SUMMARY

Studies on meiofauna have acquired considerable importance in the recent past in the context of pollution monitoring throughout the world. There is great paucity of scientific information on the meiofauna of Indian coasts. The study reported in this thesis is an attempt to describe the ecology, distribution, composition and community characteristics of estuarine meiofauna in the context of aquatic pollution in India. This study was carried out in the Poonthura and Adimalathura estuaries on the south west coast of India during February 1991 to January 1992.

The thesis can be summarised as follows.

Chapter 1. GENERAL INTRODUCTION

Describes the role of meiofauna in benthic food web and its importance in biogeocoenosis. The uniqueness of estuarine biotopes, especially of the Kerala coast and the impact of pollution as a result of persistant anthropogenic activities in these biotopes have been described. Based on these aspects, the relevance and objectives of the study have been formulated.

Chapter 2 REVIEW OF LITERATURE

A brief review of literature on meiofaunal studies have been attempted. Studies relating to the various aspects of meiofauna of the last few years have been reviewed on geographical as well as chronological basis.

Chapter 3 THE STUDY SITES

The two study sites and different stations selected for the investigation have been described in detail.
Chapter 4 MATERIAL AND METHODS

Methods adopted for the collection, enumeration, identification and analysis of meiofauna have been given in detail. Descriptions on the methods adopted for the determination of physico-chemical parameters and sedimentological parameters have also been given.

Chapter 5 METEOROLOGY, HYDROGRAPHY AND SEDIMENTOLOGY.

Discusses the environmental status of the nine selected stations, their hydrobiological and sedimentological characteristics.

Environmental status

The biotopes selected for the study receive precipitation from south-west as well as north-east monsoons. Precipitation is heavy during south-west monsoon season. Relative humidity ranged between nil and 15% in the Poonthura estuary whereas in the Adimalathura estuary it ranged between 5% and 17%. Sand bar at the inlet of the estuary is an important factor which control the health of the estuary. During the course of removal of sand bar, the polluted water in the estuary gets flushed out periodically. Maximum air temperature was recorded during the premonsoon months and low temperature during the monsoon and early postmonsoon seasons. The lowest values recorded during monsoon period were followed by a period of recovery during postmonsoon owing to the gradual decrease in rainfall and cold weather conditions.

Hydrography

The water temperature also exhibited variation following rains during the two monsoons and the consequent river discharge. Maximum water
temperature was recorded during the summer season and minimum during the monsoon season. Vertical stratification in temperature was not prominent due to the shallowness of the estuary. The temperature of water was controlled by atmospheric temperature and any change in the atmospheric temperature was reflected in the water temperature.

Marked seasonal variations were observed in the transparency of water. Due to heavy rains, river discharge, land drainage and low intensity solar radiation, low transparency values were observed during the monsoon season. Relatively low secchi depth values were recorded in almost all the stations.

The water depth in all stations was closely related to the opening and closure of the estuarine inlet, rainfall and river discharge. The depth of the water column was high when the sand bar remains closed for longer durations or on heavy rain and river discharge.

The spatial distribution of pH develops a zonal trend with high values in the marine end decreasing to the minimum figures in the freshwater end. Station II receiving large quantities of sewage also contained waters of relatively low pH. The bottom water pH was generally higher than the surface water pH and the monsoon period registered the least values. Though there were significant variations in pH between different stations, seasons and months, both the surface and bottom water pH fell within the safe range prescribed by ISI.

A marked longitudinal gradient of decreasing salinity was evident from the inlet to the interior of the estuaries. Salinity was found comparatively high in all stations within both the estuarine systems when the estuarine inlet remained open for longer durations irrespective of seasons. The salinity
distribution was influenced mainly by sea-estuary interaction consequent to the opening of inlet, besides rainfall and river discharge. The range of variation in salinity between different stations was wide in both surface and bottom waters and the range of variation between surface and bottom was also wide especially during non monsoon months.

No significant variations were observed in nitrate concentrations at different stations, seasons and months. Correlated with rainfall and river discharge higher concentrations of nitrate were recorded in June, July and November. Nitrate concentrations always showed wide fluctuations at different stations and an appreciable increase was observed at the sewage contaminated stations.

