J. mar. biol. Ass. India, 1987, **29** (1 & 2) : 177-194

ECOLOGY OF THE ASHTAMUDI ESTUARY, SOUTHWEST COAST OF INDIA

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ABSTRACT

Ashtamudi is the second largest estuary in Kerala covering an area of 32 Sq. km. Surface and bottom water characteristics from 4 stations have been analysed in the context of pollution from a paper mill effluents. The primary productivity, distribution and abundance of zooplankton and benthos have been studied in detail.

The average annual gross and net productivities in the surface water was maximum at Neendakara (St. 1) and minimum at Kadapuzha (St. 4). The zooplankton community consisted of 21 taxa, among them copepods constituted the most abundant group. Benthic fauna (56.95%) for the whole year was observed at Station 1 and lowest at St. 4 (0.87%). The study has brought to light the nature of impact of pollution in one of the productive estuaries in Kerala.

INTRODUCTION

THE ASHTAMUDI estuarine system (8°53′—9°02′ N and 76°31′—76°41′ E) with its eight major creeks is famous for its fishery resources (Fig. 1). The Kallada River enters the estuary after traversing for about 120 kms and the river carries an annual run off of 75,000 million m^3 of freshwater into the estuary. The estuary is polluted mainly due to the effluents from a paper mill situated on the banks of the Kallada River.

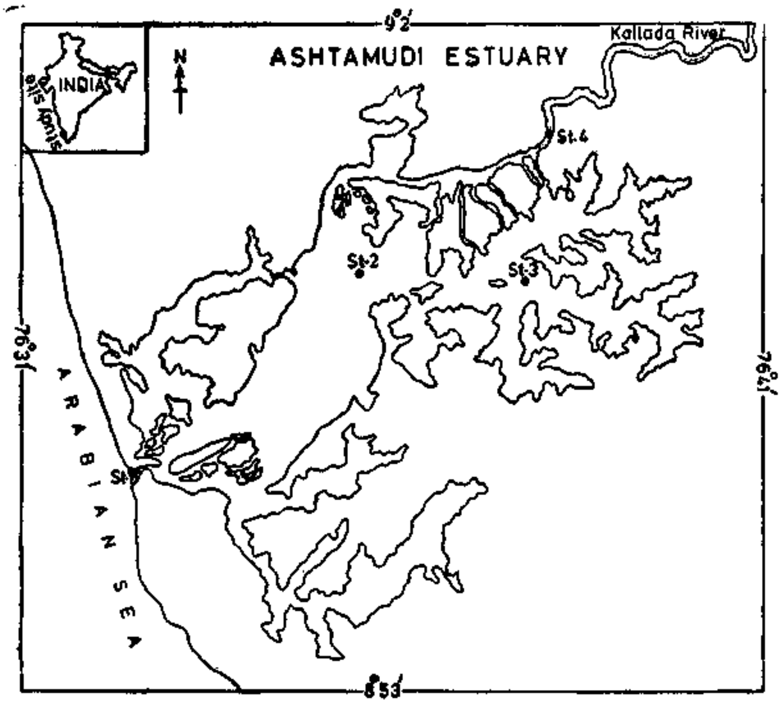

Fig. 1. Ashtamudi Estuary : 1. Neendakara, 2. Ashtamudi, 3. Kanjirakode and 4. Kadapuzha.

The present study, has been completed with the financial support of UGC and it is gratefully acknowledged.

MATERIAL AND METHODS

Observations were made covering the entire estuary including the downstream tract of the Kallada River. Fortnightly collections were taken during February 1980 to January 1981 from 4 selected stations *viz.* Neendakara (Station 1), Ashtamudi (Station 2), Kanjirakode (Station 3) and Kadapuzha (Station 4). The methods provided by Martin (1968), Strickland and Parsons (1972), Qasim *et al.* (1969) were used for the collection and analysis of samples pertaining to hydrographic data and primary productivity. Tranter (1960) was followed for the study of plankton and Holme and McInytre (1971) for the study of benthos.

RESULTS AND DISCUSSION

Hydrobiology

The data on rainfall and river discharge show a distinct seasonal variation (Fig. 2) and agrees with the findings of Haridas *et al.* (1973) and Abdul Azis and Nair (1980) from other backwater basins in Kerala. Based on rain fall, the year has been divided into the pre-monsoon, the monsoon and the post-monsoon periods. There was variation in temperature between surface and bottom layers following heavy rains and river discharge (Fig. 3).

The pattern of temperature variation at the Ashtamudi Estuary was found similar to the distribution pattern observed by Pillai (1974) in the Cochin Estuary. Light penetration was minimum at all stations during the monsoon season (Fig. 4). The present data (Fig. 4) reveal that the water at St. 4 was extremely turbid throughout the year. The size of the euphotic zone at station 1 ranged from 1.8 to 5.62 m ; at station 2 from 1.34 to 6.57 m ; at station 3 from 0.85 to 6.84 m and at St. 4 from 0.45 to 4.15 m which were more deeper than the sutdy localities of Qasim *et al.* (1968) in the Cochin Estuary and Qasim (1979) in the Mandovi Estuary where the range was 2 to 6 m and 1 to 4 m respectively. Surface and bottom waters were generally alkaline at all stations (Fig. 5) except for a brief acidic phase at stations 3 and 4 in July. A period of great fluctuations in salinity is flanked by periods of lesser fluctuations (Fig. 6). The surface and bottom water salinities diminished progressively from the estuary mouth (St. 1) to the riverine zone (St. 4). The entire water body is thus virtually stratified on the basis of salinity.

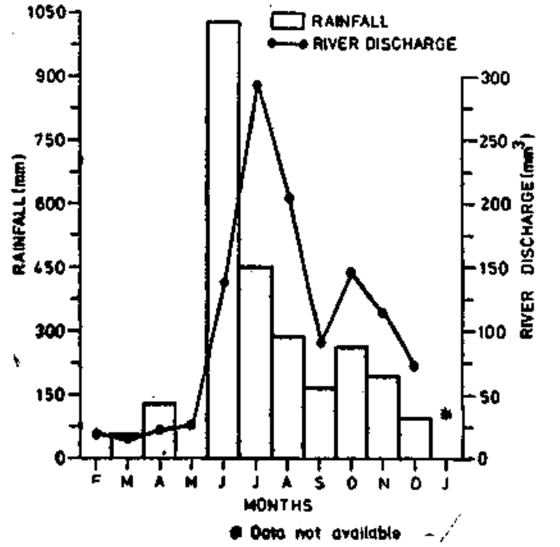

Fig. 2. Rainfall and river discharge.

Wide fluctuations and even total oxygen depletion were characteristics of the oxygen regime (Fig. 7). At station 4 pre-monsoon was particularly a period of intense pollution resulting in very low oxygen values. The oxygen depletion is believed to be caused by the paper mill effluents and entrophication.

Variations in the surface and bottom water phosphate-phosphorus, nitrate-nitrogen, nitrite-nitrogen and silicate-silicon are shown in

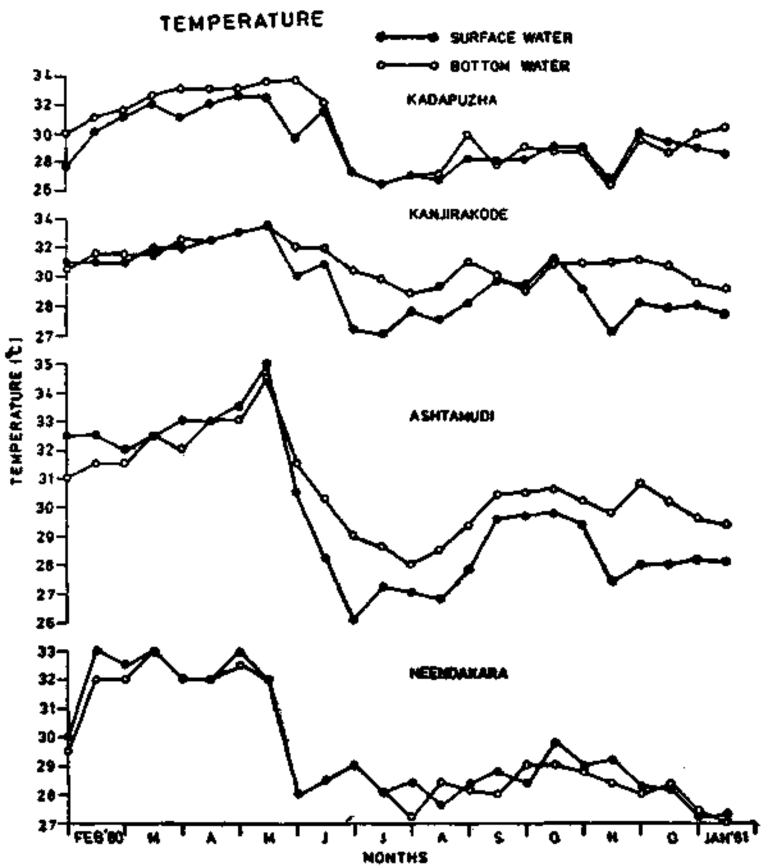

Fig. 3. Seasonal variation in the surface and bottom water temperature during 1980-'81.

