

ECOLOGY OF INDIAN ESTUARIES:
ECOLOGY AND DISTRIBUTION OF BENTHIC MACROFAUNA IN THE
ASHTAMUDI ESTUARY, KERALA

N. BALAKRISHNAN NAIR, P.K. ABDUL AZIS, M. ARUNACHALAM,
K. DHARMARAJ AND K. KRISHNAKUMAR
Department of Aquatic Biology and Fisheries, University of Kerala, Trivandrum 695 007

ABSTRACT

The occurrence and relative abundance of benthic fauna in 4 selected stations of the Ashtamudi Estuary have been studied for one year. Maximum occurrence was observed at Neendakara, the station closest to the sea and the minimum at Kadapuzha a polluted station in the lower reaches of the Kallada River, the other two stations showing intermediate values. Quantitative distribution of the different groups of benthic fauna has been discussed in relation to salinity and dissolved oxygen. Nature of sediment and bottom water characteristics have also been briefly discussed.

Key-words: Benthic macrofauna, ecology, Ashtamudi estuary.

INTRODUCTION

The benthic fauna is of considerable importance in marine food chains (McIntyre, 1971) and the benthos, like their counterparts, the plankton and nekton, are involved in the re-cycling of materials, the flow of energy through food chains, and the proliferation of their kind (Schweitzer, 1974). Only very few studies have been devoted to describe the dynamic nature of the benthic communities in the Indian estuaries and brackishwater environments (Panikkar and Aiyer, 1937; Rajan, 1964; Govindankutty, 1967; Desai and Kutty, 1967; McIntyre, 1968; Trevallion, Ansell, Sivadas and Narayanan, 1970; Ansell, Sivadas, Narayanan and Trevallion, 1972; Ansari, 1974; Dwivedi, Rahim and Nair, 1975; Parulekar and Dwivedi, 1975; Bhavanarayana, 1975; Khan, Vivekanandan and Balasubramanyan, 1975; Abdul Azis and Nair, 1978 and 1980; Parulekar, Dhargalkar and Singbal, 1980; Murugan, Divakaran, Nair and Padmanabhan, 1980) and particularly little is known about the benthos of the Ashtamudi estuary (Divakaran, Murugan and Nair, 1981). The present investigation has been prompted by the paucity of information on the benthic fauna of this backwater and detailed studies have been carried out in four representative stations for a period of one year.

THE ENVIRONMENT

The Ashtamudi Estuary (Lat. $8^{\circ}31'N$ to $9^{\circ}02'N$ and long. $76^{\circ}31'E$ to $76^{\circ}41'E$), the second biggest backwater system in Kerala is greatly exposed to pollution from paper mill effluents and waste discharges of starch, aluminium and ceramic industries. While sewage disposal from the nearby municipal town pollutes the environment in one locality, it is the retting of coconut

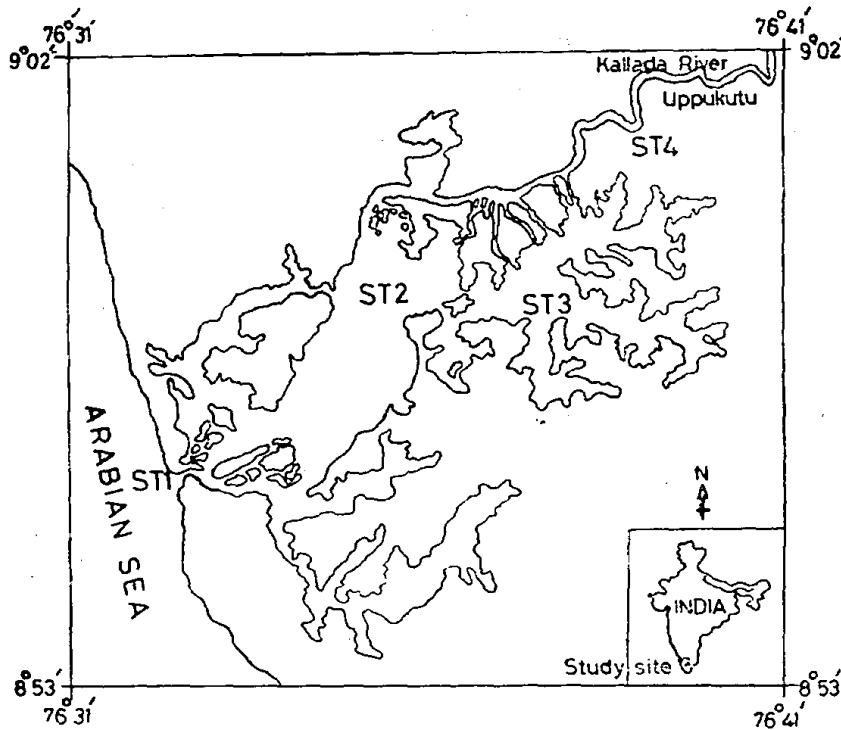


Fig. 1. Map of the Ashtamudi Estuary showing the study sites.

