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. Neendakara or Ashtamudi estuary at Quilon, Cochin backwaters at Cochin, Korapuzha, Kallai, and Beypore estuaries at Calicut, and Mahe estuary near Tellicherry. 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

was low but bottom salinity
Veli, the surface 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 attain 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 Thottappilly 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 heterogenity 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.