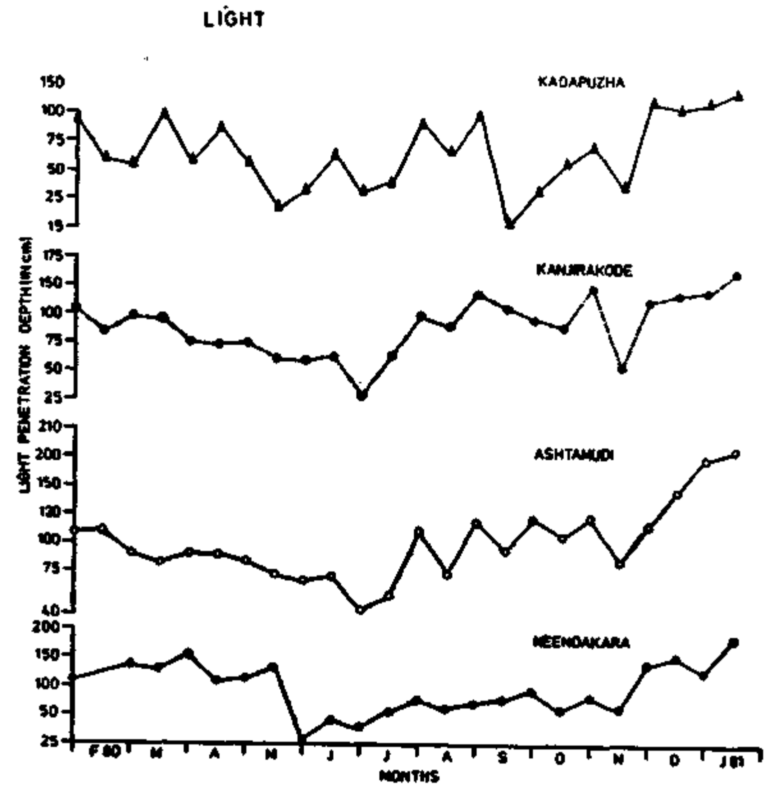

Fig. 4. Light penetration in the Ashtamudi Estuary during 1980-'81.

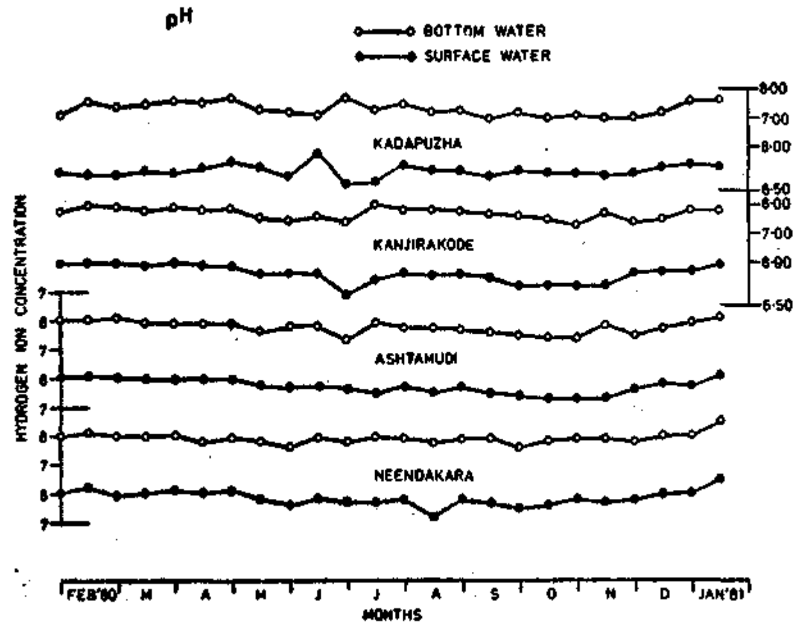

Fig. 5. Hydrogen-ion-concentration in the surface and bottom waters of Ashtamudi Estuary during 1980-'81.

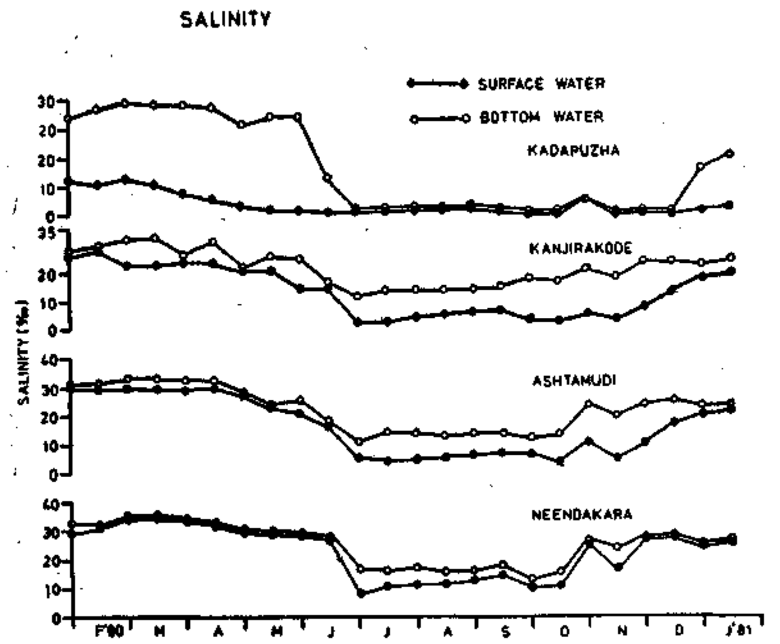

Fig. 6. Salinity variation in the surface and bottom waters of Ashtamudi Estuary during 1980-'81.

Figs. 8, 9, 10 and 11 respectively. According to Mortimer (1942) and Rittenberg *et al.* (1955) sediments in estuaries trap 80-90% of phosphorus and release the same to the overlying water. In the Ashtamudi Estuary rainfall followed by river discharge lead to massive transport of sediments. Consequently, the phosphate phosphorus values, increased culminating in peak values in the post-monsoon period. Nitrate-nitrogen in the surface and mum at St. 4 throughout the year and minimum at station 1 during the monsoon and post-monsoon periods (Fig. 10). Silicate-silicon showed high values throughout the estuary (Fig. 11). Average values showed an increasing trend from station 1 to 4 both in the surface and bottom waters. The surface water was always higher in silicate concentration, maintaining a stratification similar to the one observed in the case of other parameters.