husks that creates adverse environmental conditions in certain interior arms of the estuary. Altogether, the estuary is persistently exposed to the destructive influence of pollution at various points threatening total destruction of the animal and plant resources of this otherwise healthy and highly productive estuary. Four stations were fixed (Fig. 1) for regular fortnightly studies and they are described below:

Neendakara (st. 1): One of the biggest fish landing centres of the west coast of India, Neendakara is located at the mouth of the estuary. Sewage disposal, oil spillage from mechanised boats and organic materials dumped by various fish processing units are the major sources of pollution here. Mean depth of the area is 2.14 m.

Ashtamudi (st. 2): Represents the heart of the estuarine system and is a major fishing zone. The Kallada River joins the estuary in the vicinity at Arinalloor. The average depth of the area is 2.44 m.

Kanjirakode (st. 3): It is the interior-most segment of the estuary walled by laterite cliffs at several places. Even though retting of coconut husks and industrial effluents have created some pollution in the area it is still a good fishing zone with an average depth of 2.7 m.

Kadapuzha (st. 4): This station is located in the lower reaches of the Kallada River. The river originates from the Western Ghats, traverses for

about 120 km and drains into the Ashtamudi backwater at Arinallor. A paper mill is situated at Punalur on the banks of the river causing considerable water pollution downstream and in the estuary. The mean depth of the area is 2.94 m.

MATERIALS AND METHODS

Quantitative samples for the study of benthos were taken fortnightly from the 4 stations during Feb. 1980 to Jan. 1981. A tin corer that covered a surface area of 34 cm² and a sediment volume of 718 cm³ was used for the purpose. Three samples were taken from each station for detailed study. Monthly samples of sediments were collected for the study of textural properties. Bottom water samples were taken every fortnight for the estimation of salinity, dissolved oxygen and other hydrographical parameters.

Extraction of the fauna was carried out following Holme and McIntyre (1971). Water samples were analysed following Strickland and Parsons (1972) and sediments following Piper (1950). Core samples brought to the surface were immediately preserved in 4% formalin. The samples were sieved through a 75 μ sieve (mesh No. B.S.S. 240 A.S.T.M. 230) and all the specimens were manually separated and preserved in 4-5% formalin neutralised with 100 g hexamethylene tetramine per litre of 40% formaldehyde.

RESULTS AND DISCUSSION

Nature of the sediment

The textural characteristics of the sediments are presented in Table I. The composition of sediments varied markedly over the course of the year in all the stations. The percentage of coarse sand at Neendakara ranged from 6.80 to 56.30 and that of fine sand from 22.90 to 73.50 whereas the percentage of silt and clay remained at very low levels. Thus fine sand particles dominated in the sediments and varied from 60.50 to 85.90%, the fine sand from 7.90 to 20.50%, and the other fractions constituted very low percentages. At Kanjirakode, the coarse fraction varied from 33.30 to 92.60% and the fine fraction from 2 to 18.10% while the other fractions remained at low levels. At Kadapuzha, the riverine station, coarse sand varied from 19.40 to 67.00% and that of fine sand from 14.10 to 64.50%. When the annual averages were compared, coarse fraction formed the dominant constituent at Kadapuzha, Kanjirakode and Ashtamudi regions followed by fine sand, clay and silt. Fine sand formed the dominant component of the sediment at Neendakara and the second dominant one at Kadapuzha. The clay and silt fractions found their maximum percentage of occurrence in the Kanjirakode and Kadapuzha regions. Water currents, the ebb and flow of tides and various physiographic features of the estuary are believed to play a key role in the distribution and deposition of sediment particles in the bed of the Ashtamudi Estuary.

Table I. Textural characteristics of the sediments of the Ashtamudi estuary.

