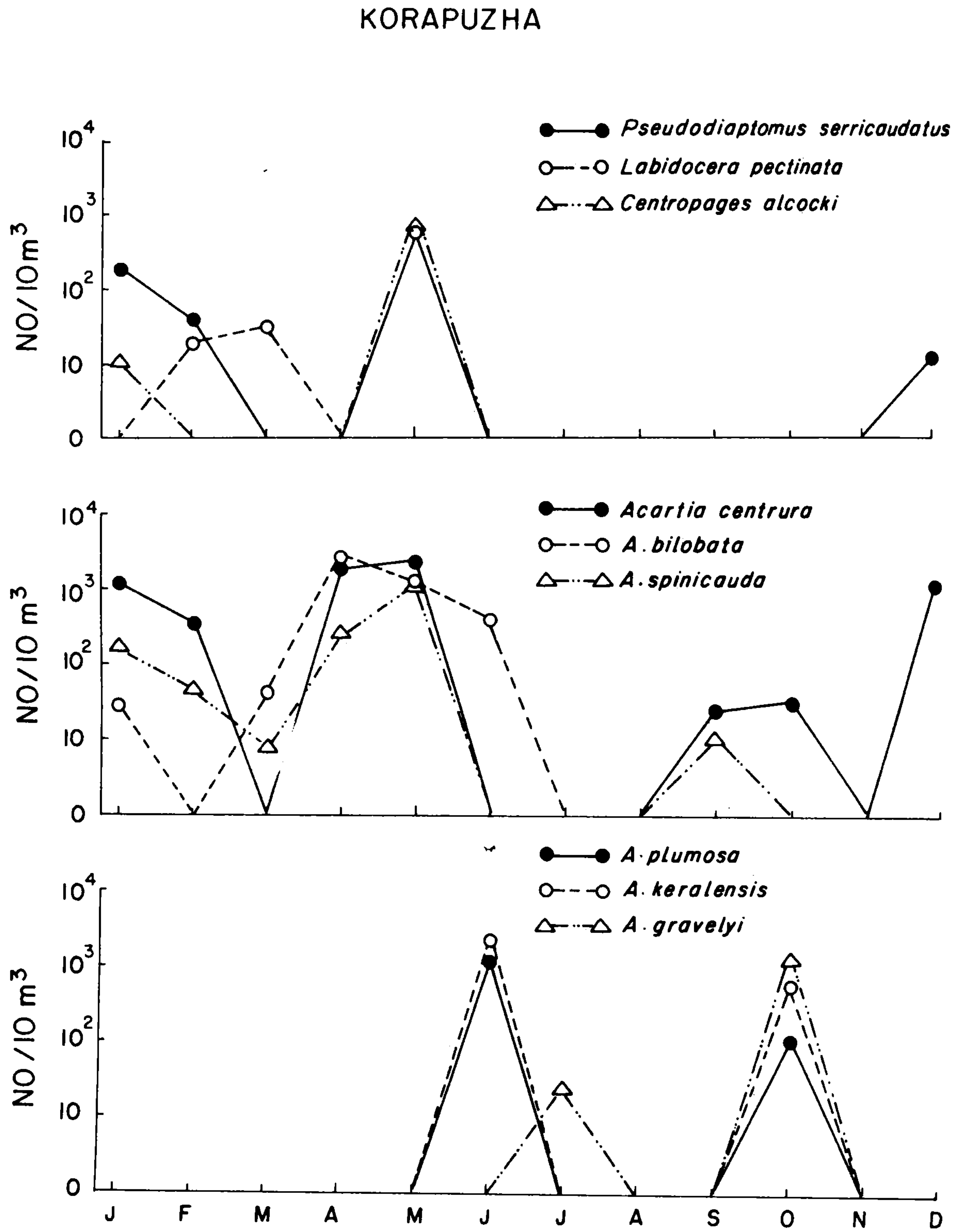

KORAPUZHA
Pseudodiaptomus serricaudatus
Labidocera pectinata
Centropages alcocki
Acartia centrura
A. bilobata
A. spinicauda
A. plumosa
A. keralensis
A. gravelyi
NO/10 m3
J F M A M J J A S O N D

Fig. 26

Fig. 27. Distribution of common copepod species at Mahe and Veli.