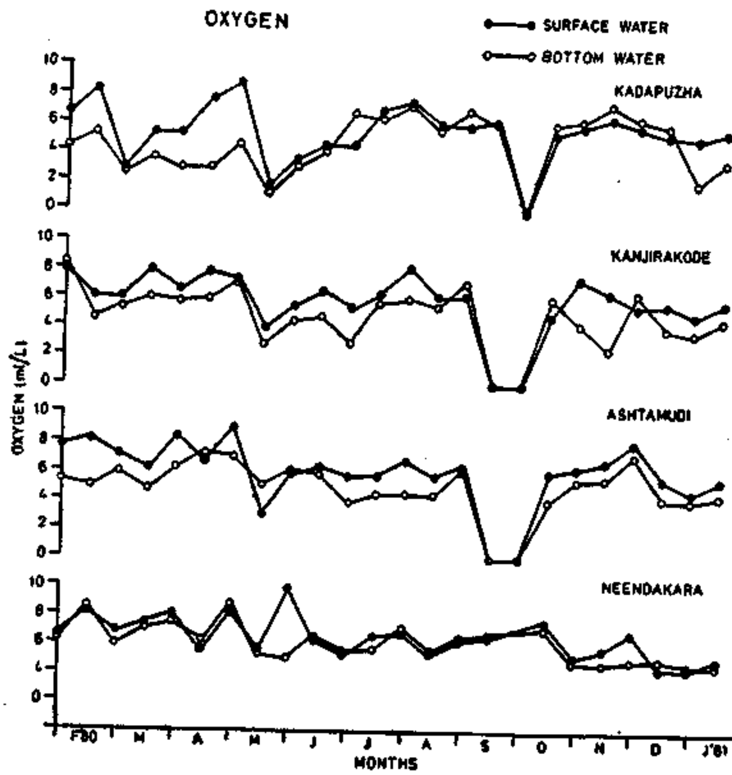

Fig. 7. Dissolved oxygen in the surface and bottom waters of Ashtamudi Estuary during 1980-'81.

bottom waters was maximum at station 4 and minimum at station 1 indicating a clear upward trend from the marine to the riverine zone. The concentration of nitrate was always high at the polluted river tract indicating the influence of river water and the decomposition of organic matter. The nitrite-nitrogen was also maxi-

Primary productivity

The average annual gross and net productivities in the surface water was maximum at station 1 and minimum at station 4, the other stations showing a transitional situation. The average net productivity was maximum at station 2 and minimum at station 4. A seasonal cycle

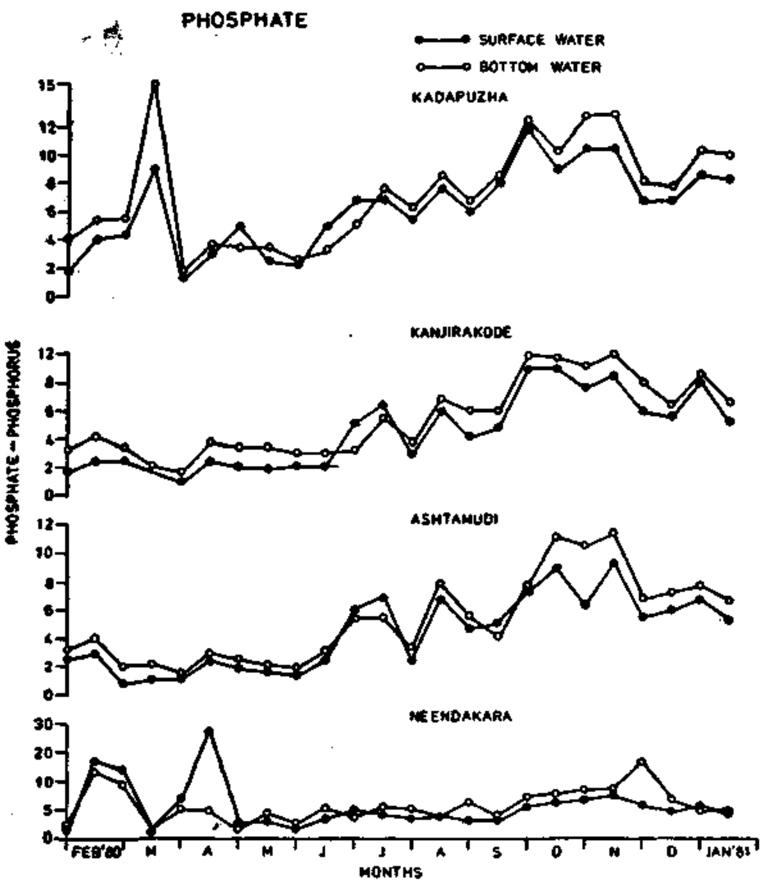

Fig. 8. Phosphate concentration in the surface and bottom waters of Ashtamudi Estuary during 1980-'81.

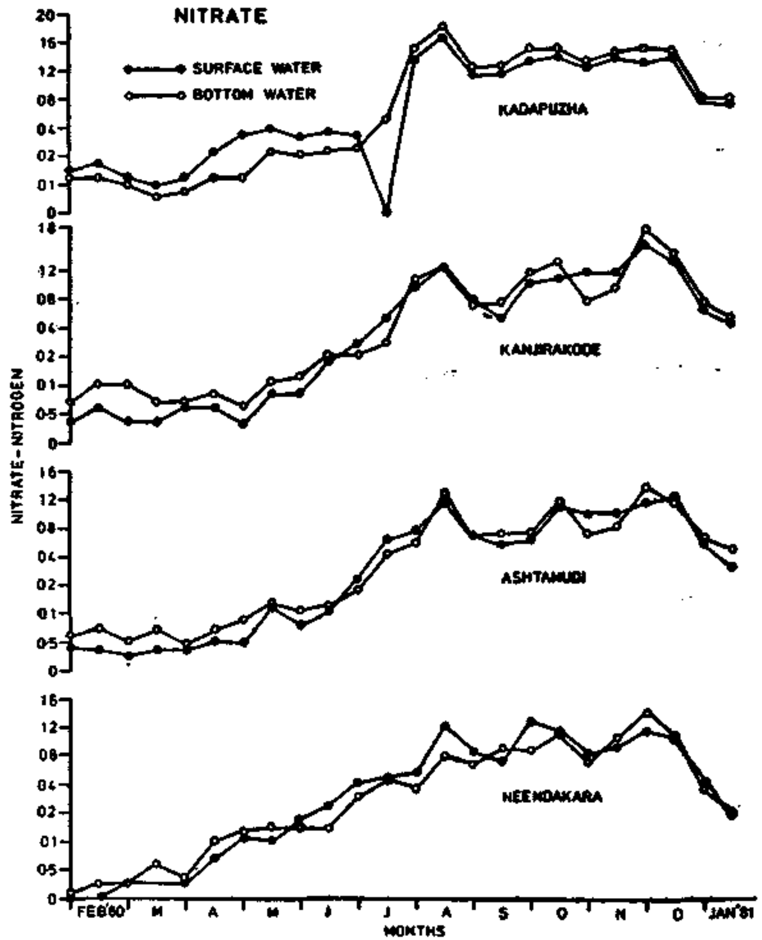

Fig. 9. Nitrate-nitrogen in the surface and bottom waters of Ashtamudi Estuary during 1980-'81.

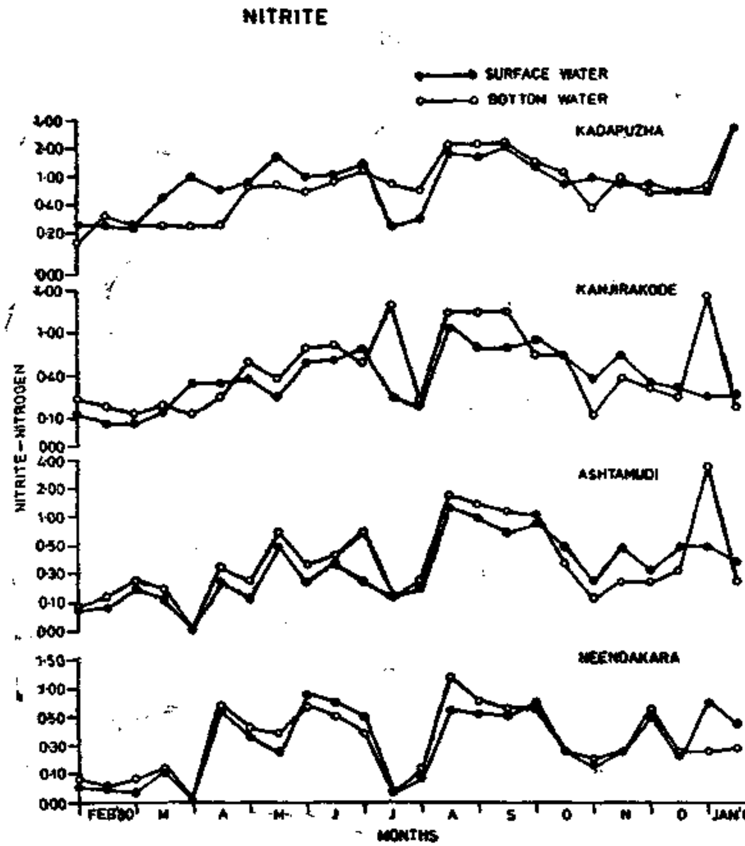

Fig. 10. Nitrite-nitrogen in the surface and bottom waters of Ashtamudi Estuary during 1980-'81.