Months	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
	St. I: Neendakara				St. II: Ashtamudi			
Feb. '80	56.30	22.90	1.00	4.20	72.80	15.10	1.60	5.20
March	29.50	57.60	1.60	2.60	85.90	7.90	2.60	7.80
April	17.40	67.70	3.80	7.80	82.50	13.20	2.60	2.60
May	14.20	70.00	4.20	1.00	74.50	14.20	1.00	6.80
June	24.80	60.50	1.00	7.80	62.70	20.00	0.00	11.50
July	6.80	73.50	0.00	7.80	75.90	12.40	1.00	4.20
Aug.	12.00	64.30	3.60	6.80	65.30	20.50	2.60	7.80
Sept.	10.10	62.70	3.60	11.50	66.00	17.40	0.50	7.80
Oct.	15.70	55.30	2.60	5.20	74.70	11.80	6.80	2.60
Nov.	12.30	63.70	3.10	6.20	69.00	16.60	0.50	17.50
Dec.	18.20	59.10	2.10	7.80	64.60	20.80	0.00	5.20
Jan. '81	21.00	61.40	2.60	12.00	60.50	17.80	0.00	5.30
	St. III Kanjirakode				St. IV Kadapuzha			
Feb. '80	50.30	10.80	6.80	18.20	19.40	14.10	2.70	15.60
Mar.	33.30	18.10	11.50	14.10	27.10	64.50	0.00	18.20
Apr.	35.40	18.10	2.60	26.00	56.60	19.90	10.40	5.20
May	73.20	11.10	1.60	5.20	58.60	22.80	9.40	8.90
June	92.60	4.80	5.20	5.20	52.40	22.40	1.60	6.20
July.	80.80	11.60	1.60	5.20	67.00	27.10	1.00	5.20
Aug.	87.90	6.90	2.60	10.40	33.30	45.20	6.60	12.00
Sept.	74.80	17.20	3.00	10.40	42.80	45.40	1.60	3.60
Oct.	57.20	15.90	0.00	11.50	46.40	41.20	5.20	10.40
Nov.	77.30	15.40	1.00	11.50	53.30	37.10	2.60	4.20
Dec.	62.80	13.60	4.20	13.00	48.30	44.70	7.80	10.40
Jan. '81	67.10	2.00	7.80	2.60	54.90	35.30	2.60	13.00

Bottom water characteristics

Temperature: Monthly variations of bottom water temperature were 27.2–32.5 °C at Neendakara; 28.25–33.75 °C at Ashtamudi; 29.05–33.25 °C at Kanjirakode and 26.75–33.25 °C at Kadapuzha (Table II). Temperature was relatively higher during the pre-monsoon and low during the monsoon at all the stations.

Salinity: Salinity varied from $14.45\text{--}34.87 \times 10^{-3}$ at Neendakara, $12.59\text{--}32.88 \times 10^{-3}$ at Ashtamudi; $12.46\text{--}31.44 \times 10^{-3}$ at Kanjirakode and $0.39\text{--}28.55 \times 10^{-3}$ at Kadapuzha (Table II). A distinct seasonal pattern was observed in the distribution of salinity in which the pre-monsoon recorded the highest average values with the monsoon registering a steep decline and the post-monsoon presenting a trend of recovery. Salinity decreased from the estuarine mouth at Neendakara to Ashtamudi and Kanjirakode and attained the lowest value at Kadapuzha in the riverine zone.

Dissolved Oxygen: Monthly averages of dissolved oxygen content ranged from 3.68–7.29 ml.l⁻¹ at Neendakara; 2.55–6.73 ml.l⁻¹ at Ashtamudi;

3.05–6.04 ml.l⁻¹ at Kanjirakode and 2.88–6.59 ml.l⁻¹ at Kadapuzha (Table II). The oxygen regime at Kadapuzha was characterised by comparatively low values whereas at Neendakara it was relatively high.

Table II. Bottom water characteristics in the Ashtamudi estuary.

