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STUDIES ON THE INTERTIDAL FAUNA OF THE VELLAR ESTUARY

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ABSTRACT

Year round studies on the seasonal fluctuations of environmental parameters like substrate particle, temperature, salinity, dissolved oxygen, organic carbon, phosphorus and nitrogen were made at the intertidal environment of the Vellar Estuary between August 1977 and July 1978. Composition and distribution of macro and meiofauna have also been studied at the marine, gradient and tidal zones of both the banks of the Vellar Estuary, in relation to seasons and tide levels.

Temperature variations are negligible, wehreas substrate particle, salinity and oxygen are affected by flooding during the north-east monsoon. Changes in the organic carbon, nitrogen and phosphorus are related to the percentage of finer particles in the substrate. The most aboundant macrofaunal groups were polychaetes, tanaids, bivalves and gastropods. Nematodes, harpacticoids, copepod nauplii and polychaetes constituted most of the meiofauna. Both macro and meiofauna were abundant during postmonsoon and summer seasons. Larger numbers of individuals belonging to different phyla were observed at the low tide level. Dominant macrofauna varied at each zone while among meiofauna, nematodes were dominant followed by harpacticoids.

INTRODUCTION

AS A PRECURSOR to the study of dynamics and production in the intertidal region of Vellar Estuary, Porto Novo, a quantitative temporal study of the meiofauna and macrofauna along with the physical and chemical characters were made. Earlier studies on the estuarine benthos of Porto Novo have been confined either to any one group of the benthos except that of McIntyre (1968) or for a short period (Balasubrahmanyan, 1964, 1966; Ramamoorthi and Alagaraja, 1969; Rajendran. 1972). Presently the study was undertaken to gain a comprehensive idea of the long term variations in the macro and meiofauna of the intertidal region of the Vellar Estuary in relation to the environmental factors on an year-round basis from August 1977 to July 1978.

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MATERIAL AND METHODS

Study area

The River Vellar enters the Bay of Bengal near Porto Novo (11°29′ N ; 79°46′ E). It has an average depth of 2 m at low tide with a maximum of 5 m. The width of the estuary is fairly uniform being about 320 m at low water except near the mouth where it is about

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450 m. During northeast monsoon the estuarine water is rendered turbid owing to silt-laden flood.

Based on salinity characteristics the Vellar Estuary has been demarcated into marine, gradient, tidal and freshwater zones (Ramamoorthi, 1954). Six stations were selected along the intertidal region for sampling; stations M_1, J_1 and R_1 on the northern bank respectively at the marine, gradient and tidal zones and stations M_2, J_2 and R_2 situated correspondingly on the south bank of the estuary (Fig. 1). For the sake of convenience a period of one year was divided into summer (April-July), Premonsoon (August-September), Monsoon (October-December) and Postmonsoon (January-March) seasons.

Sediment particle size was determined on 30 g of oven-dried sediment by wet sieving through sieves conforming to the Wentworth Scale (Morgan, 1956). Temperature was measured directly with a mercury thermometer from just below the sand surface at each tide level and also from the adjacent surface water.

The salinity and dissolved oxygen content of the surface water at knee-depth, adjacent to each sampling station was determined by modification of Harvey's direct method and Winkler's method respectively (Strickland and Parson, 1968). Estimation of organic carbon, nitrogen and phosphorus was made according to conventional methods (El Wakeel and Riley, 1956 ; Barnes. 1959 ; Murphy and Riley, 1962).

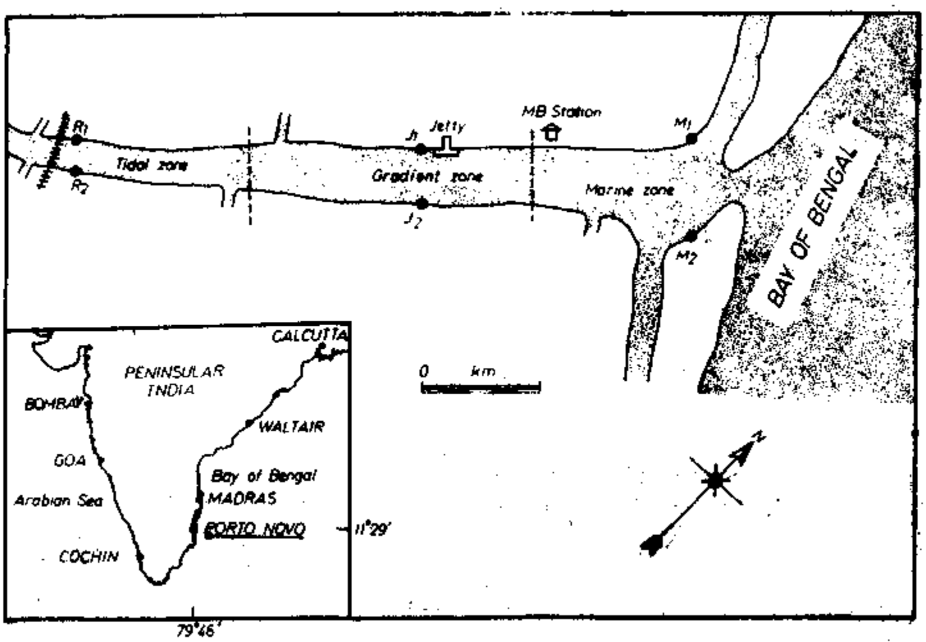

FIG. 1. The Vellar Estuary and the study areas.

Monthly duplicate samples for macro-and meiofauna were collected during low tide at the high, mid and low tide levels at six stations. Samples of macrofauna were taken by pushing a $0.1m^2$ quadrate into the substrate to a depth of 10 cm. The sediment within was washed through 500 μm. Sieve *in situ* and the residue on the sieve was preserved in 10% neutral formalin, and brought to the laboratory for sorting and counting. Meiofaunal samples were taken upto a depth of 10 cm with a corer of 2.8 cm internal diameter. Quantitative extraction of total fauna in mud was done as described by Hulings and Gray (1971). From actual counts, densities of macrofauna per metre square and meiofauna per 10 cm^2 were estimated.

Test for significant seasonal fluctuations in abundance, variation between stations and correlation between fauna and environmental parameters were made.

Result and Discussion

Substrate

No similarity was observed in the median particle size (MdQ) either at the three tidal levels in each station or between the same tide level at different stations (Table 1) indicating the unstable nature of the substrate in all the stations. Station M_2 generally contained fine sand whereas at station M_1 a mixture of medium and fine sand was observed. Though stations J_1, R_1 and R_2 recorded only fine and very fine sand, stations J_2 alone had medium sand in addition.

Except for station M_2 an increase in the MdQ was observed during monsoon months, showing a decrease in the particle size due to the deposition of silt and clay brought by the monsoon flood. Stations M_1, J_1 and R_1 on the north bank recorded higher silt and clay fraction than their corresponding stations M_2, J_2 and R_2 on the opposite bank (Table 2). Phi quartile deviation at all stations were either well sorted or less well sorted most of the time indicating that the extend to which the grains vary from that of the median particle size was not extreme (Table 3).

The median particle size of the substrate was observed to decrease with the increase in distance from the mouth of the estuary. Similar observations were made by Dye (1979) at Mngazana estuary, South Africa. Severe wave action is generally associated with steeply sloping beaches of coarse grains whereas broad flats of fine sand or mud usually occur in areas with little wave action (Brafield, 1978). Intertidal regions at all the stations presently studied were flat with higher mud and silt content whereas station M_2 which is exposed to the nearshore had a steep slope and larger particle size. Among the tidal levels larger quantities of silt and clay particles were found to be deposited at the low tide level, similar to the observations of Dwivedi *et al.* (1975) in the intertidal region of Mandovi estuary, Goa.

Temperature

In general both the water and substrate temperature were observed to be higher during summer and premonsoon (Fig. 2). Only a narrow range of temperature fluctuation was observed similar to previous observations (McLachlan, 1977 b ; Ansell *et al.*, 1972). As suggested by Ansell *et al.* (1978) it would seem that such small variations may not affect the fauna as in temperate beaches.