High values of nitrites were observed during the monsoon or rainy post monsoon months due to the active rainfall and consequent land drainage. Very high values of nitrite were observed at Station II attributed to sewage contamination consequent to the discharge of city wastes from the sewage farm.

The concentration of phosphate was reduced to its minimum during the premonsoon period. Maximum phosphate concentrations were during the postmonsoon season at Stations I to IV and at Stations V to IX maximum concentration was during the monsoon period. There were significant variations in concentration between different stations, seasons and months and Station II showed higher values owing to the discharge of wastes from sewage outfall.

Maximum concentration of silicate at Station II was attributed to the allochthonous addition of this nutrient by domestic sewage. A gradual increase
in silicate concentration was observed from the marine stations to the upstream stations. The occurrence of higher concentration of silicate was always in the surface water and a negative relationship between salinity and silicate was evident. The river water plays a major role in maintaining higher concentration of silicate.

Due to the high photosynthetic activity and higher solubility of oxygen in lower salinity surface water the oxygen content of the surface water was always higher than the bottom water. The concentration of dissolved oxygen at Stations II, III and VII was lower than other stations due to the mixing of sewage fed water. The high input of wastes at Station II resulted in near eutrophication and total depletion of dissolved oxygen was noted during February 1991. All the stations recorded the highest values of oxygen during the north-east monsoon (Oct - Jan) season.

Though detectable amount of hydrogen sulphide was present at the Stations I, II, III, VII and IX, considerable amounts of \( \text{H}_2\text{S} \) in all seasons were found only at Stations II and III. The presence of \( \text{H}_2\text{S} \) was seen linked with the depletion or a gradual decrease of dissolved oxygen as the concentration of \( \text{H}_2\text{S} \) is increased. The concentration of \( \text{H}_2\text{S} \) was particularly very high at Station II and led to the emergence of an anoxic condition covering the entire water column once during the study which lasted hardly for a month.

**Sedimentology**

The temperature variation is less extreme at greater depths in the sediment. Sediment temperature generally followed the trend of atmospheric temperature throughout the year. When the air temperature was lower, the cooling of sediment surface being marked at all stations.
The redox state in a given place is determined, of course by the input of organic matter. The marine and riverine sediments are less reduced than estuarine sediments. The most surprising situation was observed at Station II, which being located near the entrance of sewage fed water, exhibit highly reduced conditions together with very low oxygen and high hydrogen sulphide in the overlying water.

Spatial variation of organic carbon indicates its low values at the upstream regions and marine stations. Due to flooded conditions and low productivity percentage of organic carbon was low at all stations during rainy months. Due to sewage discharges and clayey nature of the sediment, Station II had high percentage of organic carbon and the values sometimes exceeded the 5% limit fixed for unpolluted estuaries.

From the estuary inlet with its generally coarse bottom sediments, there usually exists a gradation towards finer material in the head of the estuary. The marked difference between samples are due to the difference in environmental conditions like wave, wind energy etc. that are responsible for sediment transport and deposition. The sediment samples at all stations except at Stations I, II and VII fall under the major textural class of sand. The deposition of sandy sediments is due to the fact that main channel area is influenced by the sea, and the sea bed sediments are intruded into the estuary by the tidal wave through the inlet. Station I located on the upstream region is mainly characterised by weak tidal currents and heavy land drainage. Station II and VII are noticeable for its greater deposit of silt fraction due to the great amount of sewage mixed water reaching at these stations and due to heavy land drainage.
A detailed account has been given on the relative abundance, spatial and temporal distribution, systematic position, population characteristics and ecology of meiofauna.

**Density, abundance, composition, spatial and temporal variations**

Qualitatively and quantitatively, the meiobenthic organisms were considerably poor in the two biotopes. The meiofauna was composed of 12 groups namely Foraminifera, Turbellaria, Kinorhyncha, Nematoda, Oligochaeta, Polychaeta, Archiannelida, Ostracoda, Copepoda, Amphipoda, Arachnida and Bivalvia. All the 12 groups were not present at any of the stations. However, 11 groups were present at Station IV, 10 groups each at Stations II and VIII, 9 groups each at Stations III, V and IX, 8 groups at Station I, 7 groups at Station VI and 5 groups at Station VII. Foraminifera, Nematoda, Ostracoda and Copepoda were present in all stations.