Months	Tempera- ture °C	Salinity ‰	Dissolved oxygen ml.l ⁻¹	Tempera- ture °C	Salinity ‰	Dissolved oxygen ml.l ⁻¹
	St. I Neendakara			St. II Ashtamudi		
February '80	30.75	32.5	7.29	31.25	30.65	5.14
March	32.5	34.87	6.5	32.0	32.88	5.32
April	32.0	33.82	6.84	32.5	32.38	6.73
May	32.25	30.04	7.06	33.75	25.58	6.21
June	28.25	28.5	5.82	30.87	21.6	5.99
July	28.5	16.64	5.54	28.8	12.59	4.19
August	27.8	16.45	6.3	28.25	13.25	4.47
September	28.1	17.05	6.67	29.9	13.7	3.11
October	29.0	14.45	3.68	30.55	12.75	2.55
November	28.65	25.05	4.93	30.0	21.55	5.59
December	28.2	27.75	5.09	30.5	24.2	5.82
January '81	27.2	26.48	4.69	29.5	23.53	4.41
	St. III Kanjirakode			St. IV Kadapuzha		
February '80	31.0	28.2	6.04	30.5	25.2	4.75
March	31.5	31.44	5.65	32.0	28.55	3.11
April	32.5	30.74	5.77	33.0	27.82	2.94
May	33.25	23.77	5.03	33.25	22.43	2.86
June	32.0	20.52	4.58	32.75	15.42	3.79
July	30.1	12.46	4.35	26.75	0.84	6.56
August	29.01	13.58	5.77	26.95	0.95	6.59
September	30.5	14.45	3.51	28.8	1.25	6.56
October	30.0	17.05	3.05	28.9	0.39	3.11
November	31.0	19.5	3.45	27.6	1.43	6.95
December	31.0	23.1	5.37	29.0	0.46	6.27
January '81	29.4	23.0	4.19	30.2	9.3	2.89

The pattern of variation of temperature, salinity and dissolved oxygen has been almost similar to the pattern observed in other estuaries and backwaters along the south-west coast of India (Anto, 1971; Qasim, 1979; NIO, 1982; Abdul Azis and Nair, 1978, 1980 and Balakrishnan Nair, Abdul Azis, Dharmaraj, Arunachalam, Krishnakumar and Balasubramanian, 1983). The impact of rainfall and river discharge also has been similar.

Composition of the benthic fauna

The benthic fauna composed of Nemertinea, Gastrotricha, Oligochaeta, Polychaeta, Amphipoda, Isopoda, Tanaidacea, Insect larva, Sipunculoidea, Gastropoda and Bivalvia. Of the eleven taxa of benthic organisms observed in the estuary, representation of five taxa was seen at Kadapuzha and Neendakara, ten taxa at Ashtamudi and nine taxa at Kanjirakode stations. Station-

Table III. Station-wise occurrence of the benthic fauna.

S. No.	Neendakara	Ashtamudi	Kanjirakode	Kadapuzha
1	Nemertinea	Nemertinea	Gastrotricha	Oligochaeta
2	Gastrotricha	Gastrotricha Oligochaeta	Oligochaeta Polychaeta	Polychaeta Insect larvae
3	Polychaeta	Polychaeta	Tanaidacea	Gastropoda
4	Amphipoda	Tanaidacea	Isopoda	Bivalvia
5	Bivalvia	Isopoda	Amphipoda	
6		Amphipoda	Sipunculoidea	
7		Sipunculoidea	Gastropoda	
8		Gastropoda	Bivalvia	
9		Bivalvia		

wise occurrence of the benthic fauna is presented in Table III. The fauna was quantitatively extremely poor in the polluted Kadapuzha station. Polychaeta and Bivalvia occurred at all the stations of the estuary. Gastrotricha and Amphipoda were present at Neendakara, Ashtamudi and Kanjirakode.

With regard to the total groups of animals represented in the benthos, the picture at the Ashtamudi estuary is impressive when compared with certain earlier reports from the south-west coast of India (Govindankutty, 1972; Trevallion, Ansell, Sivadas and Narayanan, 1970; Ansell, Sivadas, Narayanan and Trevallion, 1972; Damodaran, 1973; Abdul Azis and Nair, 1978 and 1980; Murugan, Divakaran, Nair and Padmanabhan, 1980 and Divakaran, Murugan and Nair, 1981).

Among the four stations the highest numerical abundance was observed at Neendakara, the station closest to the sea and the lowest at Kadapuzha, the station on the riverine zone. Ashtamudi, the station directly on the gradient line from the estuarine mouth to the riverine zone and Kanjirakode — the station equidistant from Ashtamudi and Kadapuzha recorded intermediate values in the numerical abundance when compared to stations 1 and 4. The density of the fauna was always greater at st. 1 than those at the other stations. The highly favourable hydrographic conditions and the high rates of primary production may be the main causatives (Balakrishnan Nair, Abdul Azis, Dharmaraj, Arunachalam, Krishnakumar and Balasubramanian, 1983).

Quantitative distribution of the benthic faunal groups

Fortnightly changes in the numerical abundance of benthic fauna at the stations are presented in Tables IV and V.

Nemertinea: Nemertinea was absent at Kadapuzha and Kanjirakode whereas it was present in good numbers at Neendakara. Nemertines occurred at Ashtamudi also on a very few occasions. The maximum number of nemertines occurred during early April at Neendakara. However the frequency of incidence was more during the monsoon period. It occurred in the salinity range of 14.45×10^{-3} (October) to 34.87×10^{-3} (March).