Temperature fluctuations are more at the high tide level (14.8° C) than at the mid (12.0°C) and low tide levels (11.0°C) possibly due to the absence of the buffering effect of the water (Bruce, 1928 ; Johnson, 1965 ; Dye, 1978). Ayyakkannu (1971) also recorded similar observations of greater temperature variations in the interstitial water at the high tide level compared to the other two tide levels in the open sandy beaches of Porto Novo. Temperature of surf water and intertidal sand substrate recorded a decrease during monsoon as observed along the west coast of India (McLusky *et al.*, 1975 ; Achuthankutty *et al.*, 1978).

Salinity

Salinity values were high during late summer and early premonsoon seasons. With the onset of monsoon salinity decreased to the annual minimum (<1 ‰). High salinity values during summer compared to other seasons could be due to low rainfall and rise in atmospheric temperature resulting in the evaporation of surface water (Fig. 3). Dwivedi *et al.* (1975) observed similar salinity fluctuations in the intertidal area in Mandovi Estuary. At different sandy beaches, along the west coast of India, such salinity variations have been highest in summer and lowest in winter or during floods.

In the present study a horizontal gradient was observed in salinity values which were found to decrease with an increase in distance from the mouth. Rao and George (1959) at Korapuzha Estuary and Vijayalakshmi (1973) at the Vellar Estuary have also observed similar horizontal salinity gradients between stations.

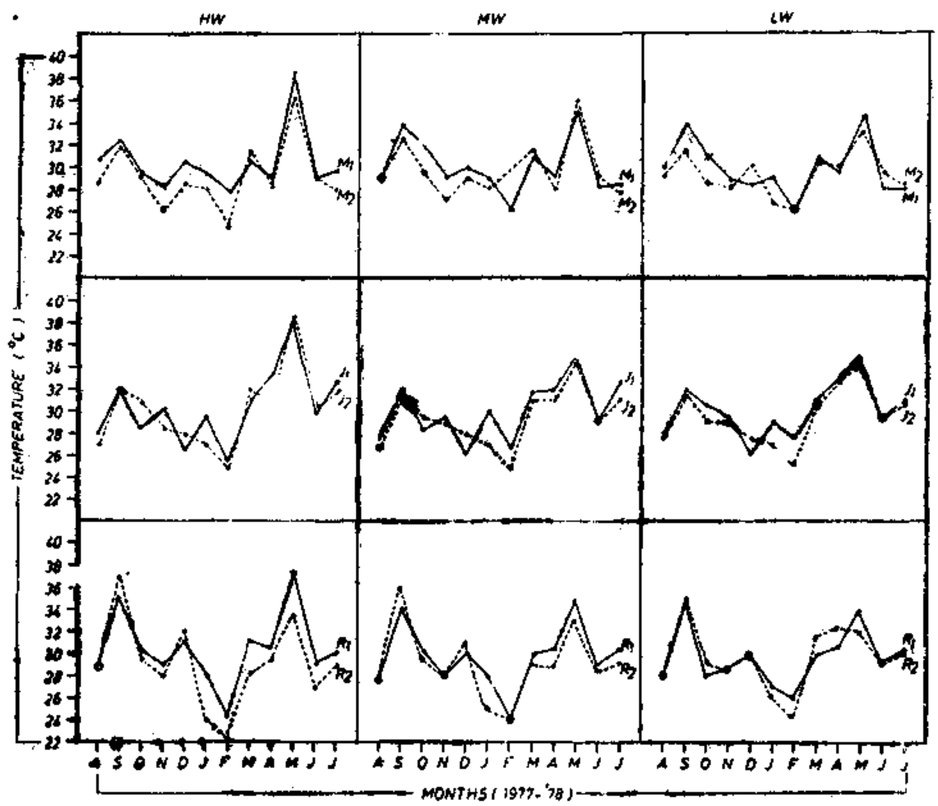

FIG. 2. Monthly variations of substrate temperature at Stations M_1, M_2, J_1, J_2, R_1 and R_2 at high water (HW), mid Water (MW) and low water (LW) levels during 1977-78.

recorded as a result of monsoon (McLusky *et al.*, 1975 ; Achunthankutty 1976 ; Achunthankutty *et al.*, 1978 ; Nair 1978 ; Trevallion *et al.*, 1970). Dye (1978, 1979) in his observations at Swartkops and Mngazana Estuaries, South Africa, also observed that salinity tended to be The variations between the pairs of stations on the south and north bank did not differ more than 2 ‰ and the lower salinity values observed at stations on the south bank may be due to the fact that the river water is deflected towards the right side of the estuary (McLusky, 1971).

TABLE 1. *Monthly variation in median particle size (Md ϕ) during* 1977-78

Month	Stations																	
	M_1			J_1			R_1			M_2			J_2			R_2		
	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW
Aug. 1977	1.50	2.55	2.40	3.10	2.95	3.25	2.95	3.00	3.25	2.45	2.30	2.30	2.30	2.65	2.90	2.55	3.20	3.05
Sept.	2.45	2.50	2.35	3.20	2.95	2.50	3.00	3.05	3.30	2.40	2.40	2.40	2.40	2.60	2.90	2.55	3.25	3.15
Oct.	2.40	2.55	2.45	3.30	3.20	3.45	2.75	3.00	2.80	2.45	2.35	2.40	2.50	2.70	2.60	3.00	2.80	2.95
Nov.	2.65	1.75	2.55	3.40	3.15	3.25	3.30	2.70	3.45	2.50	2.50	2.45	2.95	2.55	2.30	3.20	3.30	3.50
Dec.	2.50	2.45	2.60	3.35	3.35	3.25	2.80	2.60	3.15	2.50	2.60	2.50	3.00	3.15	3.40	3.05	2.75	3.45
Jan. 1978	2.25	2.35	2.40	3.20	3.20	3.40	2.60	3.05	3.20	2.35	2.35	2.25	2.55	3.30	3.15	3.25	2.70	3.20
Feb.	2.40	2.45	2.65	3.25	3.20	3.25	2.65	2.90	3.10	2.45	2.55	2.15	2.45	2.85	3.30	2.75	2.75	2.90
Mar.	2.55	2.50	2.50	3.05	3.20	2.25	2.75	2.80	3.45	2.25	2.20	2.20	2.25	2.90	3.10	3.55	3.00	3.40
Apr.	2.55	2.55	2.55	3.35	3.30	3.50	3.15	3.20	3.30	2.50	2.40	2.30	1.95	2.35	3.20	2.70	2.90	3.15
May	2.20	2.60	2.42	3.30	3.45	3.30	2.65	2.85	3.30	2.45	2.35	2.30	2.30	2.80	3.20	2.60	3.05	3.00
June	2.50	2.45	2.45	3.45	3.40	2.50	2.85	2.90	3.15	2.45	2.35	2.35	2.45	2.75	3.15	3.15	3.10	2.90
July	2.40	2.55	2.65	2.95	3.25	3.55	2.65	2.60	2.90	2.35	2.40	2.45	2.35	2.50	3.05	2.75	2.90	2.85

HW = High water ; MW = Mid water ; LW = Low water.

Dissolved oxygen content

Wide fluctuations in dissolved oxygen content were observed ranging between 3.4 ml/l and 10.6 ml/l respectively during summer and monsoon (Fig. 3). Higher concentrations of dissolved oxygen during the freshwater flow in the Vellar estury has also been recorded earlier by Krishnamurthy (1964), Vijayalakshmi (1973), Jegatheesan (1974) and Rajendran (1974). An inverse relationship between temperature and dissolved oxygen contend has also been observed by Redfield (1948), Ramamurthy (1953), Ganapati and Venkatasarma (1958) and Dye (1978). Brafield (1978) has suggested that the occurrence of low dissolved oxygen content with higher temperature may be due to an increase in the population of micro-organisms resulting in considerable oxygen demand. On the other hand Achuthankutty (1976) and Nair (1978) were of the opinion that higher oxygen values during monsoon may be due to intense mixing of surface waters and addition of freshwater.

A horizontal gradient in values of dissolved oxygen content was noticed as the distance increased from the marine to the tidal zone. The stations on the north bank invariably recorded slightly higher values (<1.1 ml/l) than those on the south bank. The horizontal gradient may be caused by the decaying of organic material whose concentration is more at the gradient and tidal zone.