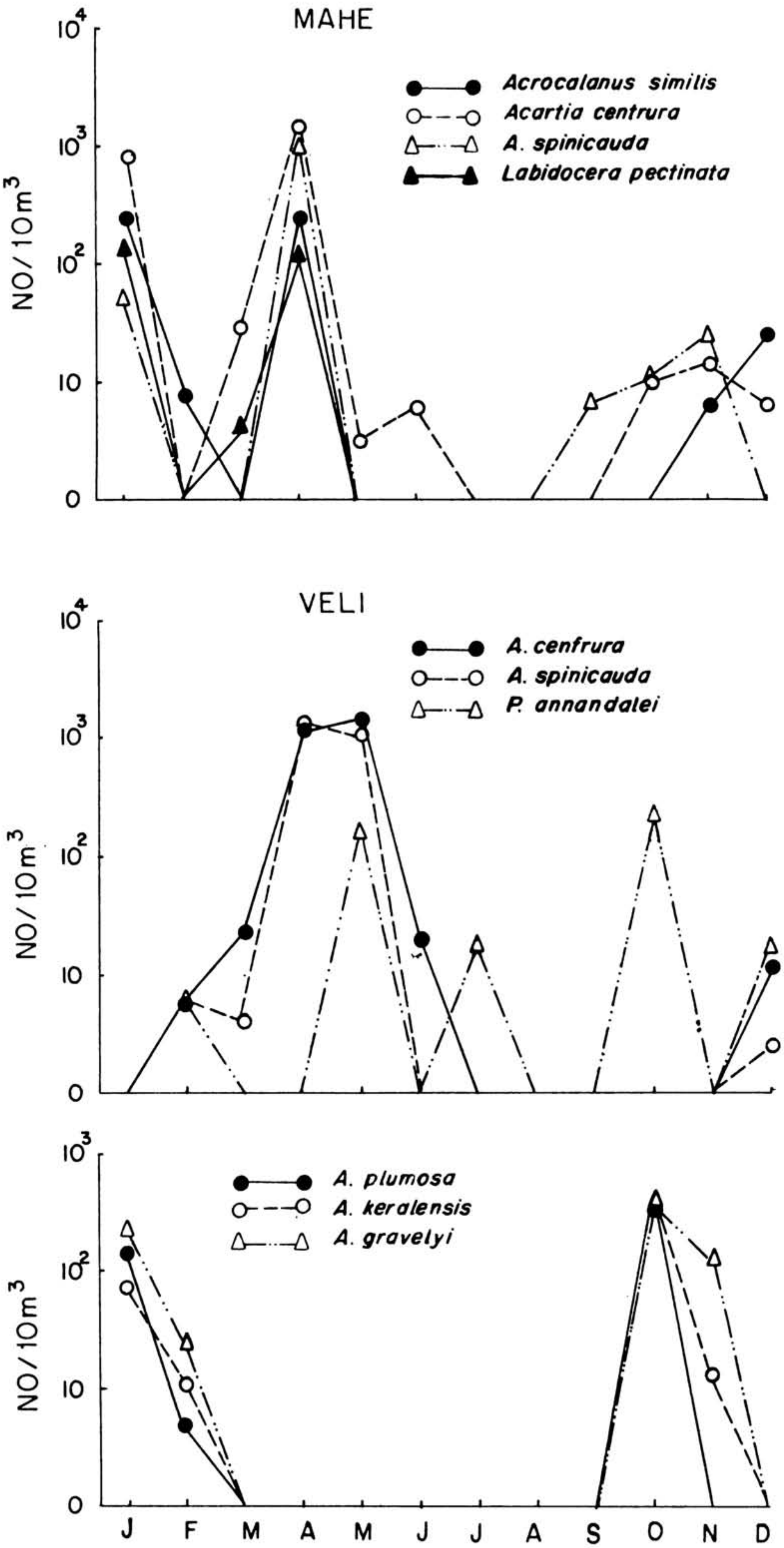