Spatial analysis revealed that total meiofauna and all major groups differed in densities between stations. In general meiofaunal content was high at the marine and estuarine (near estuarine inlet) stations compared to upstream stations. Average density was maximum at Station V and minimum at Station VI. The considerable scarcity of total meiofauna and different meiofaunal components demonstrate the polluted conditions of the biotopes especially of the organic rich stations. Nematodes are relatively resistant to pollutants and at Stations II, III and IV they contributed more than 60% of the total fauna.
A distinct feature of Indian beaches is the influence of the monsoon which adversely affect the density of the fauna. Temporal variation is identifiable for all groups at all stations. Maximum density was observed in January and minimum in June. Population density at all stations gradually began to increase from February to May whereas from June onwards a reduction in population density was observed. A reduction in meiofaunal density during the monsoon was due to strong winds, strong wave action, high turbulence and low salinity. High densities of major meiofaunal components (nematodes, foraminiferans and copepods) were also during the premonsoon and the late postmonsoon months. The monthly as well as seasonal variations of meiofauna were found to be significant at 5% level.

**Taxonomic position of meiofauna**

Nematoda was the most dominant group and was composed of 12 families namely Thoracostomopsidae, Anticomidae, Oncholaimidae, Enchelidiidae, Cyatholaimidae, Comesomatidae, Desmodoridae, Epsilonematidae, Leptolaimidae, Ceramonematidae, Desmoscolecidae, and Xylidae. Foraminifera was the second dominant group and was composed of 6 families namely Lituolidae, Textulariidae, Miliolidae, Rotalidae, Nonionidae and Globigerinidae. Oligochaeta was composed of a single genera *Enchytreus* and the polychaete population was composed of 2 families - Pisionidae and Nereidae. Archiannelid belonged to families Polygordidae and Protodrilidae. Ostracoda belonged to the genus *Stenocypris* only. Copepod population was represented by 3 families such as Thalestridae, Ameiridae and Cyanthocamptidae and the amphipod community was represented by the family Gammaridae.
Distribution and ecology of major meiofaunal groups

The Foraminifera formed the second dominant component of meiofauna. Abundance of Foraminifera was associated with substratum with varying percentage of silt and clay at the downstream and marine stations, where the sandy bottom prevailed. Their maximum abundance was at the marine stations. The foraminiferans showed the highest density during the postmonsoon months and the minimum during the monsoon period. Variation in the population of Foraminifera between stations and seasons were significant at 1% level.

The turbellarians and kinorhynchs were less abundant and were noticed only occasionally. The highest population density of these groups were observed at the marine and downstream stations and was totally absent at the riverine stations.

The Nematoda constituted the most dominant group and were present at all stations in almost all months. Nematode population showed an increasing trend in abundance from the silty zone to the sandy zone. The nematodes showed the highest density during the postmonsoon period and the lowest during the monsoon period and the variations in population density between stations, seasons and periods within seasons were significant at 1% level of significance.

The oligochaetes were almost absent during the premonsoon and monsoon seasons at all stations and the highest abundance was observed in October. It was rarely observed at the riverine stations and most of the population were encountered from the downstream stations with high salinity. Polychaetes were comparatively few in the collections and its maximum density was
recorded from Station III. Archiannelids were well represented at Station IX and were totally absent at Stations I, II, IV and VII. It was generally absent during the monsoon months and the distribution was maximum in February.

The ostracods formed an important component of the meiofauna during the present study. Though present at all stations, unlike other meiofaunal taxa, the regular occurrence of ostracods was seen only at freshwater and estuarine stations. Their maximum abundance was during the monsoon period at all stations.

The copepods formed one of the major components of the meiofauna. Though present at all stations, they were more abundant at the marine stations. The riverine stations recorded very low density and showing a picture of increasing density from the freshwater to the marine end. Their maximum abundance was noticed during the premonsoon months. Significant variations in density of copepods were observed between stations and seasons.