Organic carbon

Organic carbon of the sediment in different stations ranged between 0.14 and 10.49 mg C/gm. Seasonal variations in organic carbon content of all the stations followed a similar trend, with higher values during monsoon, postmonsoon and summer. Although higher values of carbon were observed at the low tide level throughout the year, the annual maximum was recorded at the other two tide levels during monsoon and postmonsoon (Fig. 4).

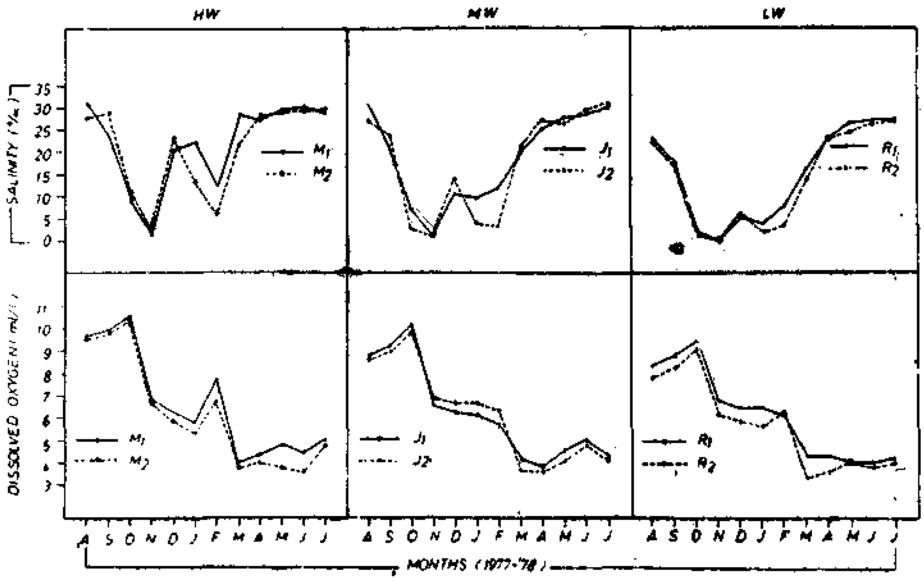

FIG. 3. Monthly variations of surface water salinity and dissolved oxygen content at Stations M_1, M_2, J_1, J_2, R_1 and R_2 during 1977-78.

The relationship of high concentration of

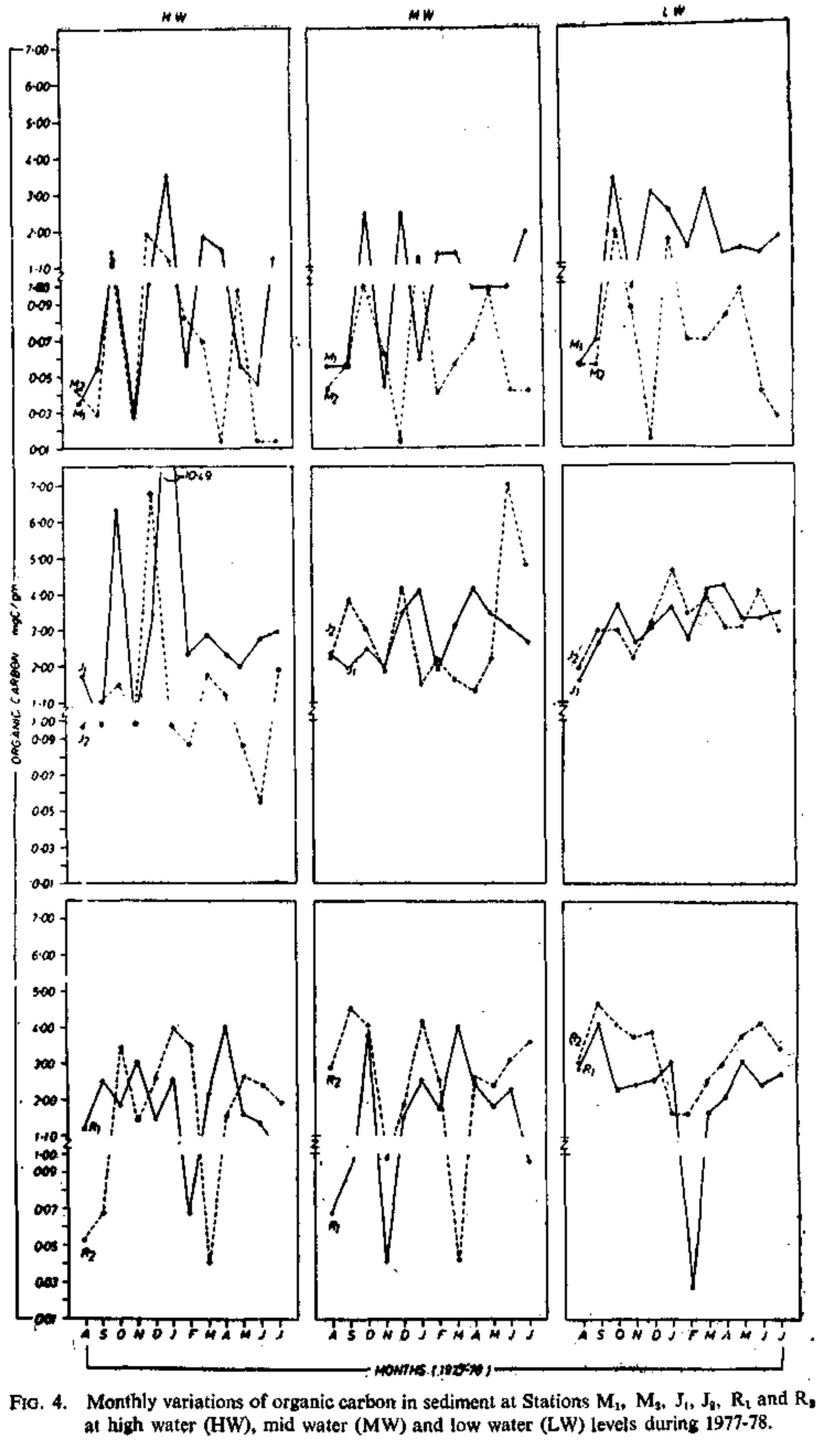

FIG. 4. Monthly variations of organic carbon in sediment at Stations M_1, M_2, J_1, J_2, R_1 and R_2 at high water (HW), mid water (MW) and low water (LW) levels during 1977-78.

Table 2. *Monthly variation in the percentage weight of silt and clay during 1977-78*

Month	Stations																	
	M_1			J_1			R_1			M_2			J_2			R_2		
	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW
Aug. 1977	0.2	1.2	1.3	21.2	15.6	20.4	10.3	10.3	26.8	0	0	0	0.7	12.3	18.3	2.7	18.3	24.1
Sep.	0	0.8	1.0	27.1	17.6	5.1	13.2	10.4	27.4	0.3	1.1	0.1	0.3	10.1	18.6	2.5	19.2	27.0
Oct.	0.3	3.6	2.9	28.2	27.0	32.1	2.0	15.1	6.3	0.3	0.1	1.0	0	11.2	8.1	21.6	19.5	21.2
Nov.	1.7	1.3	8.6	31.4	21.3	26.4	26.1	6.3	23.4	1.0	1.0	1.3	21.8	10.1	5.3	14.5	19.2	31.3
Dec.	1.0	4.5	4.3	26.1	28.3	20.1	8.4	6.5	18.1	0.2	0	0.1	24.1	21.2	28.2	19.1	9.5	29.5
Jan. 1978	0.2	0.2	1.0	23.3	23.1	29.3	4.4	16.6	14.2	0.1	0.2	0.2	6.3	23.5	18.3	28.4	10.2	20.2
Feb.	0.3	1.0	1.2	24.0	20.9	23.2	3.3	9.4	13.1	0.2	0.2	0.1	0.7	12.3	25.3	10.4	12.1	13.2
Mar.	1.1	2.7	4.1	17.2	16.1	3.3	7.2	6.4	24.3	0.1	0.1	0	1.8	17.1	17.1	19.1	20.2	24.4
Apr.	3.7	1.7	2.7	32.4	29.2	34.4	24.8	21.6	19.6	0.3	0.1	0	0	2.2	25.2	4.8	19.4	21.2
May	1.0	2.8	1.0	29.1	32.1	28.1	10.1	9.1	22.7	0	0	0	0	15.7	22.4	9.5	13.1	21.2
June	1.8	1.2	2.1	33.1	31.1	7.2	14.4	18.3	22.2	0	0	0	6.1	18.2	25.1	20.2	19.4	17.2
July	0.5	1.6	4.1	14.1	35.1	35.5	9.1	9.3	14.5	0	0	0	2.6	15.2	22.0	14.3	18.2	17.4

HW=High water ; MW=Mid water ; LW=Low water.