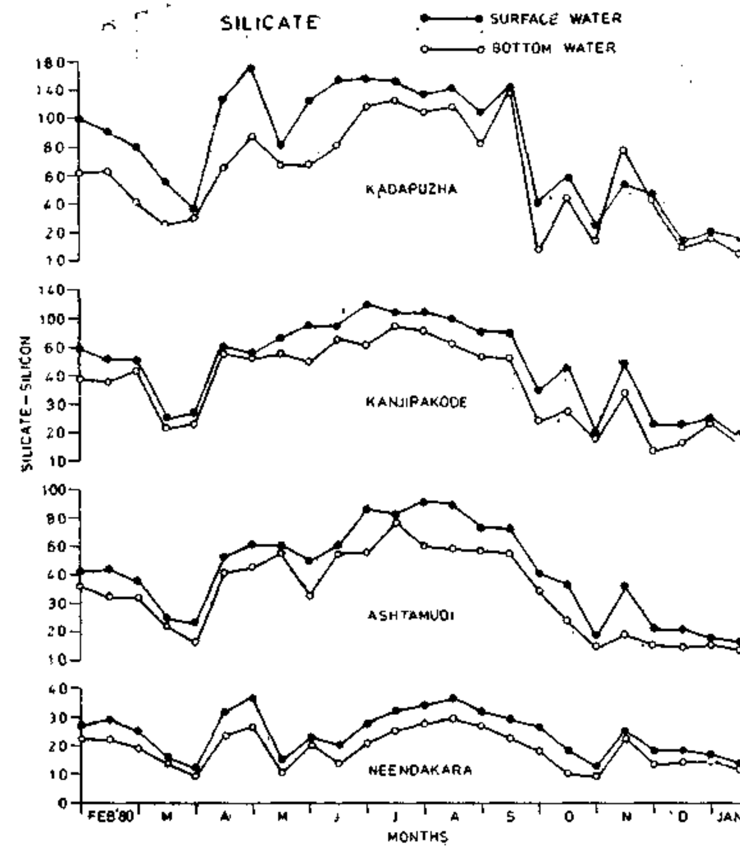

Fig. 11. Silicate silicon in the surface and bottom waters of Ashtamudi Estuary during 1980-'81.

was also evident in the net and gross productivities of the estuary (Fig. 12, 13). The correlation between productivity and oxygen was found to be significant at 5% level at station 2 and at 1% level at station 3. In the bottom water, the correlation was not significant except at station 3. The apparent failure of primary production at all the stations during September-October period was due to the depletion of dissolved oxygen in the surface and bottom waters. When the primary productivity of the Ashtamudi Estuary was compared with those of other Indian estuaries, it was seen that gross and net productivities were distinctly higher in the Ashtamudi Estuary. The productivity at the polluted Kadapuzha station was the lowest, indicates the influence of paper mill effluent.

Distribution and seasonal variation of zooplankton

i. *Plankton biomass and numerical abundance* : Biomass and numerical abundance of zooplankton were highest during the pre-monsoon except at station 4 (Fig. 14 to 17). A positive correlation (at 1% level) between salinity and zooplankton biomass has been noted at stations 1 and 2 (r=.5392 and .7890). The standing crop registered its peak in late March at St. 1 ; in early April at St. 2 ; in late April at St. 3 and in early June at St. 4.

ii. *Abundance and distribution of different zooplankton groups*

Seasonal zooplankton percentage was maximum during the pre-monsoon and the annual percentage values showed that the highest percentage was recorded at Kanjirakode (51.91%) and the lowest (1.45%) at Kadapuzha.

Quantitative variations in the fortnightly percentage composition of the major zooplankton groups at the four stations are shown in Figs. 18 to 21. The occurrence of foraminifera was confined to station 1 recording its peak in early June forming 94.6% in the collection. Hydromedusa, represented by *Obelia* sp. occurred only during the pre-monsoon months. The presence of medusa in the collection contributed substantially to the biomass. The distribution of nematodes were quite irregular. Rotifers were present in the interiormost segment of the estuary almost throughout the year, with the peaks during October (97.08%) at station 2 ; early November (97.6%) at St. 3 and late April (25.9%) at St. 4. The incidence of chaetognaths represented by *Sagitta bipunctata* and *S. pulchra* was noted during the pre-monsoon period and the distribution was confined to the brackishwater zone. Polychaetes were represented by larval forms belonging to the families Nereidae and Eunicidae and the seasonal occurrence and distribution were erratic. Copepoda was the most important component of the zooplankton throughout the year, the percentage distribution being maximum during the pre-monsoon period at all the stations. Twenty-one species belonging to 13 genera and 11 families were observed. Of the 21 species of copepods 14 were present at station 1 ; eight species each were present at stations 2 and 3 and only 5 species at station 4. The absence of many of the species at station 4 can be attributed to the low salinity. Copepod nauplii were also abundant in the collections. Cladocerans constituted the second important crustacean component of zooplankton in the estuary. Distribution was erratic. A dominance of cladocera was noted during early March (93.45%), June (91.14%) and in latter part of August (99%) in which the species represented was *Diaphanosoma*. Species of *Evadne* was present exclusively at station 1 whereas *Diaphonosoma* and *Leydigia* sp. were present in other stations. Ostracods were present at all the stations. Amphipods were presented by juvenile *Corophium* sp. Conchostraca represented by *Eulimnadia* sp. was noted at station 4. Brachyuran zoea, naupliar, mysis and post-larval stages of *Penaeus indicus, P. Monodon,* and *Metapenaeus dobsoni* were the common decaped larvae recorded in the collection. Other groups which appeared sparingly were

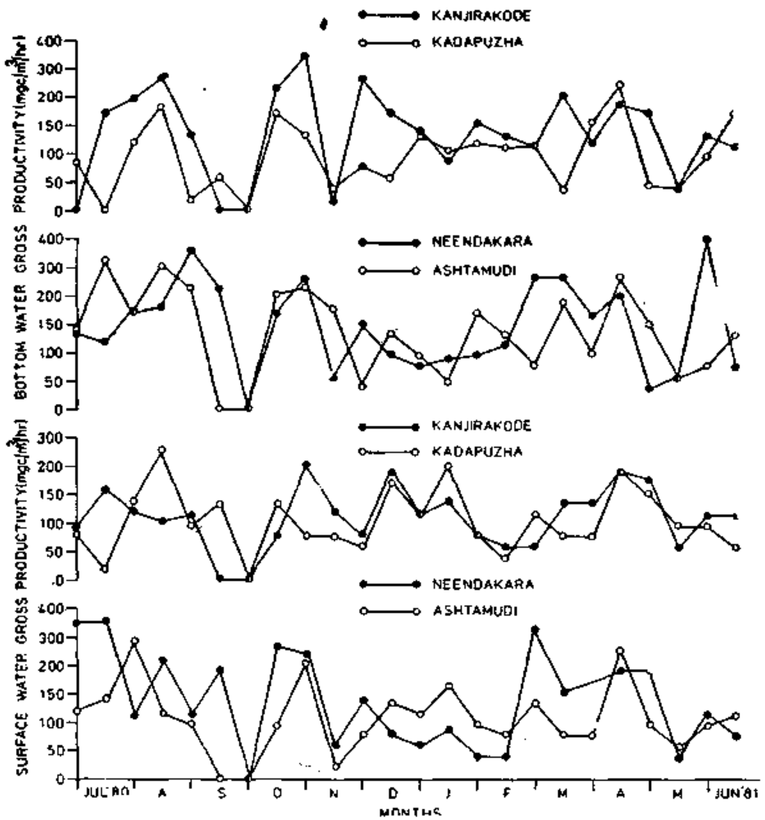

Fig. 12. Gross productivity of the surface and bottom waters in Ashtamudi Estuary during 1980-'81.