The amphipods, arachnids and bivalves were very few in the collections and any of these groups were not present regularly at any of the stations.

Species distribution of major groups

A total of 21 species of Foraminifera belonging to 12 genera were identified. The abundant species of Foraminifera during the study were *Elphidium advenum* (47.84%) and *Rotalia becarii* (23.61%). Other species in moderate abundance were *Textularia agglutinans* (8.36%), *Ammonia becarii* (variant) (4.88%), *Nonion boueanum* (3.05%), *Elphidium crispum* (2.5%), *Ammobaculis taylorensis* (2.01%) and *Globigerina dubia* (1.63%). All the arenaceous - agglutinated forms are essentially of freshwater and
estuarine habitat and oceanic sediments are characterised by calcareous forms. Calcareous species decreased in number in relation to the decreasing influence of sea water and the nature of the bottom.

Nematode fauna was composed of 17 species belonging to 15 genera. *Desmodora* was the most dominant (27%) with two species *D. extensa* and *D. inflexa*. Other dominant species were *Pterygonema ornatum* (15.28%), *Theristus alternus* (13.56%), *Mesacanthion armatus* (9.28%), *Sabatiera abyssalis* (7.24%), *Cyatholaimus ocellatus* (6.30%), *Enoploides labiatus* (4.73%), *Anticoma acuminata* (4.21%), *Sabatiera intermissa* (3.4%), *Leptolaimus* sp. (3.34%) and *Pontonema valviferum* (3.26%). Distribution and ecology of each species is discussed in detail.

Chapter 7 VERTICAL DISTRIBUTION OF MEIOFAUNA

The vertical distribution and ecology of total meiofauna and different meiofaunal groups have been discussed in detail.

The top 10 cm (0 -5 and 5 - 10 cm sections) had almost of the concentration, each contributing about 35% of the total population. Below this level the density of total meiofauna and varied meiofaunal components generally declined with increasing depth. The packing of sediment was found to influence the vertical distribution of meiofauna. Stations with higher percentage of sand had a higher percentage of fauna in deeper layers. Stations V, VII, VIII and IX had higher population density in the 5 - 10 cm layer. In riverine and organic rich environments the maximum density was within the surface layer (0 - 5 cm). Higher levels of organic matter affect the structure of the sediment, deteriorating the conditions for locomotion and influence vertical distribution. Meiofauna of the beach stations
appears to be more concentrated at the 5 - 10 cm levels where desiccation is not too severe and oxygen is available. Since the anoxic zone moves towards the surface, during summer the concentration of meiofauna was greater at the upper layers than other seasons.

Chapter 8 COMMUNITY STRUCTURE

The community structure of two most dominant groups Foraminifera and Nematoda have been discussed and the status of indicator species associated with sewage pollution have been indentified to the extent possible.

A considerable decrease in population size and the number of species of Foraminifera during monsoon months with low salinity was evident. Species diversity is relatively higher in the estuarine stations as compared with other stations. Low diversity values were observed in almost all stations due to the decreased population density. Dominance index was comparatively high at station II as a result of dominant species like Ammonia bacarii.

All the community indices of nematodes showed minimum values during monsoon and maximum during summer. Considerable change in community structure took place in monsoon, especially during June-July. Generally low diversity and density were recorded in the upper reaches of estuaries. Notable changes in community structure are associated with organic enrichment. At Station II observed a decrease in abundance as well as species diversity and an increase in species dominance, particularly when anoxic event and high nutrient enrichment were recorded. Moderate diversity, dominance, richness and evenness indices were recorded at almost all stations due to the low density of meiofauna. The total scarcity in the density of meiofauna may be due to the unhealthy nature of the system.
Pollution from organic enrichment had resulted in extreme environmental deterioration leading to the dominance of certain species. 3 species of meiofauna have been identified and assigned to the status of indicator species associated with sewage pollution in the organic rich stations of the present study. They are *Ammonia becarii*, *Desmodora extensa* and *Sabatiera intermissa*. 