However the peak and the minimum incidence of nemertines were found to be independent of the variations of salinity.

Gastrotricha: Absent at Kadapuzha and Kanjirakode, Gastrotricha made their appearance only at Neendakara and Ashtamudi, the incidence being quite insignificant. Their occurrence at Neendakara was confined to a salinity that ranged between 26.48×10^{-3} and 30.04×10^{-3} and dissolved oxygen content that ranged between 4.69 and 7.06 ml.l⁻¹. At Ashtamudi gastrotrichs occurred only once. Gastrotrichs composed of *Macrodasyus caudatus* and *Tetranchyroderma* sp. Both the species generally occurred together. These species have been earlier reported from the Shankumughom beach and the Cochin beaches in Kerala (Rajan, 1972; Govindankutty, 1967) and from the Paravur backwater (Abdul Azis and Nair, 1982).

Oligochaeta: Oligochaetes had a restricted distribution in the Ashtamudi Estuary during the period of investigation. They were totally absent at Neendakara and were very few at Kadapuzha. Oligochaetes constituted an important faunal component only at Kanjirakode. They occurred almost throughout the year at salinities that ranged from $12.46-30.74 \times 10^{-3}$ whereas at Ashtamudi and Kadapuzha they occurred thrice during the year at salinities that ranged from $12.75-24.2 \times 10^{-3}$ and 2.89 to 6.59×10^{-3} respectively. Most of the specimens belong to two genera namely *Enchytraeus* and *Pontodrilus*. These genera have been reported earlier from the Edava-Nadayara-Paravur backwaters (Abdul Azis and Nair, 1983) and from the Travancore region (Aiyer, 1929).

Polychaeta: Polychaetes were present at all the stations constituting the largest assemblage of the benthic organisms in the Ashtamudi Estuary. The maximum and minimum abundances were noted at the two extreme stations viz. at Neendakara and Kadapuzha respectively. When the seasonal distribution was examined polychaetes were maximum during monsoon at Neendakara, during post-monsoon at Ashtamudi and during pre-monsoon at Kanjirakode. Polychaetes at Neendakara appeared in all salinities that ranged from 14.45 to 34.87×10^{-3} , at Ashtamudi occurred in all salinities that ranged from 12.59 to 32.88×10^{-3} and at Kanjirakode occurred in all salinities that ranged from 12.46 to 31.44×10^{-3} . The variation of polychaetes however, did not show any definite pattern with the variation in salinity.

A detailed examination of the polychaete population has shown that about 16 species are represented in the Ashtamudi estuarine system. The species were *Nerine cirratulus*, *Ancistrosyllis constricta*, *Nemalycastis indica*, *Diopatra* sp., *Perinereis* sp., *Platynereis* sp., *Prionospio* sp., *Goniada* sp., *Ophiodromus* sp., *Mercierella enigmatica*, *Nereis* sp., *Lumbrinereis* sp., *Opisthosyllis* sp., *Glycera* sp., *Polydora ciliata* and *Sabella* sp. Of the 16 species 9 species were present at Neendakara, 8 species at Ashtamudi, 5 species at Kanjirakode and one species at Kadapuzha.

July		August		September		October		November		December		Jan. '81	
1	2	1	2	1	2	1	2	1	2	1	2	1	2
—	292	877	3214	1753	1461	1169	877	292	—	—	—	2046	877
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	2450	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	2922	4383	—	—	—	584	—	—
3214	2834	1461	20164	3214	19579	3214	3214	4383	1461	19579	—	1461	292
3506	2046	—	—	292	—	2834	3506	9643	—	—	3214	2046	1461
—	—	877	—	1461	—	584	3506	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	292	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
1169	—	—	—	—	—	—	584	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
1169	—	—	—	—	—	292	584	—	—	—	292	3799	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	292	—	—	584	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	3506	—	2046	2834	877	1461	—	4091	—	—	—	—
—	292	292	18410	877	12273	292	2450	4091	292	2922	—	3799	877
—	—	584	—	2046	—	1753	2834	—	292	—	1461	584	—