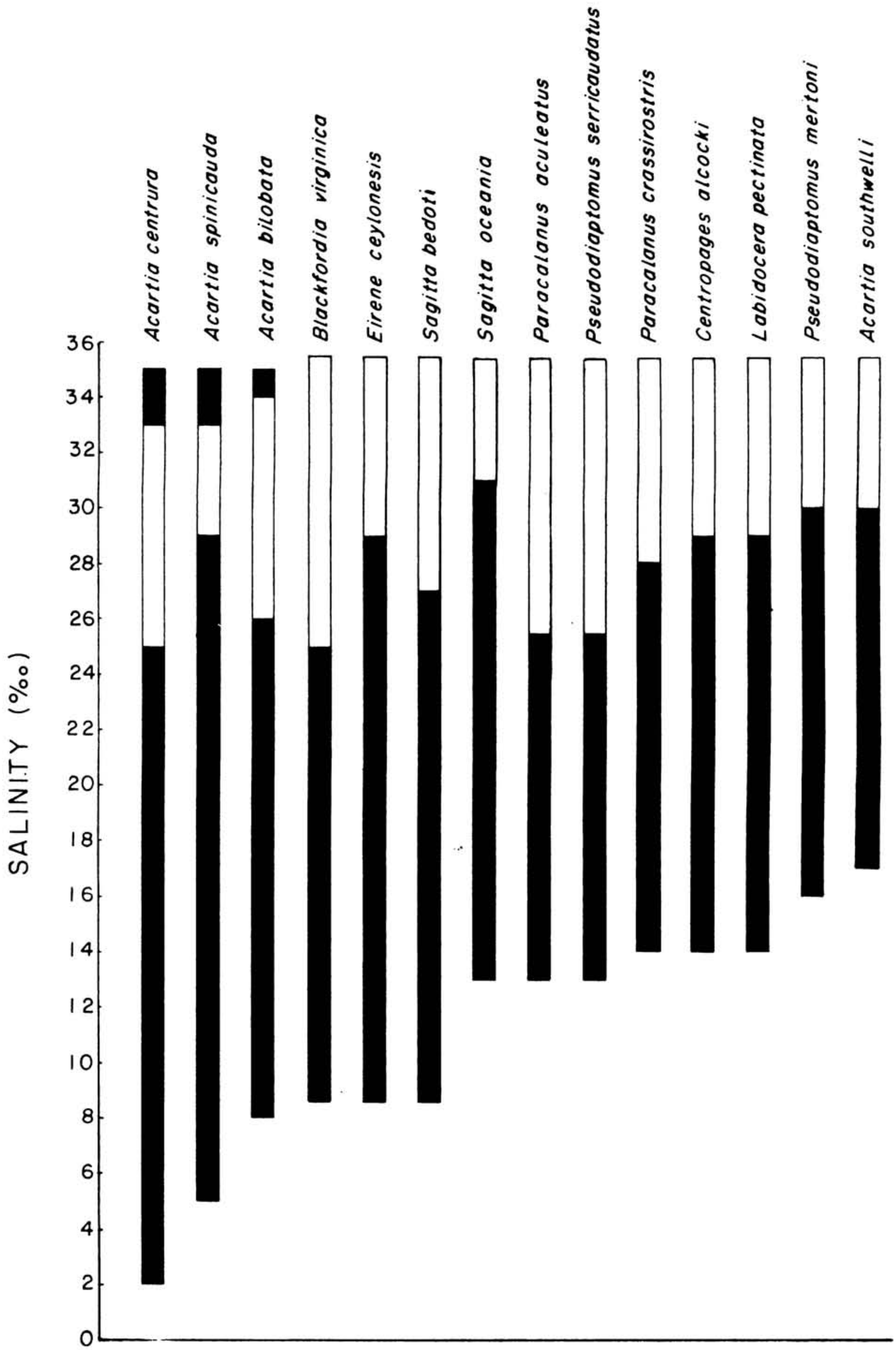