TABLE 3. *Phi quartile deviation during* 1977-78

Month	Stations																	
	M_1			J_1			R_1			M_2			J_2			R_2		
	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW	HW	MW	LW
Aug. 1977	0.600	0.425	0.275	0.775	0.700	0.675	0.625	0.625	0.775	0.300	0.450	0.400	0.675	0.625	0.750	0.350	0.675	0.800
Sep.	0.400	0.375	0.400	0.875	0.725	0.500	0.650	0.625	0.750	0.350	0.375	0.500	0.850	0.600	0.725	0.350	0.650	0.825
Oct.	0.405	0.550	0.525	0.800	0.825	0.800	0.525	0.650	0.575	0.375	0.325	0.375	0.375	0.650	0.575	0.750	0.725	0.775
Nov.	0.400	0.600	0.650	0.825	0.750	0.750	0.750	0.550	0.525	0.325	0.325	0.325	0.750	0.450	0.600	0.575	0.625	0.700
Dec.	0.250	0.450	0.550	0.675	0.775	0.675	0.550	0.550	0.650	0.450	0.575	0.300	0.850	0.700	0.725	0.725	0.525	0.725
Jan. 1978	0.475	0.400	0.400	0.700	0.775	0.750	0.375	0.675	0.600	0.375	0.450	0.525	0.600	0.700	0.675	0.650	0.600	0.600
Feb.	0.375	0.375	0.375	0.700	0.700	0.700	0.425	0.575	0.600	0.350	0.375	0.600	0.375	0.675	0.725	0.600	0.575	0.625
Mar.	0.375	0.450	0.450	0.650	0.650	0.650	0.550	0.525	0.575	0.700	0.550	0.600	0.625	0.725	0.725	0.675	0.750	0.650
Apr.	0.525	0.400	0.450	0.850	0.825	0.825	0.775	0.675	0.625	0.325	0.350	0.425	0.650	0.550	0.800	0.450	0.750	0.725
May	0.625	0.500	0.425	0.850	0.825	0.800	0.675	0.575	0.700	0.325	0.375	0.375	0.525	0.775	0.775	0.550	0.750	0.750
June	0.550	0.400	0.425	0.850	0.850	0.675	0.725	0.750	0.725	0.325	0.450	0.375	0.650	0.875	0.825	0.750	0.750	0.775
July	0.375	0.400	0.525	0.700	0.750	0.825	0.650	0.625	0.725	0.350	0.325	0.325	0.650	1.350	0.850	0.700	0.800	0.800

HW=High water ; MW=Mid water ; LW=Low water.

organic matter to sediments with high mud content has been observed by Van Andel (1964). Kemp (1971), Reinson (1975), Willey (1976) and Rashid and Reinson (1979). In the present study higher values of organic carbon were observed during monsoon and postmonsoon months when deposition of finer particles took place. Maximum concentration of organic carbon (140-10490 μg/gm) was observed at J_1 and J_2 where maximum silt deposition was recorded while minimum values of organic carbon (0.14—1.93 μg/gm) and silt deposition was at M_1 and M_2, where there is erosion resulting perhaps in a wash off.

On the west coast of India, a maximum organic carbon content of 2100 μg/gm was recorded at Sancole Beach (Achuthankutty, 1976) and 16000 μg/gm at Baina Beach (Achuthankutty *et al.*, 1978). McLusky *et al.* (1975) observed a dramatic increase of organic carbon content in the early stages of the monsoon period. Comparatively organic carbon value of sand was low during monsoon and Ansell *et al.* (1972) suggested that peak organic carbon value observed in sand and surf water at the south-west coast during June/July may be due to heavy rain resulting in the erosion with the organic material in the sand getting washed into the water.

Phosphorus and nitrogen

Monthly values of sediment phosphorus ranged between 0.003 and 1.441 mg P/gm, with the maximum during monsoon and summer. A gradual increase in the annual values of phosphorus was observed from the marine towards the tidal zone on the northern bank while a decreasing trend was observed on the south bank (Fig. 5). Monthly values of sediment nitrogen ranged between 0.005 and 0.135 mg N/gm. Maximum values were observed during monsoon as that of phosphorus (Fig. 6).

Phosphorus commonly determines and regulates organic production and consequently, concentration of phosphorus is related to the amount of organic matter in the sediment. Moore (1930) observed that areas with strong tides usually had low phosphate and nitrate values. Emery and Rittenberg (1952), Kemp (1971) and Willey (1976) observed that the nitrogen content of the sediment is related to the amount of particulate organic matter deposited. In the present observation also, higher nitrogen content occurred in finer substrate and may probably be due to trapping of detritus by finer particles which may result in an increase in the bacterial population as observed by Dye (1978) at Swartkops Estuary.

Fauna

The most abundant macrofaunal groups were polychaetes, tanaids, young bivalves and the gastropods *Cerithidea sp.* Macrofauna was present throughout the year but larger numbers were observed only during postmonsoon and summer (Fig. 7). In general it was observed that at stations M_1 and M_2, maximum numbers of polychaetes occurred at the high tide level, while at the mid and low tide levels bivalves dominated. At stations J_1 and J_2, the high tide level harboured abundant polychaetes, while at the low tide level tanaids were present in largest numbers. Gastropods were dominant at the high tide level of stations R_1 and R_2, while at the mid tide level polychaetes were dominant at station R_1 and bivalves at R_2. The least represented group at stations M_1 and M_2 was tanaids, at J_1 and J_2 bivalves and at R_1 and R_2 both tanaids and bivalves.

The most abundant meiofaunal groups were nematodes, harpacticoids, polychaetes and copepod nauplii. Seasonal variation of total meiofauna followed a similar trend to that of the macrofauna, with the maximum in post monsoon and summer (Fig. 8). Maximum numbers of meiofauna occurred at J_1 on the north bank (33,916/10 cm^2/y) and at M_2 on the south bank (35,870/10 cm^2/y). Minimum numbers were observed at stations R_1 and R_2 at the tidal zone (15,849 and 19,725/10 cm^2/y respectively) (Table 4).