July		August		September		November		October		December		Jan. '81	
1	2	1	2	1	2	1	2	1	2	1	2	1	2
292	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	292	—	292	2834	—	584	—	—	2834	584	1753	3506	1461
—	—	—	—	—	1169	—	—	—	—	—	292	—	1169
4967	877	584	2922	1461	1753	—	584	—	—	1753	2450	584	—
—	—	—	—	—	—	—	—	—	—	—	292	—	—
—	—	—	—	1169	—	—	—	—	—	—	292	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	584	—	—	—	2450	—	—	—	—	1753	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	292	—	—	—	—	—	—	292	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	292	292	—	—	877
—	—	—	—	—	—	—	—	—	—	—	1461	292	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	1169	—	—	2046	—	292	—	—	—	—	292
—	—	—	—	—	—	—	—	—	—	—	—	—	584
—	584	292	2834	8658	6028	—	—	—	—	2046	9520	292	292
—	—	—	—	—	—	—	—	292	—	—	—	—	—

The most important species in terms of abundance and incidence at Neendakara was *Diopatra* sp. whereas at Ashtamudi and Kanjirakode it was *Lumbrinersis* sp. *Ophiodromus* sp. occurred both at Neendakara and Ashtamudi, *Mercierella enigmata*, *Polydora ciliata*, *Lumbrinereis* sp., *Opisthosyllis* sp. and *Glycera* sp. occurred at both Ashtamudi and Kanjirakode. The polychaete community that occurred in the Ashtamudi Estuary is of typical estuarine components except that at Kadapuzha where it tends to be limnetic. Many of the species reported now from the estuary have been reported earlier by Divakaran, Murugan and Nair (1981) from Neendakara and by Murugan, Divakaran, Nair and Padmanabhan (1980) from the Veli Lake. As in the present instance polychaetes formed the largest group of benthic organisms at Shertallai beaches (Trevallion, Ansell, Sivadas and Narayanan, 1970), in the mud-bank region of Kerala (Damodaran, 1973) and in the Vellar estuary (Khan, Vivekanandan and Balasubramanyan, 1975).

Amphipoda, Isopoda and Tanaidacea were present at Ashtamudi and Kanjirakode stations. Crustaceans were totally absent in the polluted Kadapuzha region and represented solely by amphipods at Neendakara. The salient features of the distribution are given below.

Amphipoda: Amphipods were present at all the stations except Kadapuzha. The richest amphipod population in terms of incidence, number and species was found at Neendakara and the poorest at Ashtamudi. Amphipods at Neendakara occurred in all observed salinities, that at Ashtamudi between 23.53 to 30.65×10^{-5} and that at Kanjirakode between 13.58 to 30.74×10^{-5} . Five species of amphipods, viz., *Corophium triaenonyx*, *Ampelisca scabripes*, *Photis geniculata*, *Eriopisa chilkenis* and *Quadrivisia bengalensis* constituted the amphipod fauna in the estuary. *C. triaenonyx* was the most abundant at Neendakara and *E. chilkenis* at Kanjirakode. *C. triaenonyx*, *A. scabripes* and *P. geniculata* were earlier reported from the Ashtamudi estuary (Divakaran, Murugan and Nair, 1981). *E. chilkenis* from the salt takes of lower Bengal, the Vembanad Lake at Cochin and from the Paravur backwaters (Abdul Azis and Nair, 1983) and *Q. bengalensis* from the backwaters at Veli, Vaikom, Shertallai and from the Paravur backwaters (Abdul Azis and Nair, 1983).

Isopoda: Isopoda was present only at Ashtamudi and Kanjirakode. The isopod population at Ashtamudi and Kanjirakode was composed of *Xenanthura linearis*, *Cirolana fluviatilis*, *Corallana nodosa*, *Idanthura carinata* and *Paranthura plumosa*. *X. linearis* was the most abundant species at both the stations. The absence of isopoda at Kadapuzha and Neendakara can be attributed to the highly unstable characteristics of the bottom sediments prevailing in the area. Cirolanid isopods were earlier reported from the Kerala backwaters (Pillai, 1961 and Abdul Azis and Nair, 1983).

Tanaidacea: Tanaidacea represented by *Tanais estuarius* was observed only at Ashtamudi and Kanjirakode. The population was extremely rich at Ashtamudi. At Kanjirakode, the tanaid population was very poor. The total

absence of the group at Kadapuzha and Neendakara is probably due to the unstable characteristics of the bottom sediments in these regions. *Tanais* sp. was earlier reported to occur very sparsely at Neendakara (Divakaran, Murugan and Nair, 1981).

Mollusca was represented in the estuary by Bivalvia and Gastropoda forming the second biggest component of benthic fauna in the Ashtamudi estuary.