MAHE
Acrocalanus similis
Acartia centrura
A. spinicauda
Labidocera pectinata
VELI
A. cenfrura
A. spinicauda
P. annandalei
A. plumosa
A. keralensis
A. gravelyi
NO/10m3
10^4
10^3
10^2
10
0
J F M A M J J A S O N D

Fig. 27

Fig. 28 A. Salinity ranges of common zooplankton species.
(Blank space shows the optimum range).



Acartia centrura
Acartia spinicauda
Acartia bilobata
Blackfordia virginica
Eirene ceylonesis
Sagitta bedoti
Sagitta oceania
Paracalanus aculeatus
Pseudodiaptomus serricaudatus
Paracalanus crassirostris
Centropages alcocki
Labidocera pectinata
Pseudodiaptomus mertoni
Acartia southwelli
SALINITY (‰)
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0

Fig. 28A

Fig. 28 B. Salinity ranges of common zooplankton species.
(Blank space shows the optimum range).

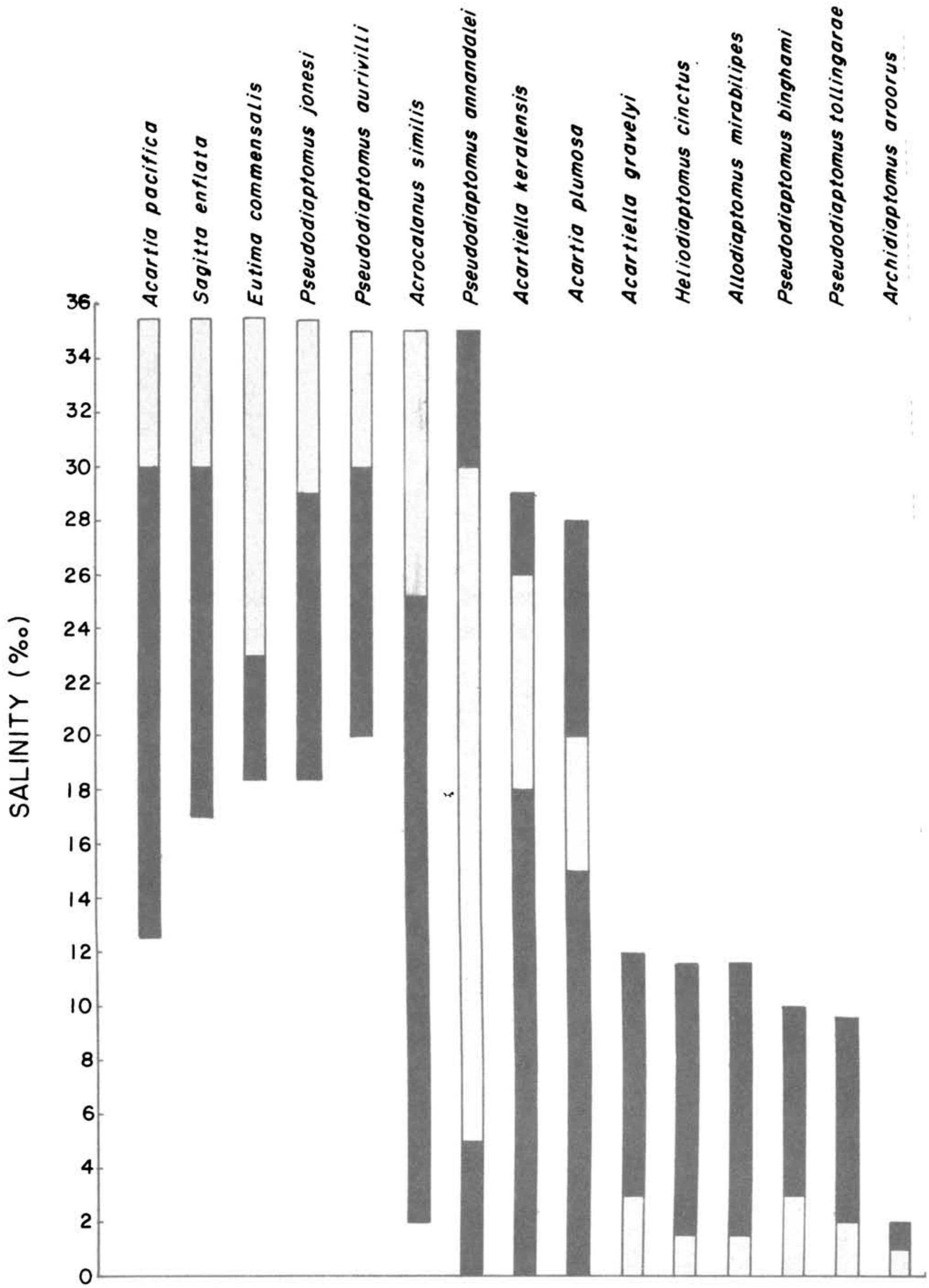

Acartia pacifica
Sagitta enflata
Eutima commensalis
Pseudodiaptomus jonesi
Pseudodiaptomus aurivilli
Acrocalanus similis
Pseudodiaptomus annandalei
Acartiella keralensis
Acartia plumosa
Acartiella gravelyi
Heliodiaptomus cinctus
Allodiaptomus mirabilipes
Pseudodiaptomus binghami
Pseudodiaptomus tollingarae
Archidiaptomus aroorus
SALINITY (‰)
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0

Fig. 28 B

Fig. 29 A. Curves showing gross surface primary production (adapted from Qasim *et al.*, 1969) and zooplankton standing stock in Cochin backwaters. The values are not strictly comparable, but the intention is to show the trends in productions.

Fig. 29 B. Curves showing relation between carnivores and herbivores in Cochin backwaters. The numbers of carnivores are magnified since they never occur in numbers comparable to herbivore abundance. Here also the purpose is only to show the relationship.