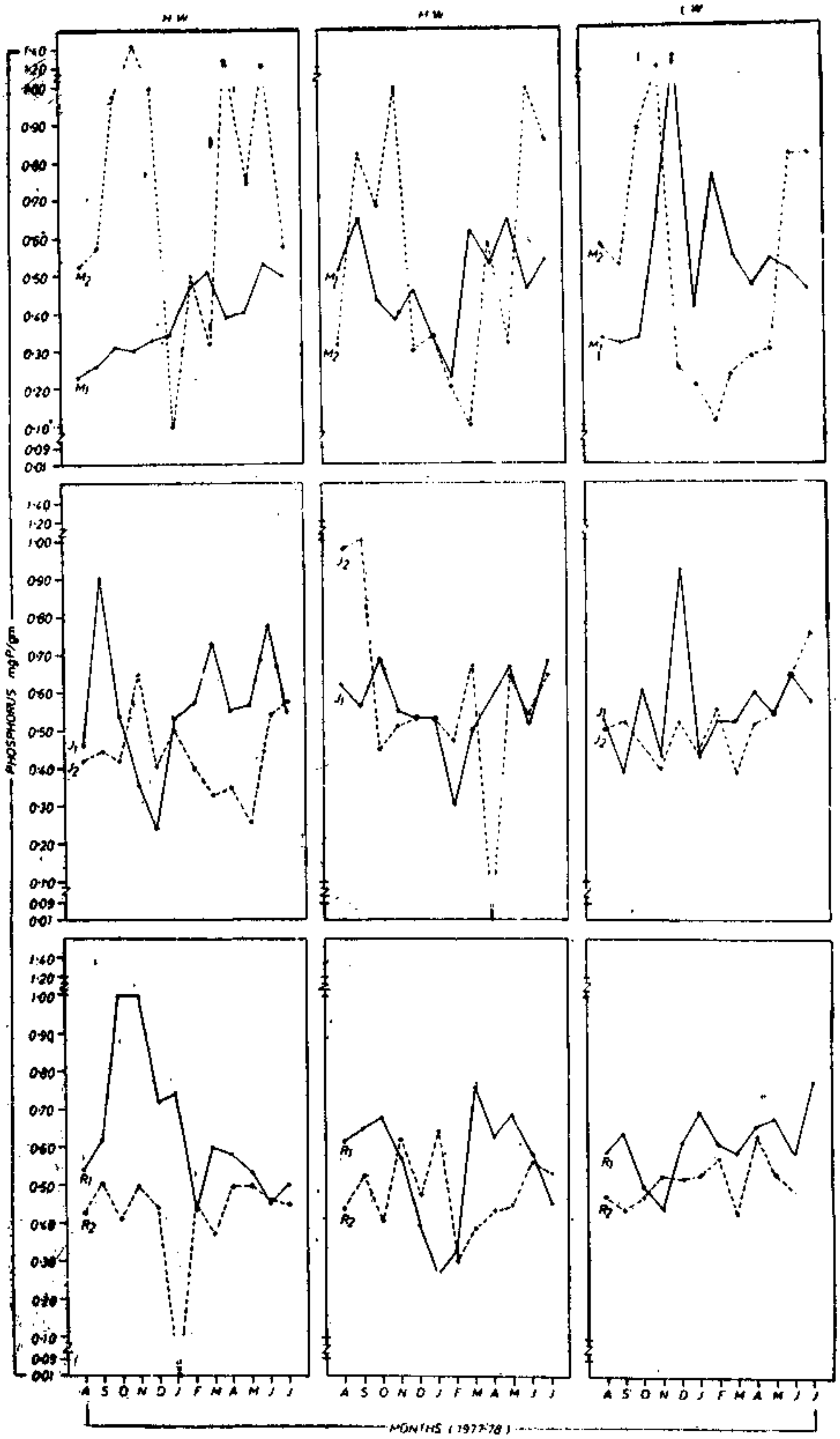

FIG. 5. Monthly variations of total phosphorus in sediment at Stations M_1, M_2, J_1, J_2, R_1, and R_2 at high water (HW), mid water (MW) and low water (LW) levels during 1977-78.

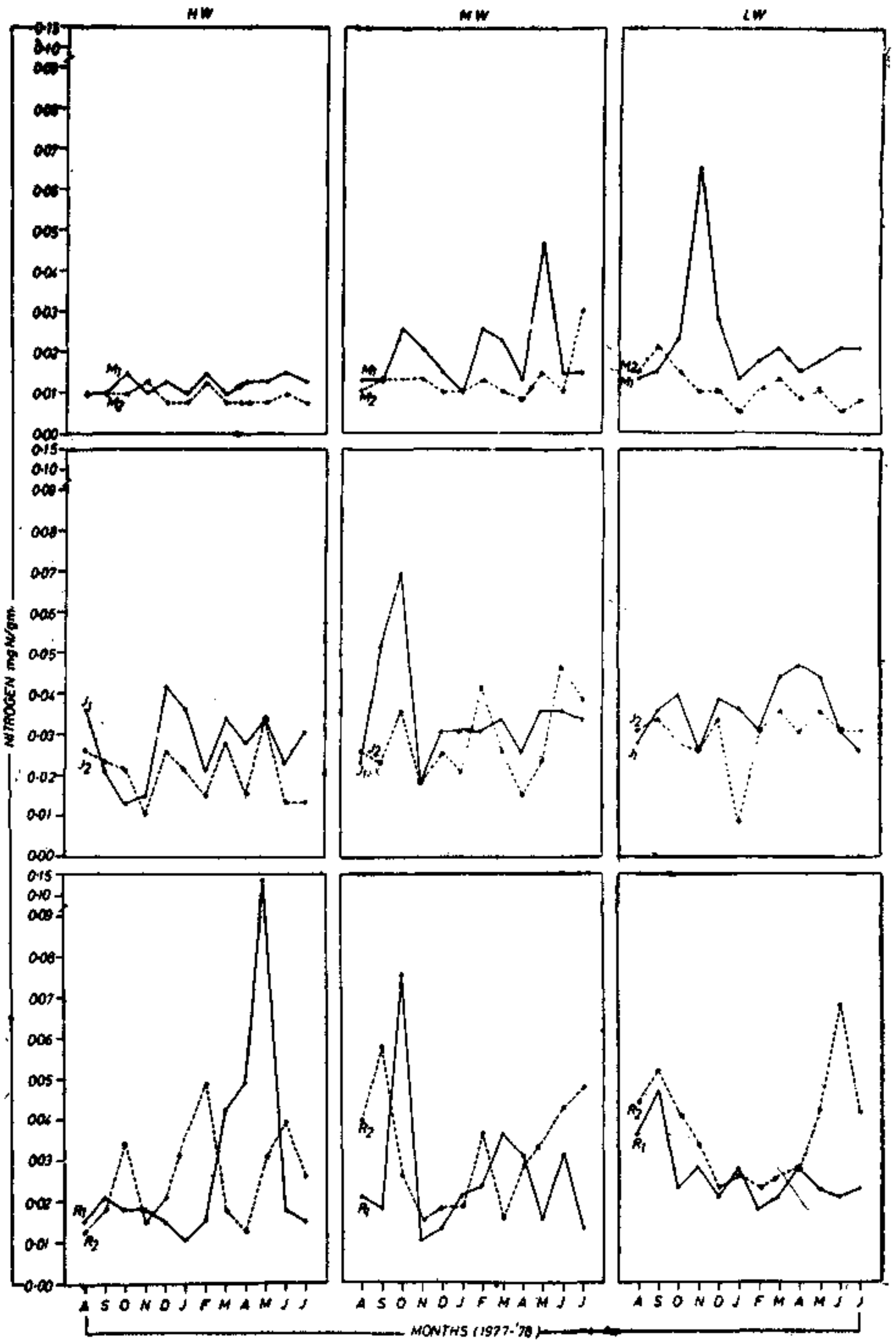

FIG. 6. Monthly variations of total nitrogen in sediment at Stations M_1, M_2, J_1, J_2, R_1 and R_2 at high water (HW), mid water (MW) and low water (LW) levels during 1977-78.

At all the tide levels of all the stations nematodes were the dominant component (48-79%) of the meiofaunal community, whereas the percentage composition of other components namely, harpacticoids, polychaetes and nauplii were not always consistent. The least represented forms at the mid and low tide levels of all stations were polychaetes, except at the mid tide level of M_2 where nauplii were observed in lowest numbers. The high tide levels of stations M_1 and M_2 were least populated by nauplii and stations R_1 and R_2 by harpacticoids ; at station J_1 it was polychaetes and at J_2 harpacticoids.

Station J_1 and J_2 of the gradient zone and R_1 and R_2 of the tidal zone showed patterns of meiofaunal abundance similar to that of the macrofauna in that the maximum numbers were observed at the low tide level. On the other hand at stations M_1 and M_2, such faunal abundance was at mid (6,696/10 cm^2) and low tide levels (7,470/10 cm^2) respectively.

A distinct feature of the Indian Beaches is the influence of the monsoon which adversely affects the density of the fauna. The biomass of macrofauna was observed to be almost nil or very poor during monsoon season in the beaches at Cochin (South-west coast of India) (Kutty and Nair, 1966 ; Ansell *et al.*, 1972) and Goa (McLusky *et al.*, 1975 ; Achuthankutty 1976 ; Nair 1978 ; Achuthankutty *et al.*, 1978). McLusky *et al.* (1975) suggested that the monsoon, by reducing the salinity and altering the beach profile may adversely affect the macrofaunal population. Achuthankutty (1976) is of the opinion that severe erosion could limit the substratum for sand dwellers by shifting the intertidal zone landwards and restricting the intertidal expanse.