Gastropoda : Gastropods made their occurrence in all stations except Neendakara. Gastropoda was totally absent at Ashtamudi during the pre-monsoon period and they occurred in salinities ranged from 12.75 to 21.55×10^{-3} . At Kanjirakode it occurred only on 4 occasions and at Kadapuzha only once. *Cerithedia fluviatilis* represented the gastropod fauna at all the stations.

Bivalvia : Bivalves were the most important molluscan component in the estuary, appearing in the benthos at all the stations. The bivalve fauna at Neendakara was extremely rich when compared to other stations. The maximum density was observed in June. Bivalves were totally absent in the benthos in early July and in late December and they survived in all salinities. *Meretrix casta*, *Donax* spp., *Katylisis opima*, *Musculista arcuatuta*, *M. senhausia*, *Villorita cyprinoides* and *Modiolus plumicens* constituted the bivalve population at Neendakara. Most of the species are economically important and their flesh consumed by local people. *Meretrix casta*, *Katylisis opima* and *V. cyprinoides* are the most important commercially exploited species in the locality. *Musculista senhausia* has been found to be quite common. Extensive beds of *M. arcuatuta* and *M. plumicens* are located around the numerous islands that dot the eastern portion of the Neendakara bridge.

The distribution of bivalves at the Ashtamudi station was mostly confined to monsoon and post-monsoon periods comprising of *Villorita cyprinoides* only, occurring in salinities that ranged from 12.75 to 30.65×10^{-3} . *V. cyprinoides* is extensively exploited in the area.

Kanjirakode is also a rich ground for *V. cyprinoides*, representing the entire bivalve population and occurring in all salinities with the peak in late December.

At Kadapuzha, bivalves represented by *V. cyprinoides* occurred only twice during the year and their total absence during most fortnights of the year can be attributed to the continuous reclamation of the bottom sand.

Insect larvae : Insect larvae belonging to *Pentaneura* sp. occurred only at Kadapuzha and that too occasionally during the post-monsoon period. It did not however constitute an important component of the benthic fauna.

Sipunculoidea : This group appeared only in the Ashtamudi and Kanjirakode zones. Their occurrence was confined to the months of October and November at Ashtamudi and August, December and January at Kanjirakode.

ACKNOWLEDGEMENTS

This work was carried out under a University Grants Commission funded project No. F. 22-9/7 (SR-II) entitled "Studies on the Coastal Ecosystem of Kerala in relation to Fisheries". The financial support provided is gratefully acknowledged.

REFERENCES

- Abdul Azis, P.K. and N.B. Nair, 1978. The nature of pollution in the retting zones of the backwaters of Kerala. *Aquatic Biology*, **3**: 41-62.
- Abdul Azis, P.K. and N.B. Nair, 1980. Ecology of the Paravur lake -- a tropical backwater system along the south-west coast of India. In: *Management of Environment*, edited by B. Patel, Wiley Eastern Ltd., New Delhi, p. 417-431.
- Abdul Azis, P.K., and N.B. Nair, 1983. Meiofauna of the Edava-Nadayara Paravur backwater system, south-west coast of India. *Mahasagar--Bulletin of the National Institute of Oceanography*, **16**: 55-65.
- Ansari, Z.A., 1974. Macrobenthic production in Vembanad lake. *Mahasagar--Bulletin of the National Institute of Oceanography*, **7**: 197-200.
- Aiyer, K.S.P., 1929. An account of the Oligochaeta of Travancore. *Records of the Indian Museum*, **XXXI(I)**: 13-76.
- Ansell, A.D., P. Sivadas, B. Narayanan and A. Trevallion, 1972. The ecology of two sandy beaches in south west India. 1. Seasonal changes in physical and chemical factors and in macrofauna. *Marine Biology*, **17**: 38-62.
- Anto, V.J., 1971. On the grain size distribution of the Cochin backwater sediments. *Bulletin of the Department of Marine Biology and Oceanography*, University of Cochin, **3**: 109-122.
- Balakrishnan Nair, N., P.K. Abdul Azis, K. Dharmaraj, M. Arunachalam, K. Krishnakumar and N.K. Balasubramanian, 1983. Ecology of Indian Estuaries: V -- Primary productivity of the Ashtamudi Estuary, S.W. coast of India. *Proceedings of the Indian Academy of Sciences (Animal Sciences)*, **93**: 9-23.
- Bhavanarayana, P.V., 1975. Some observations on the benthic faunal distribution in the Kakinada Bay. In: *Recent Researches in Estuarine Biology*, edited by R. Natarajan, Hindustan Publishing Corporation, Delhi, p. 146-150.
- Damodaran, R., 1973. Studies on the benthos of the mud banks of the Kerala Coast. *Bulletin of the Department of Marine Sciences*, University of Cochin, **VI**: 1-126.
- Desai, B.N. and M.K. Kutty, 1967. Studies on the benthic fauna of Cochin estuary. *Proceedings of the Indian Academy of Sciences*, **66**: 123-142.
- Divakaran, O., T. Murugan, and N.B. Nair, 1981. Distribution and seasonal variation of the benthic fauna of Ashtamudi Lake, S.W. coast of India. *Mahasagar--Bulletin of the National Institute of Oceanography*, **14**: 167-172.
- Dwivedi, S.N., A. Rahim, and S.A. Nair, 1975. Ecology and production of intertidal sand fauna during south-west monsoon along Mandovi estuary (Goa). In: *Recent Researches in Estuarine Biology*, edited by R. Natarajan, Hindustan Publishing Corporation, Delhi, p. 1-20.