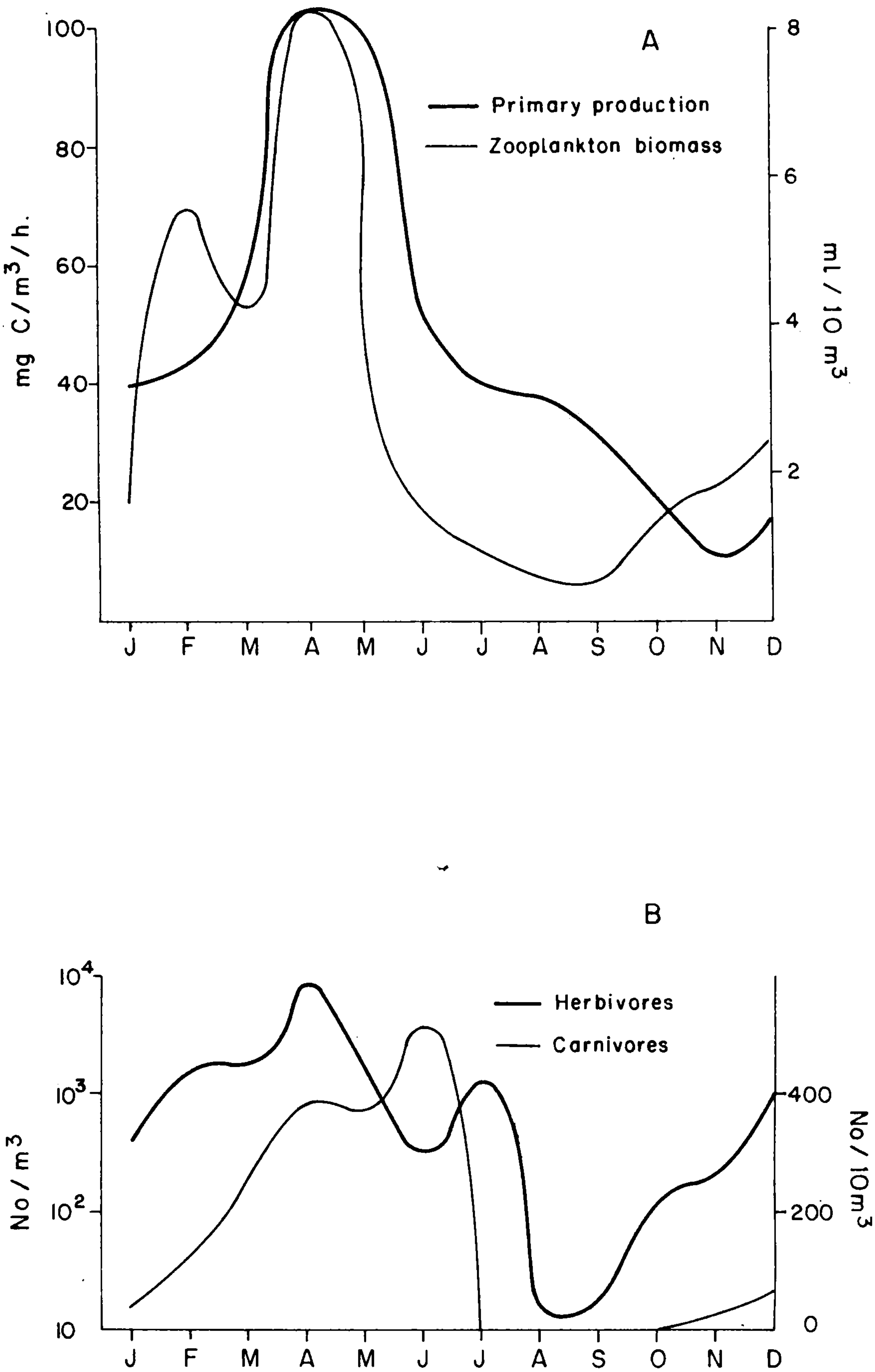

A
Primary production
Zooplankton biomass
mg C / m3 / h.
ml / 10 m3
100
80
60
40
20
8
6
4
2
J F M A M J J A S O N D
B
Herbivores
Carnivores
No / m3
No / 10m3
10^4
10^3
10^2
10
400
200
0
J F M A M J J A S O N D

Fig. 29

Fig. 30 A,B & C. Succession of species groups/species in the eight estuaries during 1978.

A - *Acartia centrura*
B - *Sagitta bedoti*
C - Caridean larvae
D - Other Decapod larvae
E - *Eutima commensalis*
F - Fish larvae
G - *Acartiella gravelyi*
H - *Corophium triaenonyx*
J - *Acetes* sp.
K - *Acartiella keralensis*
L - *Lucifer hanseni*
M - *Plurobrachia globosa*
N - *Pseudodiaptomus annandalei*
O - *Acartia bilobata*
P - *Paracalanus aculeatus*
R - *P. crassirostris*
S - *Evadne tergestina*
T - *Oithona nana*
U - *Acartia plumosa*
V - *Acartia spinicauda*
W - *Pseudodiaptomus aurivilli*
X - *Heliodiaptomus cinctus*
Y - *Allodiaptomus mirabilipes*
Z - Zoea larvae

....