Stations on the north bank, recorded greater densities of macrofauna than the corresponding stations on the south bank, probably because of the sheltered nature of the shore. Considering all the six stations, only stations at the tidal zone were found to be poorly populated. This observation supports Rochford's (1951) suggestion that an estuary represents a rigorous environment, with stress conditions becoming particularly severe, as one moves up the estuary to the gradient zone.

Occurrence of larger numbers of macrofaunal individuals as well as representatives from many phyla observed at the low tide levels may be due to greater stability, lesser desiccation, lower temperature range and increased feeding time (McLachlan, 1977 b). Such a distribution has been described as a typical pattern by Eltringham (1971). Stations J_1 on the north bank and M_2 on the south bank recorded maximum meiofauna. Both these stations differed considerably in their substrate as well as organic carbon content. Despite these differences equally high numbers were observed at both these stations and may be due to the difference in the composition of the meiofauna. Harris (1972) also observed that the total meiofauna was similar at different tide levels, but its component species varied according to tide level and seasons.

The maximum abundance of meiofaunal communities of well drained beaches have been observed to increase towards the lower shore level (Wieser, 1959 ; Ganapati and Rao, 1962 ; McIntyre, 1968 ; McLachlan, 1977 a), while, at more sheltered beaches with shallower water table and slow drainage they were observed at the upper layers of high tide level (McLachlan, 1977 a). Thus meiofauna appears to be concentrated at those levels where desiccation is not too severe and oxygen availability is not too low, (Pennak, 1940 ; Ganapati and Rao, 1962 ; Jansson, 1967 ; McLachlan, 1977 a McLachlan *et al.*, 1977) While the distribution of meiofauna on a beach may be mainly due to water content and oxygen availability, Ganapati and Rao (1962), Hulings (1974) and McLachlan (1977 a, b) suggested that meiofaunal densities are probably largely determined by amounts of available food.

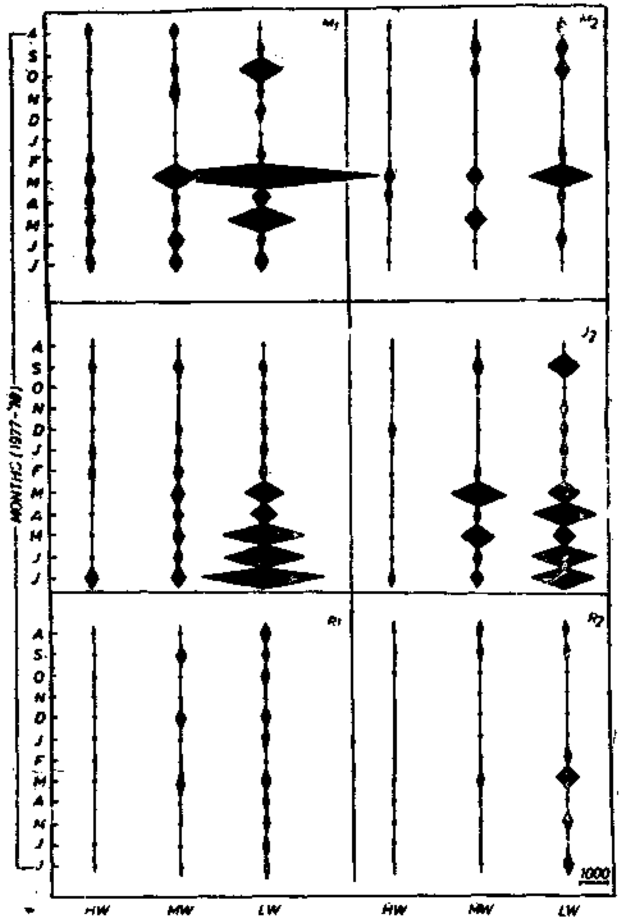

FIG. 7. Monthly variations in numbers of total macrofauna/m^2 at Stations M_1, M_2, J_1, J_2 R_1 and R_2 at high water (HW), mid water (MW) and low water (LW) levels during 1977-'78.

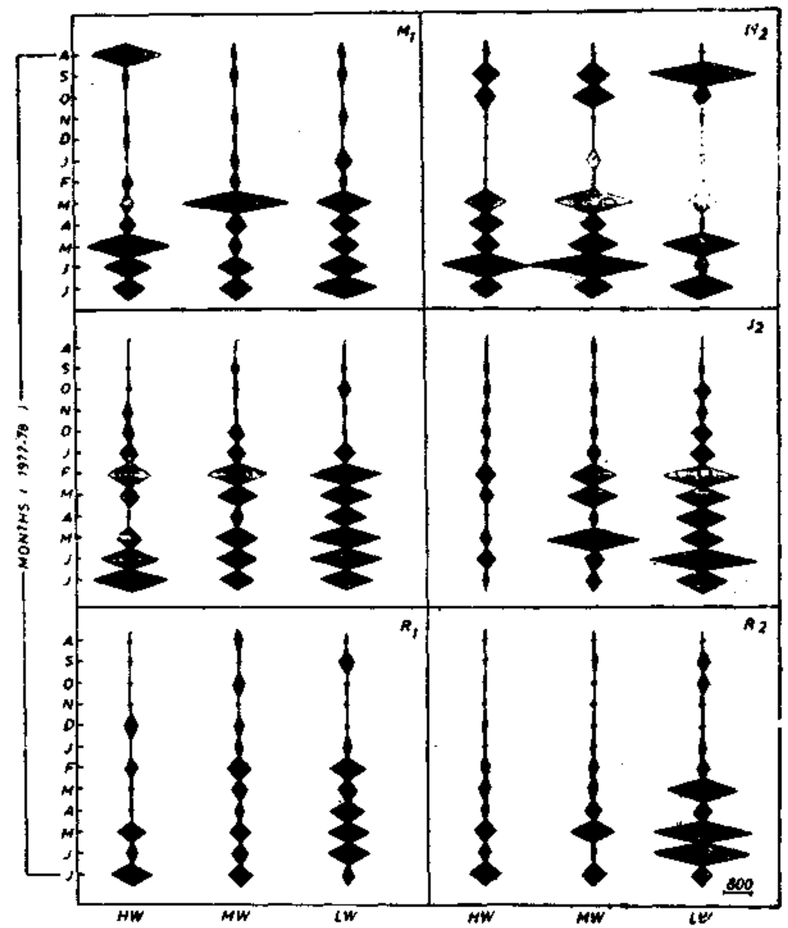

FIG. 8. Monthly variations in numbers of total meiofauna/10 cm^2 at Stations M_1, M_2, J_1, J_2, R_1 and R_2 at high water (HW), mid water (MW) and low water (LW) levels during 1977-'78.

In the present study also more sheltered stations at the gradient and tidal zones of the Vellar Estuary recorded larger numbers at the low tide level and the minimum at the high tide level. But at the marine zone of the estuary the meiofaunal density was least at the low tide level and more at the high tide level possibly due to more turbulence at the low tide level as observed by Brown (1971) in African shores.