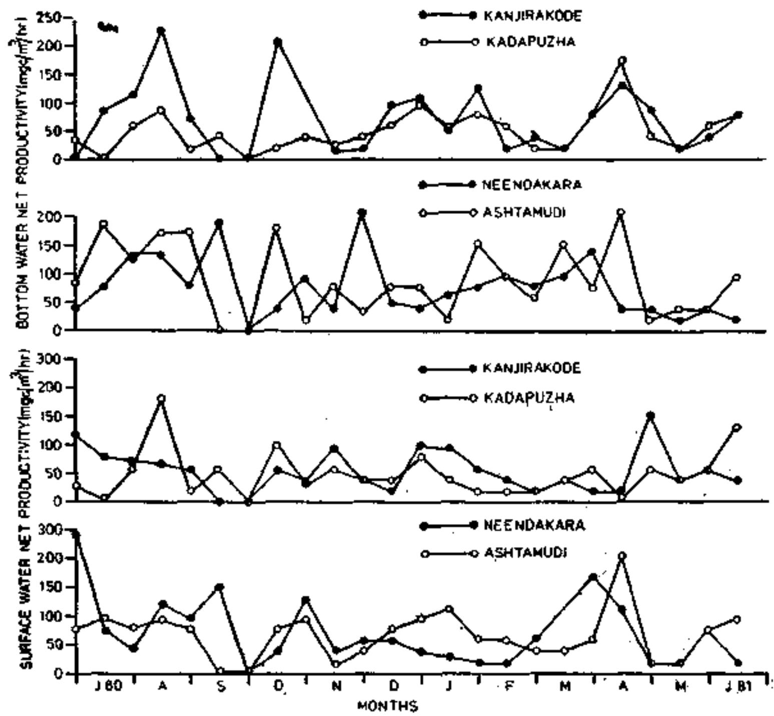

Fig. 13. Net productivity of the surface and bottom waters in Ashtamudi Estuary during 1980-'81.

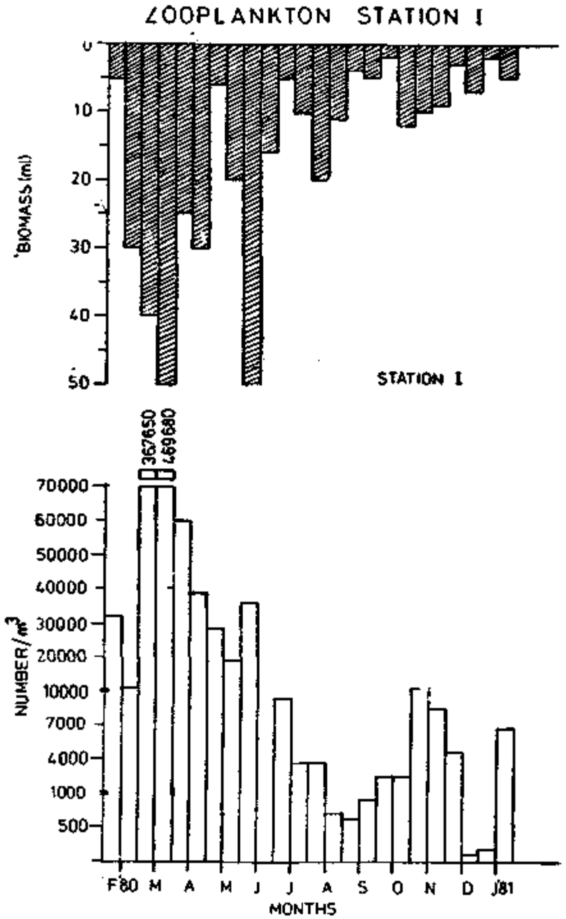

Fig. 14. Seasonal variation in the biomass and numerical abundance of zooplankton at station 1.

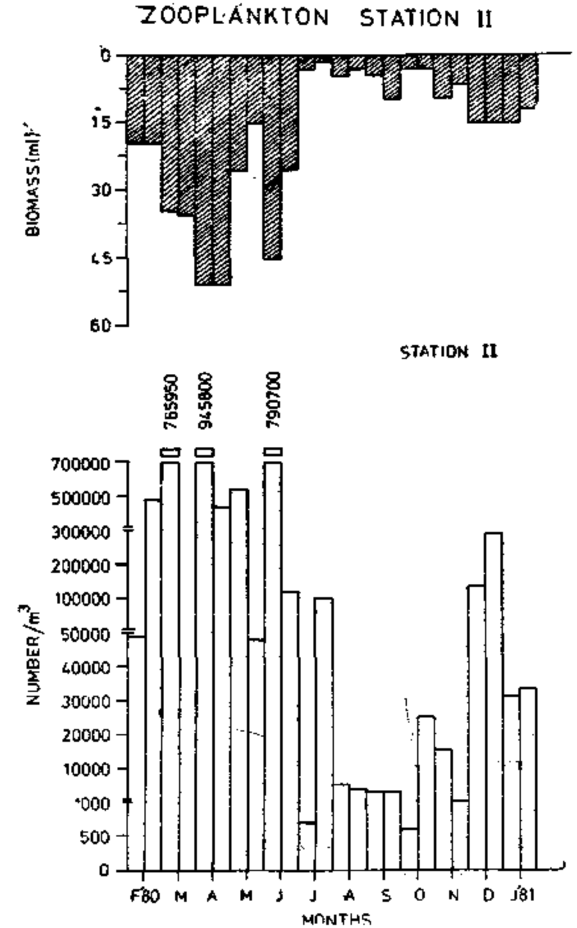

Fig. 15. Seasonal variation in the biomass and numerical abundance of zooplankton at station 2.

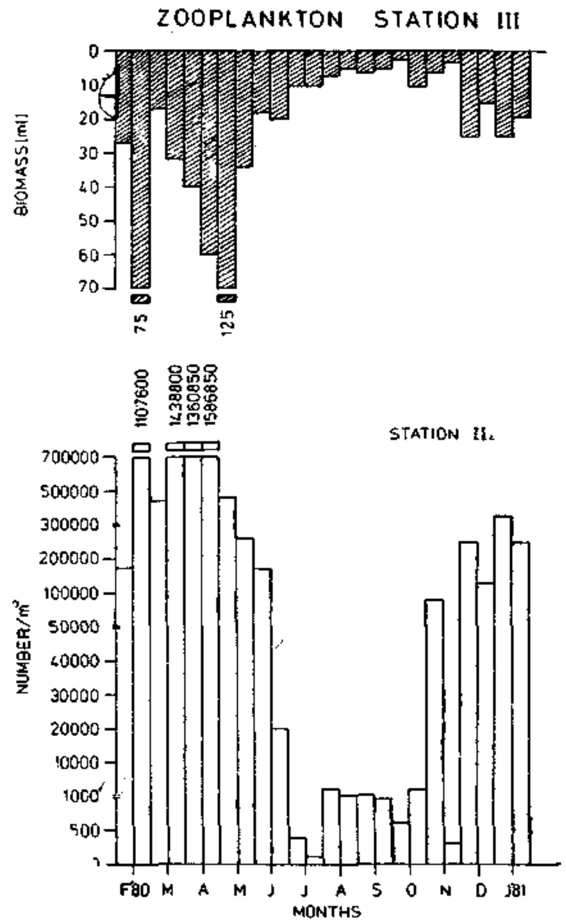

Fig. 16. Seasonal variation in the biomass and numerical abundance of zooplankton at station 3.