- Govindankutty, A. G., 1967. Studies on the interstitial fauna of the south-west coast of India with special reference to nematodes. *Ph. D. Thesis*, University of Kerala, 360 pp.
- Holme, N.A. and A.D. McIntyre, 1971 (Editors). *Methods for the Study of Marine Benthos*, IBP Handbook No. 16, Blackwell Scientific Publications, Oxford and Edinburgh, 334 pp.
- Khan, S.A., E. Vivekanandan and K. Balasubramanyan, 1975. Bottom fauna in two regions of the Vellar estuary. In: *Recent Researches in Estuarine Biology*, edited by R. Natarajan, Hindustan Publishing Corporation, Delhi, p. 255-272.
- McIntyre, A.D., 1968. The meiofauna and macrofauna of some tropical beaches. *Journal of Zoology, London*, **156**: 377-392.
- McIntyre, A.D., 1971. Introduction: Design of sampling programmes. In: *IBP Handbook No. 16*, edited by N.A. Holme and A.D. McIntyre. Blackwell Scientific Publications, Oxford and Edinburgh.
- Murugan, T., O. Divakaran, N.B. Nair and K.G. Padmanabhan, 1980. Distribution and seasonal variation of benthic fauna of the Veli lake, south-west coast of India. *Indian Journal of Marine Sciences*, **9**: 184-188.
- NIO, 1982. *Estuarine Research in India—State of the art report*, National Institute of Oceanography, Goa, India, 75 pp.
- Panikkar, N.K. and R.G. Aiyar. 1937. The brackishwater fauna of Madras. *Proceeding of the Indian Academy of Sciences*, **6B**: 284-337.
- Parulekar, A.H. and S.N. Dwivedi, 1975. Ecology of benthic production during south-west monsoon in an estuarine complex of Goa. In: *Recent Researches in Estuarine Biology*, edited by R. Natarajan, Hindustan Publishing Corporation, Delhi, p. 21-30.
- Parulekar, A.H., V.K. Dhargalkar and S.Y.S. Singbal, 1980. Benthic studies in Goa estuaries: Part III. Annual cycle of macrofauna distribution, production and trophic relations. *Indian Journal of Marine Sciences*, **9**: 184-200.
- Tillai, N.K., 1961. *Wood-boring Crustacea of India*, Monograph, Forest Research Institute, Dehra Dun, 61 pp.
- Piper, C.S., 1950. *Soil and Plant Analysis*, Interscience Publishers, New York, 67 pp.
- Qasim, S.Z., 1979. Primary production in some tropical environments. In: *Marine Production Mechanisms*, edited by J. Dunbar, Cambridge University Press, Great Britain.
- Rajan, S., 1964. Environmental studies of the Chilka lake: 2. Benthic animal communities. *Indian Journal of Fisheries*, **12**: 492-499.
- Rajan, K.C., 1972. Studies on the interstitial fauna of the south-west coast of India, *Ph. D. Thesis*, University of Kerala.
- Schweitzer, J.P., 1974. Meiobenthic fauna. *LSU Marine Science*, Teaching Aid, Issue 5, p. 8.
- Strickland, J.D.H. and T.R. Parsons, 1972. A practical handbook of sea water analysis. *Fisheries Research Board of Canada, Bulletin*, **167** (11nd edition), 311 pp.
- Trevallion, A., A.D. Ansell, P. Sivadas, and B. Narayanan, 1970. A preliminary account of two sandy beaches in south-west India. *Marine Biology*, **6**: 268-279.