TABLE 4. *Percentage of individual fauna during* 1977-78

		Macrofauna					Meiofauna				
Stations	Tide	Poly-chaetes	Ceri-thidea	Bivalves	Tan-aides	Others	Nema-todes	Harp-acticoids	Poly-chaetes	Nauplii	Other
M_1	HW	60.12	13.09	8.63	0.00	18.16	59.29	6.98	1.55	1.33	30.85
	MW	19.28	26.40	49.67	1.23	3.42	67.08	3.76	1.25	6.00	21.91
	LW	5.22	13.35	34.64	0.08	46.71	63.24	4.95	1.94	3.28	26.59
J_1	HW	55.02	33.19	2.62	6.11	3.06	79.45	6.16	1.52	6.36	6.51
	MW	47.96	12.07	10.60	24.47	4.90	74.01	7.74	3.71	6.71	7.83
	LW	11.47	7.95	4.65	73.89	2.04	67.88	17.81	4.06	5.19	5.06
R_1	HW	31.71	58.54	2.44	2.44	4.87	57.48	2.44	3.73	13.32	23.03
	MW	66.92	21.54	6.15	3.08	2.31	60.66	12.45	1.08	12.55	13.26
	LW	55.62	15.37	11.90	11.90	5.21	60.04	18.43	0.48	6.68	14.37
M_2	HW	56.96	10.18	23.42	3.16	6.28	74.96	8.71	3.86	2.53	9.94
	MW	11.79	8.21	38.74	0.84	40.42	68.32	11.20	3.04	2.18	15.26
	LW	12.38	13.23	47.09	0.00	27.30	51.61	5.18	6.45	1.12	35.64
J_2	HW	30.77	20.51	4.27	26.49	17.96	48.85	2.42	9.13	16.63	22.97
	MW	10.85	15.55	3.93	67.95	1.72	64.42	6.09	2.47	5.26	21.76
	LW	9.55	26.04	3.76	57.43	3.22	67.85	12.07	1.70	8.01	10.37
R_2	HW	16.66	36.66	6.66	23.33	16.69	65.38	1.22	4.17	19.21	10.02
	MW	42.86	31.58	7.52	4.51	13.53	72.64	6.15	2.82	11.00	7.39
	LW	23.75	24.40	41.18	3.48	7.19	76.06	7.08	0.75	9.18	6.93

HW=High Water ; MW=Mid Water ; LW=Low Water.

McIntyre (1968) based on his short-term observation, both in the Vellar Estuary and in the open sea beach, compared the general paucity of the macrofauna to the exposed beaches in north temperate zones. Though he recorded more species he found their densities were considerably lower than in other estuarine areas studied (Fraser, 1932 ; Beanland, 1940 ; Rees, 1940 ; Spooner and Moore, 1940). While in the temperate zone the biomass is largely due to lamellibranchs, McIntyre (1968) observed that in general, Porto Novo beaches are like those of lower latitudes around the world, where the dominant group is Crustacea. However the present observation revealed that the dominant group at each zone of the Vellar Estuary was different at different tidal levels, zones and seasons.

The abundance of macrofauna during post-monsoon at the mid and low tide levels of the marine zone was only due to bivalve spats. Absence of adults during the other seasons was conspicuous and no evidence of growth was observed during the period of study. Similar occurrence of such newly recruited bivalves, showing no evidence of growth at the area of study was also reported by Achuthankutty *et al.* (1978) at Baina Beach, Goa. In general, nematodes have been observed to dominate (60—80%), the total percentage composition of meiofauna (Rees, 1940 ; Weiser, 1959 ; McIntyre, 1964, 1968, 1969 ; McLachlan, 1975) followed by harpacticoids (McIntyre, 1968). The seasonality of total meiofauna, however masks the seasonality of individual taxa. As Gerlach (1971) has pointed out, it is essential to know the life history of the components of meiofauna. The problem of determining a seasonal pattern for each site is complicated by spatial and temporal variations in meiofaunal distribution. Ganapati and Rao (1962) stated that food, temperature, moisture and substrate texture were the factors affecting meoifaunal distribution at Waltair, on the north-east cost of India, while Panikkar and Rajan (1970) found no clear correlation between meoifaunal distribution and chlorophyll values in sands along the west coast. Wafer *et al.* (1980) suggested that availability of food may not be a primary factor controlling the fluctuations of animal population in the types of tropical sandy beaches they studied. Hulings (1974), however, considered food supply a primary factor in the seasonality of Lebanese sand beach meiofauna. In the present study seasonal variations observed both in meiofauna as well as other factors, such as organic carbon and total nitrogen seem to indicate the importance of food supply as one of the major factors affecting the meiofauna.

Heip (1971) suggested that some predator—prey relationship and the differences in reproductive rates may be the cause for annual succession but according to Holland and Polgar (1976) the elevation of the beach and substrate characteristics may be the dominant factors controlling community structure of macrofauna. While it is true that the physicochemical conditions in the environment controls the overall nature and distribution of the organisms living in the intertidal zone, it is equally true that biological factors may profoundly influence conditions in the habitat (Newell, 1979). Modifications of the environment by the activities of the primary components of the fauna may also play a part in the exclusion of other organisms which might otherwise be able to live in the same habitat.

References

Achuthankutty, C. T. 1976. Ecology of sandy beach at Sancole, Goa. Part I: Physical factors influencing production of macrofauna. *Indian J. mar. Sci.*, 5 (1) : 91-97.

———, A. Striling, S. Nair, P. A. Loka Bharati and M. R. Menezes 1978. Sandy beach at Baine, Goa : Its ecology and production. *Ibid.*, 7 (1) : 23-29.

Ansell, A. D., P. Sivadas, B. Narayanan, V. N. Sankaranarayanan and A. Trevallion 1972. The ecology of two sandy beaches in south-west India. I. Seasonal changes in physical and chemical factors and in the macrofauna *Mar Biol.*, 17 : 38-62.

———, D. S. McLusky, A. Stirling and A. Trevallion 1978. Production and energy flow in the macrobenthos of two sandy beaches in south-west India. *Proc. Roy. Soc. Edinb.*, 76 B : 269-296.

Ayyakkannu, K. 1971. Studies on the variations in the environmental factors and nutrients in interstitial water in a sandy beach at Porto Novo. *J. Annamalai Univ. Sci.*, 29 : 199-207.

Balasubrahmanyam, K. 1964. Studies on the ecology of the Vellar Estuary 3. The intertidal and estuarine Polychaeta. *Ibid.*, 25:101-104, BALASUBRAHMANYAM, K. 1966. Studies in the ecology of the Vellar Estuary 4. Distribution of crabs in the intertidal region. *Proc. Second All India Cong. Zool., Varanasi* (1962) **2** : 307-311.

BARNES, H. 1959. *Apparatus and Methods in Oceanography. I. Chemical.* George Allen and Unwin Ltd. London, pp. 341.

BEANLAND, F. L. 1940. Sand and mud communities in the Dovey estuary. *J. Mar. Biol. Ass. U.K.*, **24** : 587-611.

BRAFIELD, A. D. 1978. *Life in Sandy Shores.* The Institute of Biology's Studies in Biology No. 89. Edward Arnold (Publ.) Ltd., pp. 60.

BROWN, A. C. 1971. The ecology of the sandy beaches of the Cape Peninsula, South Africa. Part I : Introduction. *Trans. roy. Soc. S. Afr.*, **39** (3) : 247-279.

BRUCE, J. R. 1928. Physical factors on the sandy beach. Part I. Tidal, climatic and edaphic. *J. Mar. Biol. Ass. U.K.*, **15** : 535-552.

DWIVEDI, S. N., A. RAHIM AND S. AYYAPPAN NAIR 1975. Ecology and production of intertidal sand fauna during south-west monsoon along Mandovi Estuary (Goa). In : R. Natarajan (Ed.) *Recent Researches in Estuarine Biology* Hindustan Publishing Corporation (I), Delhi, India. pp. 1-20.

DYE, A. H. 1978. An ecophysiological study of the meiofauna of the Swartkops Estuary I. The sampling sites. : Physical and chemical features. *Zool. afr.*, **13** : 1-18.

——— 1979. Aspects of the ecology of meiofauna in Mngazana Estuary, Transkei. *S. Afr. J. Zool.*, **14** (2) : 67-83.

ELTRINGHAM, S. K. 1971. *Life in Mud and Sand.* English Universities Press Ltd., London. pp. 218.

EL WAKEEL, S. K. and J. P. RILEY 1956. The determination of organic carbon in marine muds. *J. du Conseil*, **22** : 180-183.

EMERY, K. O. AND S. C. RITTENBERG 1952. Early diagenesis of California basin sediments in relation to origin of oil. *Bull. Am. Assoc. Pet. Geol.*, **36** : 735-806.

FRASER, J. H. 1932. Observations on the fauna and constituents of an estuarine mud in a polluted area. *J. Mar. Biol. Ass. U.K.*, **18** : 69-85.

GANAPATI, P. N. AND G. C. RAO 1962. Ecology of the interstitial fauna inhabiting the sandy beaches of Waltair coast. *J. mar. biol. Ass. India*, **4** (1) : 44-57.

——— AND D. VENKATASARMA 1958. Hydrography in relation to production of plankton off the Vishakapatnam coast. *Andhra Univ. Mem. Oceanogr.*, **2** : 168-192.