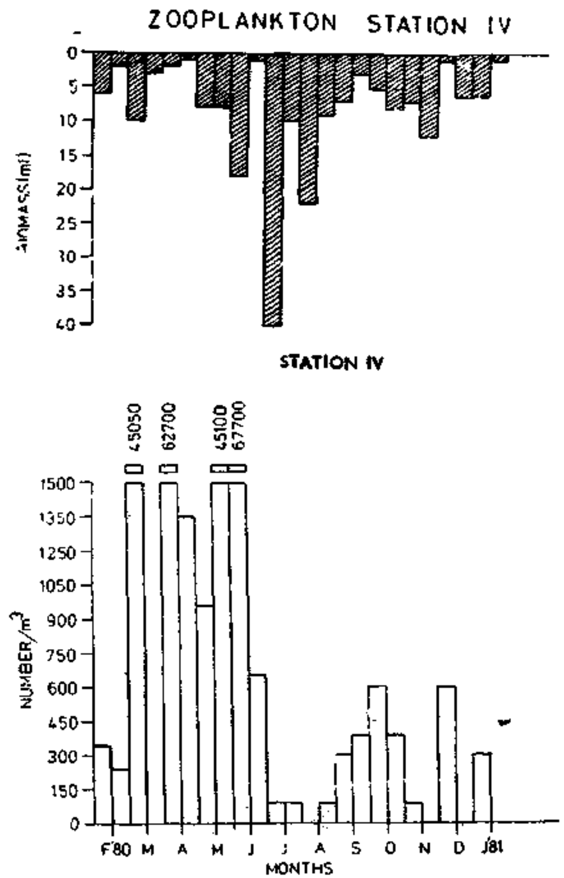

Fig. 17. Seasonal variation in the biomass and numerical abundance of zooplankton at station 4.

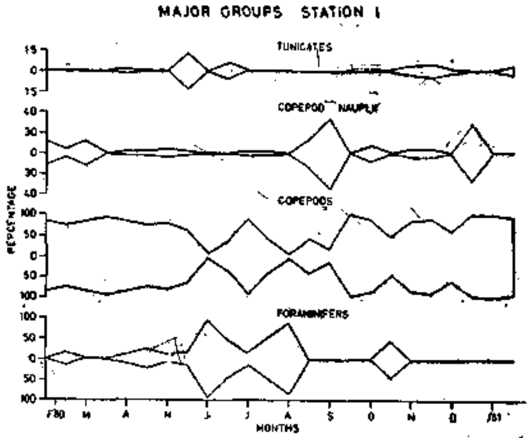

Fig. 18. Fortnightly variations in the percentage composition of major zooplanktonic groups at station 1.

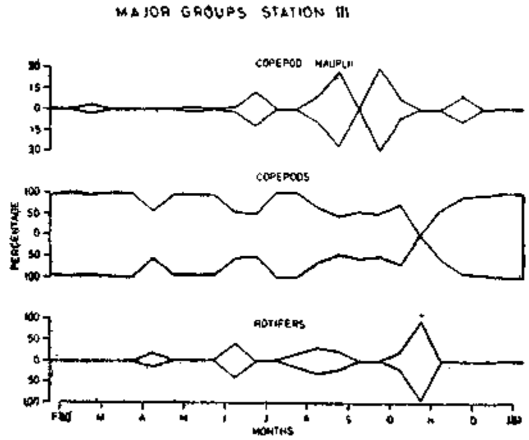

Fig. 20. Fortnightly variations in the percentage composition of major zooplanktonic groups at station 3.

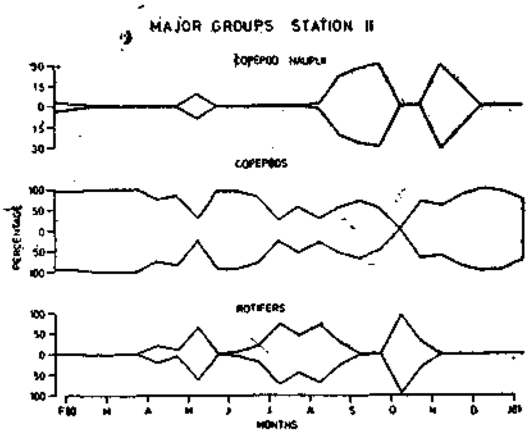

Fig. 19. Fortnightly variations in the percentage composition of major zooplanktonic groups at station 2.

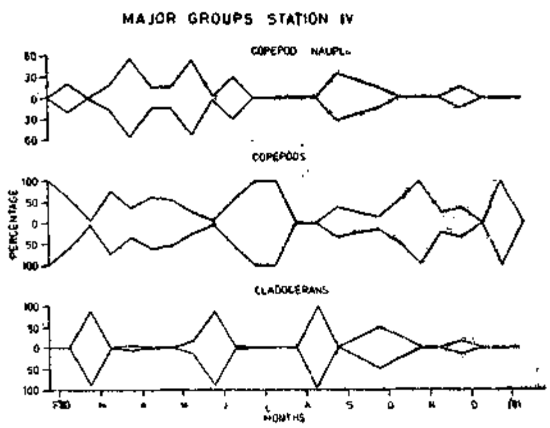

Fig. 21. Fortnightly variations in the percentage composition of major zooplanktonic groups at station 4.

mysidacea and gastropods at St. 1. Water mites and insect larvae appeared sparingly at stations 2 and 4 and were absent at other stations. Insect larvae, mainly odonate nymphs and species of *Pentaneura* were present only at station 4. Appendicularians represented by *Oikopleura* sp. occurred at all the stations in small numbers. Fish eggs and larvae were also present at all the stations in small concentrations.

An interesting correlation has been noticed between the distribution of copepod and the regime of salinity in the estuary. The distribution pattern of copepod species along with the range of salinity is given in Figs. 22-24. The distribution of copepods in relation to salinity compares well with the pattern observed by Pillai (1971). While *Centropages elongatus* was present in the stations 1-3, with salinity ranges of 26.2 to 32.8 $\times$ 10^{-3} at station 1; 7.8-28.6$\times 10^{-3}$ at station 2 and 5.0-14.6$\times 10^{-3}$ at station 3. *C. alcocki* was present only at stations 1 and 3, species of *Pseudodiaptomus* follow a pattern described by Pillai (1971). Neretic species such as *Acrocalanus gracilis* was recorded almost throughout the year from the mouth to the middle reaches, but this species was present only during the pre-monsoon in the Mandovi-Zuari estuarine system (Goswamy and Selvakumar, 1977).

High zooplankton density was noted all along the Ashtamudi Estuary with peaks in number and biomass during the pre-monsoon season, which agrees with the observations of Madhupratap (1978), Madhupratap and Haridas (1975) and Abdul Azis and Nair (1983). However an earlier study in the Ashtamudi Estuary reported by Divakaran *et al.* (1982) and in the Veli Lake reported by Arunachalam *et al.* (1982) showed that the peak incidence of zooplankton was in the post-monsoon period. Higher values of biomass observed in the Ashtamudi Estuary during the pre-monsoon agrees with the situation reported from the Cochin Backwater by Haridas *et al.* (1973) and from the Mandovi-Zuari Estuary by Selvakumar *et al.* (1980). Though the biomass values recorded during the present study are in accordance with the reports from the Cochin Backwaters, the numerical abundance is relatively higher (Madhupratap, 1978). Dominance of copepods in the zooplankton has been reported by Subbaraju and Krishnamurthy (1972) from the Vellar Estuary, Madhupratap (1978) from the Cochin Back-

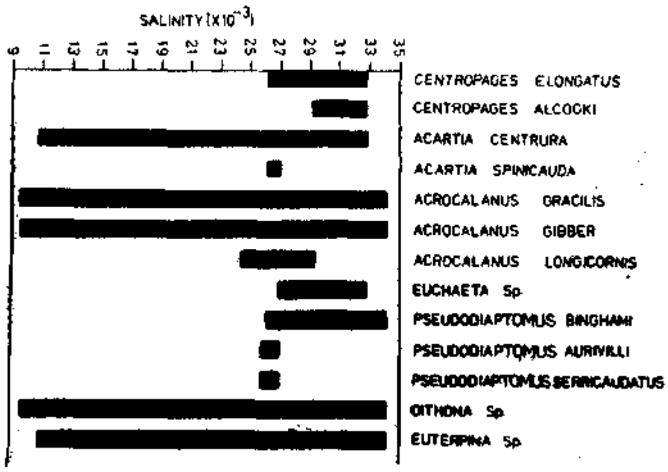

Fig. 22. Salinity range of copepod species at station 1.

waters and Goswamy (1982) from the Mandovi-Zuari estuarine system.

