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 forms, and to a lesser extent stenohaline forms 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 (Brownlee, 1960; Fisher and Yates, 1957). The model used for the analysis was

$$Yijkv = \mu + \alpha i + \beta j + \gamma_k + \delta ij + \delta ik + eijk + Zijkv$$

where

μ = Grand mean

αi = i^{th} species effect

βj = j^{th} station effect

γ_k = k^{th} month effect

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

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

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

eijk = 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 Zijkv = 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. Korapuzha 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 become 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 200 to 48500/10 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, 98.9% at Mahe, 74.5% at Veli 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 2 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 zooplankton 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 zooplankton 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. 12-27. Seasonal distribution of major groups in the estuaries is presented in Table 5. (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 Veli (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 sommensalis, E. neucaledonia, Eirene menoni, E. ceylonensis and Eucheilota menoni were identified in the present study. Among these Eutima sommensalis, 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 sommensalis 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 E. 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 neucalidonia 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 (Kale and Gae, 1935). Eutima commensalis is confined to the estuarine waters only. The other species which occurred at the mouth of estuaries are neretic.

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 copepoda (they formed only 1.8% 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 7595/10 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 subtaloidea was observed at Neendakara (26/10 m^3 in November). At Mahe L. subtaloidea was observed in May. Maximum abundance of this group was noted at Kallai (526/10 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 occurrences 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).

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

4.2.4. Chaetognaths.

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. oceania and S. robusta were identified from this system. Two more species - S. pulchra and Kronhitta 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. oceania 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. serrania 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 - 125/10m^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 Veli.

The three carnivorous groups viz. hydromedusae, ctenophora and Chaetognatha 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 chaetognatha 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 (Madhu-pratap 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.

4.2.6. 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 prefers 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 herbivores, 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 8,485/10m^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 (10,365/10m^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 (2,343/10m^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 (48) 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. 22-27. 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 Copepods 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 50% 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 at 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 3582/10m^3 respectively). At Kallai A. plumosa was observed only in November (10/10m^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 745/10m^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. ioneni 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. martoni and P. aurivilli. P. martoni was 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 - 35‰) 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 (545/10m^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. pinchani malayalus, P. tollingerae and Archidiaptomus aroorus were the low saline species belonging to family Pseudodiaptomidae. P. pinchani 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 aroorus

were observed during September and October respectively in small numbers. These two species were not encountered in other estuaries except A. *aroorus* 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 (542/10m^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. attenuatus 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 Korapuzha 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. helgae, O. rigida, O. brevicornis and O. plumifera and species of Corycaeus, Oncea and Sapphirina. Among the genus Oithona, O. nana and O. helgae were more common and exhibited tolerance to lower salinities. O. plumifera and Oncea 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 Microsetella sp. 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.

Copepoda of Veli and Thottappilly lakes:

Copepoda which constituted 69.5% 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 15 genera were observed, of them, 23 belonged to Calanoida while Cyclopoida and harpacticoida shared two each.

Maximum density of copepods 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 copepods dwindled to 12.7% (in July) of the total numbers. Copepods 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 mirabilimus 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 (355/10m^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 2.5‰ 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. ionesi, 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 (724/10m^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 negligens, Tortanus gracilis, Acrocalanus gibber in few numbers. Pseudodiaptomus binghami malayalus was also present and showed the maximum density in this month (25/10m^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. spiniscuda, Acrocalanus similis, Pseudodiaptomus serricaudatus, P. aurivilli, Centropages sleocki 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 552/10m^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 copepods (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 copepods. At Kallai these families contributed to 88.6% of the total copepod counts, Acartiidae being 72.5%, Pseudodiaptomidae 7.5% 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 copepods. At Beypore it formed 9%. Family Paracalanidae constituted 20.5% and 8.9% in these two estuaries respectively. 89.8% of the total copepods was constituted by these three families at Neendakara, Acartiidae contributing 67.6%, Pseudodiaptomidae 14.5% and Paracalanidae 7.7%. At Veli they formed 79.3%, 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 Bhotia 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 Rhotia 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 (2880/10m^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 Veli 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 Veli 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, Korapuzha 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 226/10m^3 in August.

4.2.12. Ascidia.

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 17.9% of the total annual counts at Mahe estuary followed by Veli (15.6%), Beypore (14.7%), Neendakara (11.4%),

Kallai (9.3%), 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 269/10m^3 respectively). At Kallai and Veli maximum density was in May (1471/10m^3 and 850/10m^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 pre-monsoon and postmonsoon periods. They were more

abundant in the Cochin backwaters, and maximum density was recorded in December (4490/10m^3). At Beypore also highest density was in this month (1004/10m^3) (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 (41/10m^3). Phyllosoma larvae occurred at Neendakara estuary in April (32/10m^3 - Table 7).

Cirripeda larvae were present in these estuaries except at Thottappilly. They were present throughout the year in Cochin backwaters except in July (maximum density - 360/10m^3 in February). In the other estuaries these were observed only during the premonsoon months and June. Highest density was in Kallai estuary in April (1404/10m^3). At Beypore, Neendakara and Veli 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 (588/10m^3) in March.

Larvae of fishes mainly belonging to the families Ambassidae, Mugilidae 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 (2410/10m^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 salp 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 60‰, 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/m^3 (maximum 4 ml/m^3) and counts of 92,000/m^3 (maximum 286,000/m^3) from Vellar estuary during summer months. Grindley and Wooldridge (1974) recorded the density of a single estuarine copepod Pseudodiaptomus charteri as high as 42,700/m^3. 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/m^3 and counts were between 98 and 1091/m^3 in a nearshore environment in the southwest coast of India (Haridas et al., 1980). Representative figures show that the average biomass ranged between 0.07 and 0.08 ml/m^3 (Nair et al., 1977) and 0.09 and 0.3 ml/m^3 (Nair et al., 1981) in the Bay of Bengal and 0.09 and 0.1 ml/m^3 (Nair et al., 1978) in the Arabian Sea. In the Andaman Sea the range was from 0.02 to 0.1 ml/m^3 and with counts of 7 to 14/m^3 (Madhupratap et al., 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 et al., 1969; Radhakrishna et al., 1978 a,b; Bhattathiri et al., 1980), but because many of the estuarine organisms are

omnivores and feed on detritus and bacteria as well (see Chapter 5). 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 a s 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, A cartiella 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. tollingeras and Archidiaptomus armorus 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 those 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 (Konnur et al., 1981).

The zooplankton counts of the Kali estuary were reported to vay 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 Currie, 1958) and York river, U.S.A. (Jeffries, 1964). Polychaete larvae form the major compnent 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 Brachura have been reported to dominate the zooplankton of Cochin backwaters (Madhupratap, 1978) in certain months. In the present collections decaped 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 Veli during January-February months when salinity was between 2‰ (surface) and 15‰ (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 35‰). 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 could be expected but a