GERLACH, S. A. 1971. On the importance of marine meiofauna for benthos communities. *Oecologia* (Berl.), **6** : 176-190.

HARRIS, R. P. 1972. The distribution and ecology of the interstitial meiofauna of a sandy beach at Whitsand Bay, Cornwall. *J. Mar. Biol. Ass. U.K.*, **52** (1) : 1-18.

HEIP, C. 1971. The succession of benthic micrometazoans in a brackishwater habitat. *Biologisch Faarboek*, **39** : 191-196.

HOLLAND, A. F. AND T. T. POLGAR 1976. Seasonal changes in the structure of an intertidal community. *Mar. Biol.*, **37** : 341-348.

HULINGS, N. C. 1974. A temporal study of Lebanese sand beach meiofauna. *Cah. Biol. mar.*, **15** : 319-337.

——— AND J. S. GRAY 1971. A manual for the study of meiofauna. *Smithson. Contr. Zool.*, **78** : 1-83.

JANSSON, B. O. 1967. The significance of grain size and pore water content for the interstitial fauna of sandy beaches. *Oikos*, **18** : 311-322.

JEGATHEESAN, G. 1974. *Studies on the particulate matter of Vellar Estuary and the nearshore waters of, Porto Novo.* Ph. D. Thesis, Annamalai University pp. 256.

JOHNSON, R. G. 1965, Temperature variation in the infaunal environment of a sand flat. *Limnol. Oceanogr.*, **10** : 114-120.

KEMP, A. L. W. 1971. Organic carbon and nitrogen in the surface sediments of Lakes Ontario Erie and Huron. *J. Sediment. Petrol.*, **41** : 537-548.

KRISHNAMURTHY, K. 1964. *Studies on plankton and nutrients in the inshore and estuarine waters of Porto Novo.* Ph. D. Thesis. Annamalai Univ., pp. 239.

KUTTY, A. G. GOVINDAN AND N. B. NAIR 1966. Preliminary observations on the interstitial fauna of the South-west coast of India. *Hydrobiologia*, **28** : 101-122.

MCINTYRE, A. D., 1964. Meiobenthos of sublittoral muds. *J. Mar. Biol. Ass. U.K.*, **44** : 665-674.

——— 1968. The meiofauna and macrofauna of some tropical beches. *J. Zool. Lond.*, **156** : 377-392.

——— 1969. Ecology of marine meiobenthos. *Biol. Rev.*, **44** : 245-290.

MCLACHLAN, A. 1975. *Studies on the psammolittoral meiofauna of Algoa Bay.* Ph.D., Thesis, Univ. Port Elizabeth.

——— 1977 a. Studies on the psammolittoral meiofauna of Algoa Bay. II. The distribution, composition and biomass of the meiofauna and macrofauna. *Zool. afr.*, **12** : 33-60.

——— 1977 b. Composition, distribution, abundance and biomass of the macrofauna and meiofauna of four sandy beaches. *Ibid.*, **12** : 279-306.

McLachlan, A. 1975. T. Erasmus and J. P. Furstenberg 1977. Migrations of sandy beach meiofauna. *Ibid.*, **12** : 257-277.

McLusky, D. S. 1971. *Ecology of Estuaries.* Heinemann Educational Books Ltd., London : pp. 144.

———, S. A. Nair, A. Stirling and R. Bhargava 1975. The ecology of a central west Indian beach, with particular reference to *Donax incarnatus. Mar. Biol.*, **30** : 267-276.

Morgans, J. F. C. 1956. Notes on the analysis of shallow water soft substrata. *J. Anim. Ecol.*, **25** : 367-387.

Moore, H. B. 1930. The muds of the Clyde Sea. area, I. Phosphate and nitrogen contents. *J. Mar. Biol. Ass. U.K.*, **16** : 595-607.

Murphy, J. and J. P. Riley 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta*, **27** : 31-36.

Nair, A. 1978. Production ecology of a tropical sandy beach at Benaulim, Goa, *Indian J. mar. Sci.*, **7** : 163-167.

Newell, R. C. 1979. *Biology of Intertidal Organisms.* Marine Ecological Surveys, Ltd., Kent 3rd ed. ix + 781p.

Panikkar, B. M. and S. Rajan 1970. Observations on the ecology of some sandy beaches of the south-west coast of India. *Proc. Indian Acad. Sci.*, **71B** : 247-260.

Pennak, R. W. 1940. Ecology of the microscopic Metazoa inhabiting the sandy beaches of some Wisconsin lakes. *Ecol. Monogr.*, **10** : 535-615.

Rajendran, A. 1972. Distribution of *Uca annulipes* (Latreille) in the intertidal mud-flats of the Vellar Estuary. *Proc. Indian nat. Sci. Acad.*, **38B** : 378-379.

——— 1974. *Studies on the ecology of Vellar Estuary : Chemistry and microbiology of regeneration of nutrients.* Ph.D. Thesis, Annamalai Univ., pp. 323.

Ramamoorthi, K. 1954. A preliminary study of the hydrology and fauna of Vellar Estuary (South. Arcot District) *Proc. Indo-Pacific Fish. Coun., Symp.*, **9**: Bangkok.

——— and K. Alagaraja 1969. A preliminary study of growth in *Cerithidea (Cerithideopsilla) fluviatilis* (Potiez and Michaud), (Prosobranchia-Gastropoda) *Proc. Symp. Mollusca, Mar. biol. Ass. India*, **2** : 418-420.

Ramamurthy, S. 1953. Hydrological studies in the Madras coastal waters. *J. Madras Univ.*, **23** : 148-163.

Rao, S. V. S. and P. C. George 1959. The hydrology of the Korapuzha Estuary, Malabar, Kerala state. *J. mar. biol. Ass. India*, **1** : 23-43.

Rashid, M. A. and G. E. Reinson 1979. Organic matter in surficial sediments of the Miramichi Estuary, New Brunswick, Canada. *Est. Coastl. mar. Sci.*, **8** : 23-36.

Redfield, A. C. 1948. The exchange of oxygen across the sea surface. *J. Mar. Res.*, **7** : 347-361.

Rees, C. B. 1940. A preliminary study of the ecology of a mud-flat. *J. Mar. Biol. Ass. U.K.*, **24** : 185-199.

Reinson, G. E. 1975. Geochemistry of muds from a shallow restricted estuary, Australia. *Marine Geology*, **19** : 297-314.

Rochford, D. J. 1951. Studies in Australian estuarine hydrology. I. Introductory and comparative features. *Aust. J. mar. Freshw. Res.*, **2** : 1-116.

Spooner, G. M. and H. B. Moore 1940. The ecology of the Tamar estuary. VI. An account of the macrofauna of the intertidal muds. *J. Mar. Biol. Ass. U.K.*, **24** : 283-330.

Strickland, J. D. H. and T. R. Parsons 1968. A practical handbook of seawater analysis. *Bull. Fish. Res. Bd. Can.*, **167** : pp. 311.

Trevallion, A., A. D. Ansell, P. Sivadoss and B. Narayanan 1970. A preliminary account of two sandy beaches in South-west India. *Mar. Biol.*, **6** : 268-279.

Van Andel, Tj. H. 1964. Recent marine sediments of Gulf of California. pp. 216-310. *In* : Marine Geology of the Gulf of California. A Symposium. *Am. Assoc. Petrol. Geol. Mem.*, **3** .

Vijayalakshmi, G. S. 1973. *Hydrobiological Studies in the Vellar Estuary.* Ph. D. Thesis, Annamalai University, pp. 183.

Wafar, M. V. M., M. D. Rajagopal, M. R. Menezes and A. Stirling 1980. Physico-chemical features and energy input in three sandy beaches of west coast of India. *Indian J. mar. Sci.*, **9** : 25-30.

Wieser, W. 1959. The effect of grain size on the distribution of small invertebrates inhabiting the beaches of Puget Sound. *Limnol. Oceanogr.*, **4** : 181-194.

Willey, J. E. 1976. Geochemistry and environmental implications of the surficial sediments in northern Placentia Bay. Newfoundland. *Canadian Journal of Earth Science*, **13** : 1393-1410.