Distribution and seasonal variation of the benthic fauna

The benthic fauna was quantitatively and qualitatively very poor in the polluted station 4. Of the dozen groups of benthic organisms observed in the estuary, nominal representation in terms of total number of organisms observed at the four stations clearly bring out the impact of paper mill effluents upon the fauna of this estuary. 56.95% of the benthic fauna for the whole year was observed at station 1 ; while at station 4, the representation was only 0.87% ; it was 21.37% at station 2 and 21.32% at station 3. The density of the benthic fauna at station 1 was always greater than those

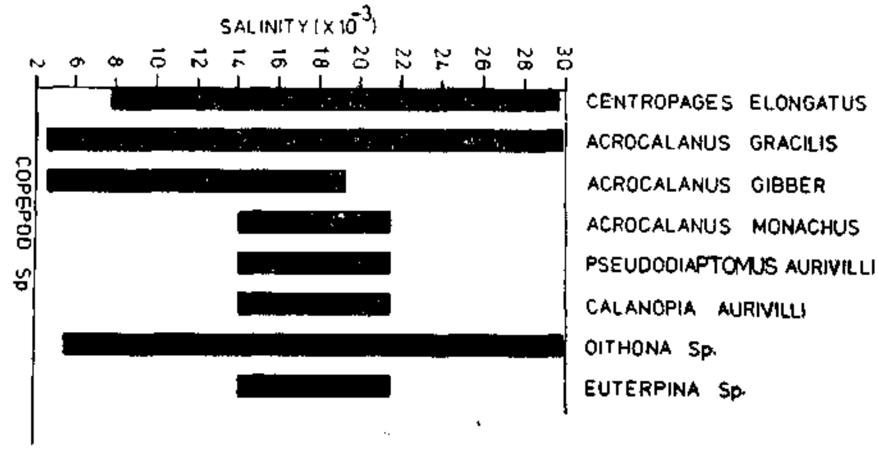

Fig. 23. Salinity range of copepod species at station 2.

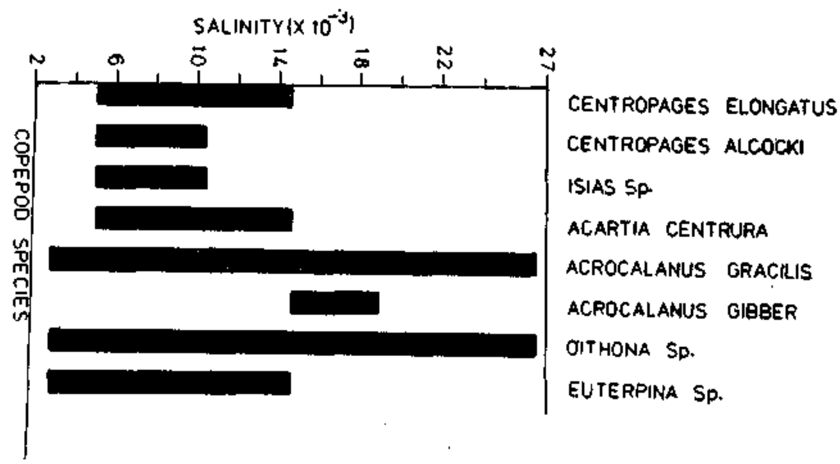

Fig. 24. Salinity range of copepod species at station 3.

of only five groups was seen at St. 4 whereas six groups were present at St. 1, ten groups at St. 2 and nine groups at St. 3. The variation at the other stations in the estuary. The highly favourable hydrographic conditions and the high rate of primary production can be cited as the reason for this situation. Paper mill effluents that spreads overl at stations 2 and 3 coupled with uninterrupted dredging for sand prevents large scale colonisation by the benthic fauna during the pre-monsoon and post-monsoon periods. The population density of benthic fauna at stations 1, 2 and 3 was maximum during the monsoon period.

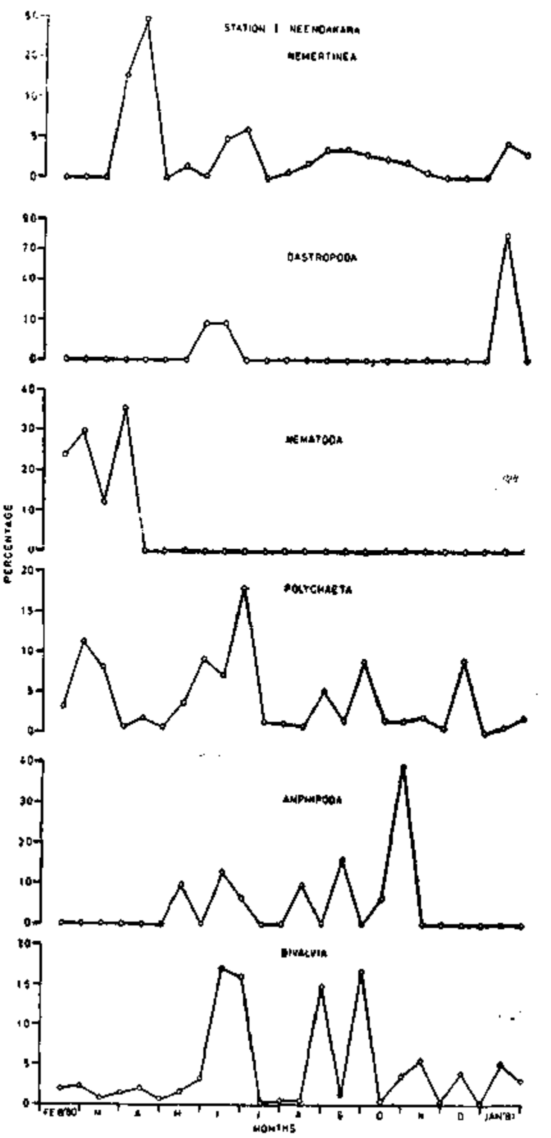

Fig. 25. Fortnightly percentage distribution of benthic fauna at station 1.

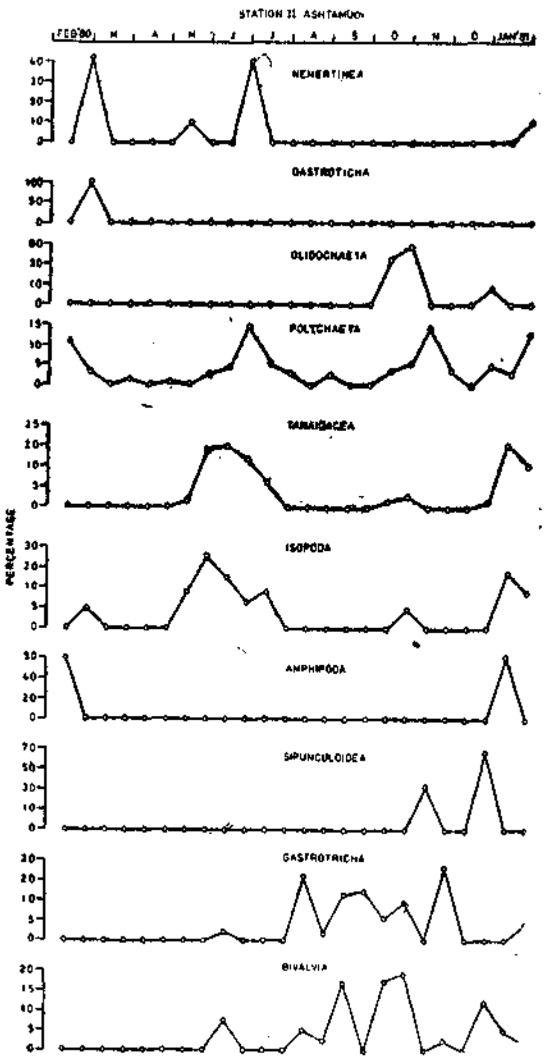

Fig. 26. Fortnightly percentage distribution of benthic fauna at station 2.