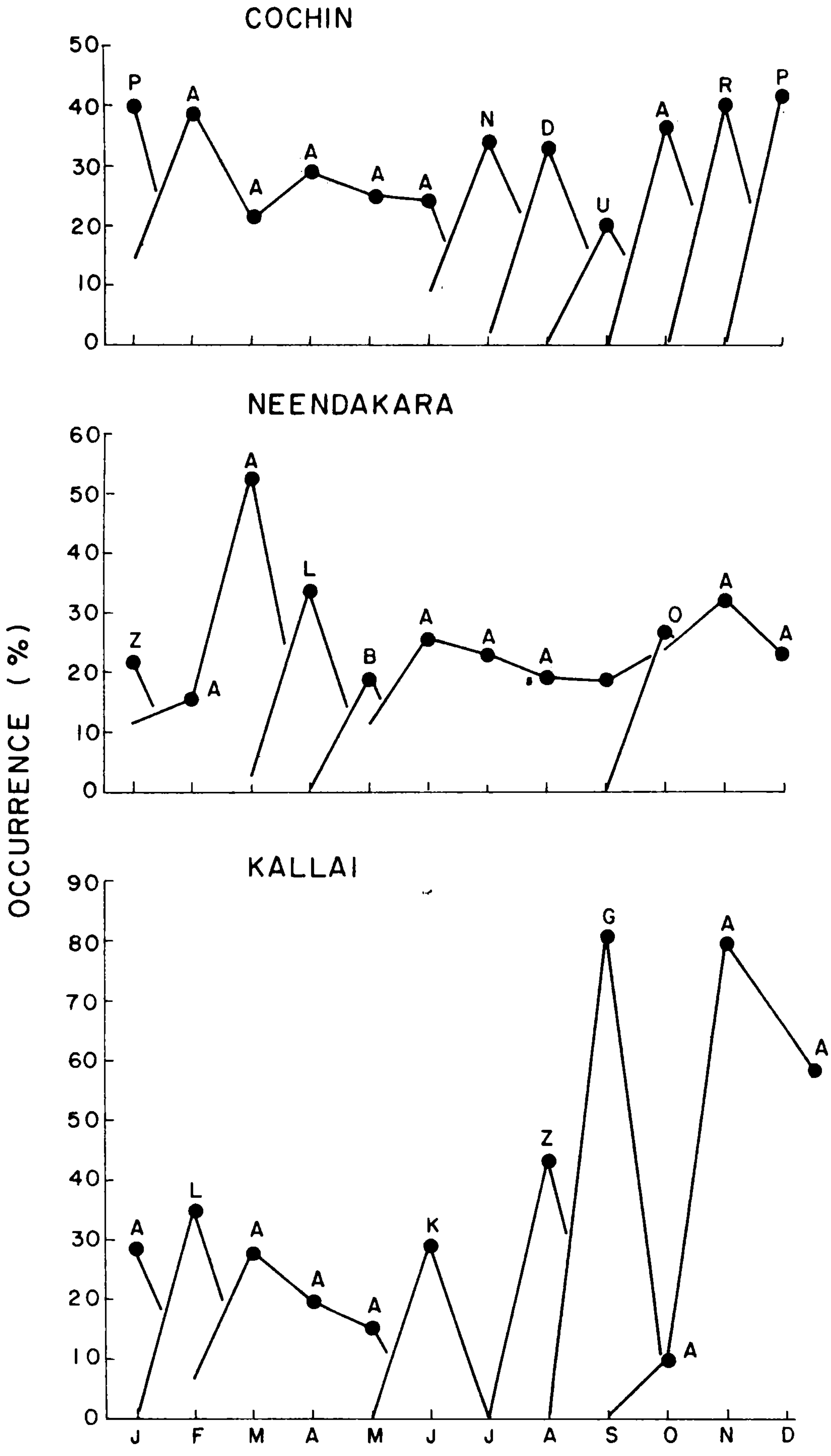

COCHIN
NEENDAKARA
KALLAI
OCCURRENCE (%)
P
A
N
D
U
R
Z
L
B
O
G
K
J F M A M J J A S O N D

Fig. 30 A

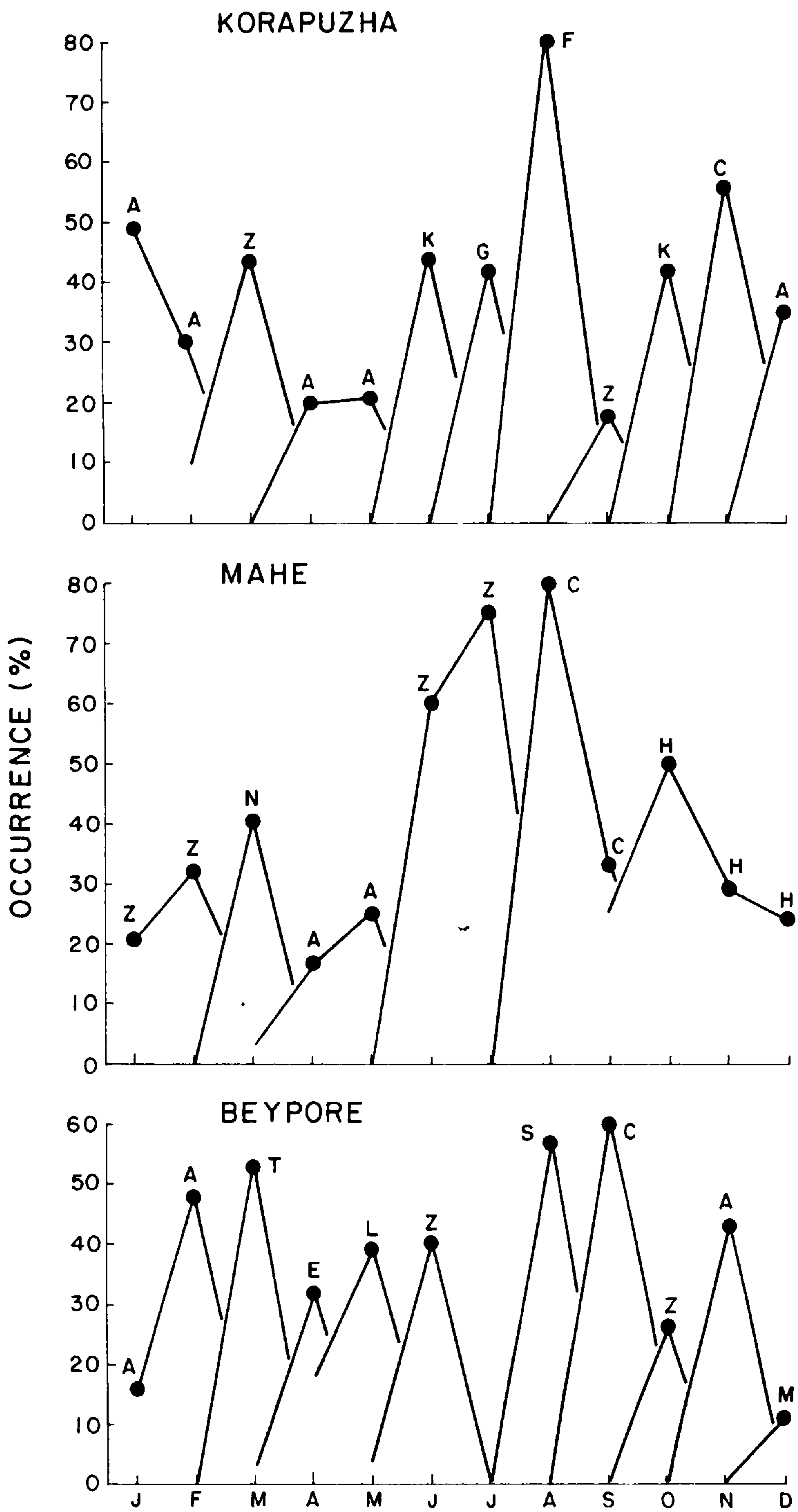

KORAPUZHA
MAHE
BEYPORE
OCCURRENCE (%)
0
10
20
30
40
50
60
70
80
J
F
M
A
M
J
J
A
S
O
N
D
A
Z
K
G
F
C
N
H
E
T
L
S
M

Fig. 30 B

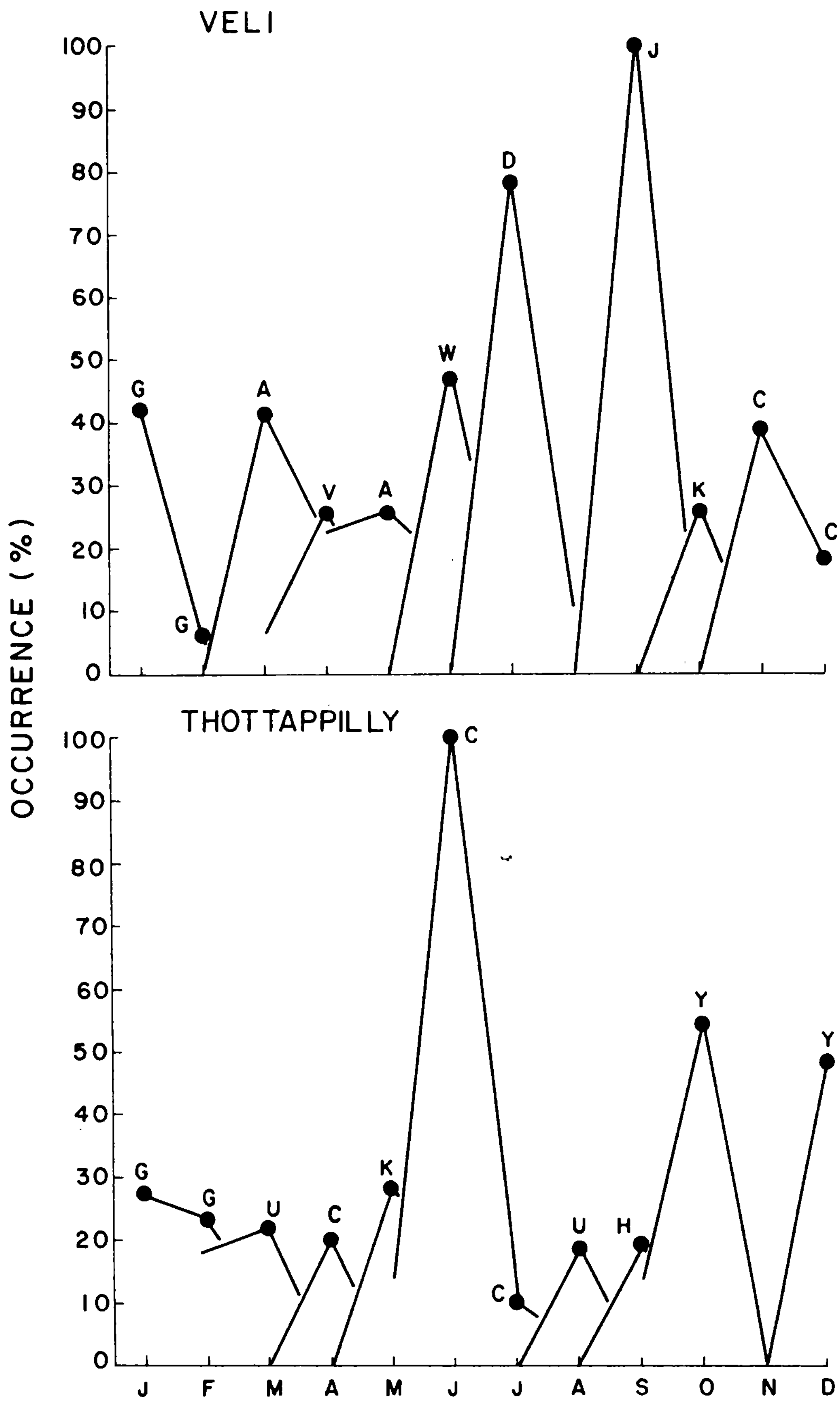

VELI
THOTTAPPILLY
OCCURRENCE (%)
0
10
20
30
40
50
60
70
80
90
100
G
G
A
V
A
W
D