Percentage composition of the benthic fauna are presented in Figs. 25 to 28. Nemertenea was present only at stations 1 and 2, the former registering peak numbers. It occurred in the salinity range of 14.45×10^{-3} (October) to 34.87×10^{-3} (March). Gastrotricha appeared only at stations 1 and 2, the incidence being quite insignificant. Oligochaetes represented by *Enchytraeus* and *Pontodrilus* constituted an important faunal component at stations 2, 3 and 4, the highest density being at station 3 occurring almost throughout the year. Polychaetes, present at all the stations constituted the largest assemblage of the benthic organisms in the Ashtamudi Estuary. 65.97% of the polychaetes occurred at St. 1, followed by 17.4% at St. 3, 16.78% at St. 2 and 0.11 at St. 4. The depletion observed at St. 4 can be attributed primarily to the paper mill effluents and the dredging for river sand taking place throughout the year. Of the 16 species of polychaetes noticed in the estuary 9 species were present at station 1, eight species at station 2, five species at station 3 and one species at St. 4. The most important species in terms of abundance and incidence at station 1 was *Diopatra* sp. whereas at station 2 and 3 it was *Lumbrinereis* sp. *Ophiodronus* occurred both at stations 1 and 2; *Mercirella ensigmatica, Polydora ciliata, Lumbrineresis* sp., *Opisthosyllis* sp. and *Glycera* sp. occurred both at stations 2 and 3. The Polychaete community that occurred in the Ashtamudi Estuary is of typical estuarine component except that at Kadapuzha where it tends to

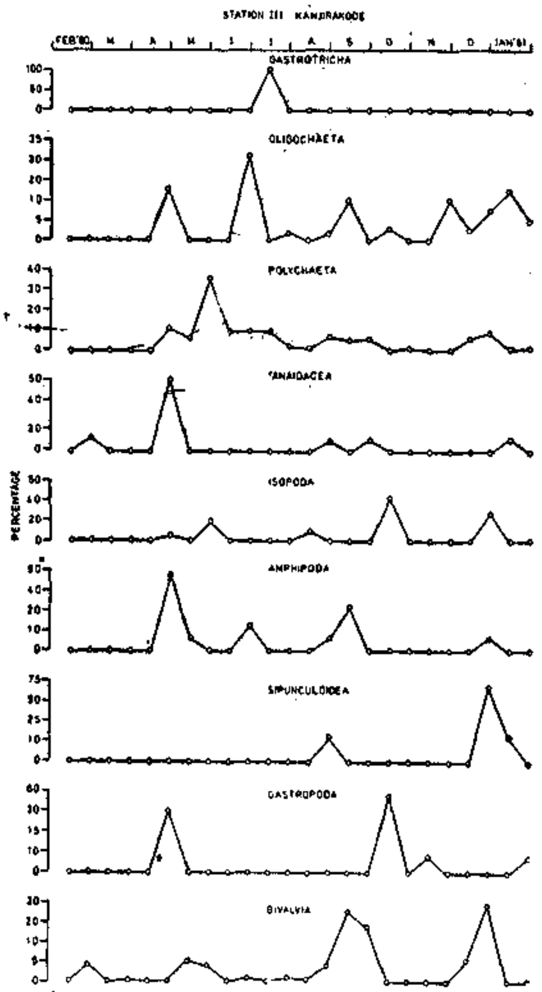

Fig. 27. Fortnightly percentage distribution of benthic fauna at station 3.

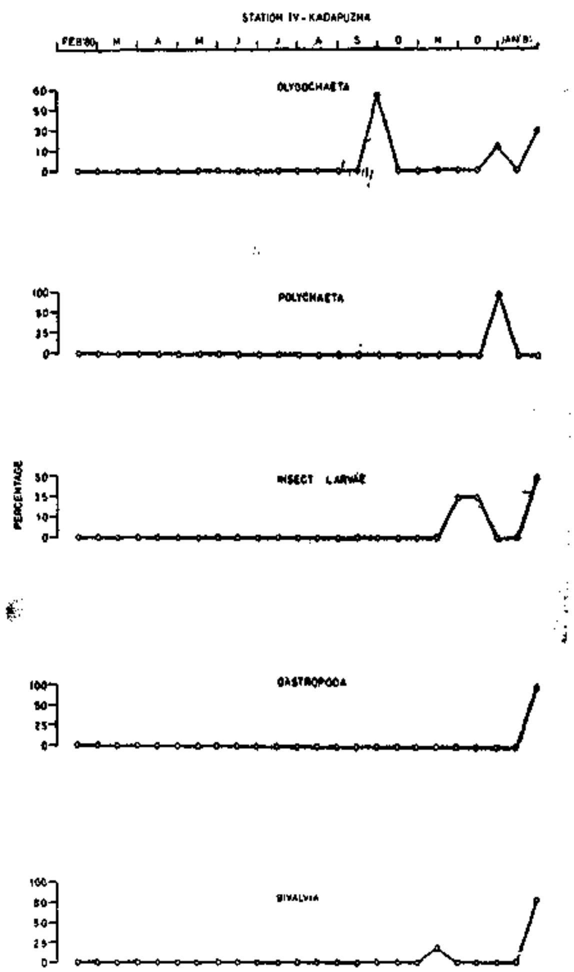

Fig. 28. Fortnightly percentage distribution of benth c fauna at station 4.

be limnetic. Amphipods, isopods and tanaids formed the crustacean component in the Estuary. Crustaceans were apparently absent at station 4 and represented solely by amphipods at station 1. All the three groups were present at stations 2 and 3. Amphipods at St. 1 occurred in all observed salinities, that at St. 2 between 23.53 to 30.65 $\times 10^{-3}$ and that at St. 3 between 13.58 to 30.74 $\times 10^{-3}$. They were composed of 5 species, viz., *Corophium triaenonyx*, *Ampelisca Scabripes*, *Photis geniculata*, *Eriopisa chilkensis* and *Quadrivisio bengalensis*. The isopods were representated by *Xenanthura linearis*, *Cirolana fluviatilis*, *Corallana nodosa*, *Idanthura carinata* and *Paranthura plumosa*. *X. linearis* was the most abundant species. *Tanaids* were represented by *Tanais estuarius* and were extremely rich at station 2. The absence of crustacea at station 4 can be attributed to the polluted conditions prevailing there. Many of these species were earlier reported from other backwater regions. Among Mollusca, gastropods represented by *Cerithedia fluviatilis* occurred in all stations except at station 1 in all salinities that ranged between 12.75 to 21.55 $\times 10^{-3}$. Bivalves occurred in all stations, the fauna being extremely rich at station 1, *Meretrix casta*, *Donax* sp., *Katelysia opima*, *Musculista arcuatula*, *M. senhausia*, *Villorita cyprinoides* and *Modiolus plumicens* formed the bivalve population. *M. casta*, *K. opima*, and *V. cyprinoides* were the commercially exploited species. Extensive beds of *M. arcuatula* and *M. plumicens* have been located around the numerous island that dot the eastern portion of the Neendakara bridge. The total absence of bivalves during most fortnights of the year at station 4 can be attributed to the continuous reclamation of the bottom sand. Insect larvae and sipunculids occurred sparsely during the period of observation. The observations on the benthic faunal distribution revealed the extensive distruction that the paper mill effluents have inflicted upon the benthic fauna of this estuarine system.

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