J
K
C
C
C
U
C
K
C
U
H
Y
Y
J
F
M
A
M
J
J
A
S
O
N
D

Fig. 30 C

Fig. 31. Number of species and salinity distribution in the Cochin backwater system.

COCHIN BACKWATERS

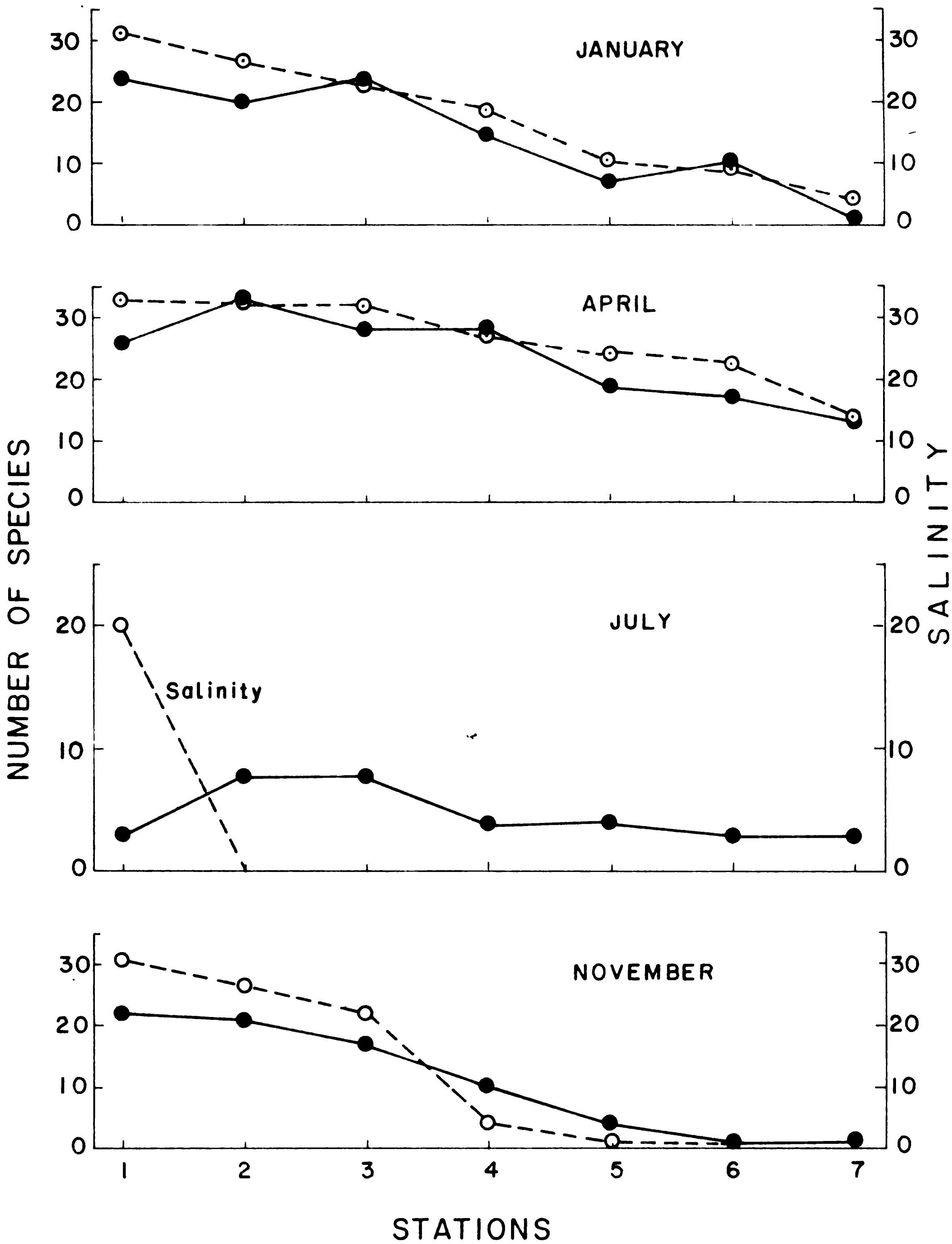


Fig. 31