

# Ecology and Production of Intertidal Sand Fauna During Southwest Monsoon Along Mandovi Estuary (Goa)

S. N. DWIVEDI, A. RAHIM and S. AYYAPPAN NAIR  
*National Institute of Oceanography, Panaji-Goa*

Mandovi estuary exhibits great fluctuations in the physico-chemical conditions during monsoon. The salinity of the estuary varies from 2‰ to 32‰. The change is also associated with beach building, erosion processes and important qualitative and quantitative changes in the biomass of macro-fauna. Studies were undertaken during the monsoon months from June-September, 1971, along three transects of a beach at the mouth of the estuary. Fortnightly observations were made along these transects between the high and low tide mark at 5 metre intervals. The various environmental changes such as beach profile, temperature, pH, salinity, dissolved oxygen and qualitative and quantitative changes in the intertidal fauna have been studied. The study of the features indicates progressive changes from marine conditions in the premonsoon months to freshwater conditions following the onset of the monsoon.

## Introduction

Sandy beaches have been the object of extensive ecological and faunistic studies all over the world. The beaches in India have not received much attention except for the work of McIntyre (1968), Rao and Ganapati (1968) and Trevallion *et al.* (1970).

The present studies have been taken up in the beaches of the Central part of the West Coast of India which is subject to heavy monsoonal rains of the Southwest Monsoon.

The heavy influx of freshwater, caused by the rains during the Southwest Monsoons affects the beach environment and its macrofauna, forming the major constituent in the intertidal production. During this period, rapid changes in beach profile coupled with building up and erosion processes and wide fluctuations in salinity and other environmental parameters influence the ecology of intertidal region. This brings about qualitative and quantitative changes in the macrofauna *in toto* and affects the life of the individual species.

In this paper we have dealt with the distribution of macrofauna in relation to environmental conditions during monsoon months in three different sectors of a beach, situated along north-south plane on the left bank of Mandovi estuary (15° 30' N-73° 45' E) (Fig. 1). The exact location of these sectors which are situated on the beach about 1½ km apart from each other, is given in the following paragraphs.

- (a) *Miramar Light House* transect is the northern most sector situated opposite to the Verem Jetty.

- (b) *Miramar* transect is opposite to the Aguada Fort point where the estuary opens into the sea.
- (c) *Caranzalem* is the southernmost transect, situated along Caranzalem village. This area is subjected to erosion, therefore in the supralittoral zone an embankment has been constructed to check erosion.

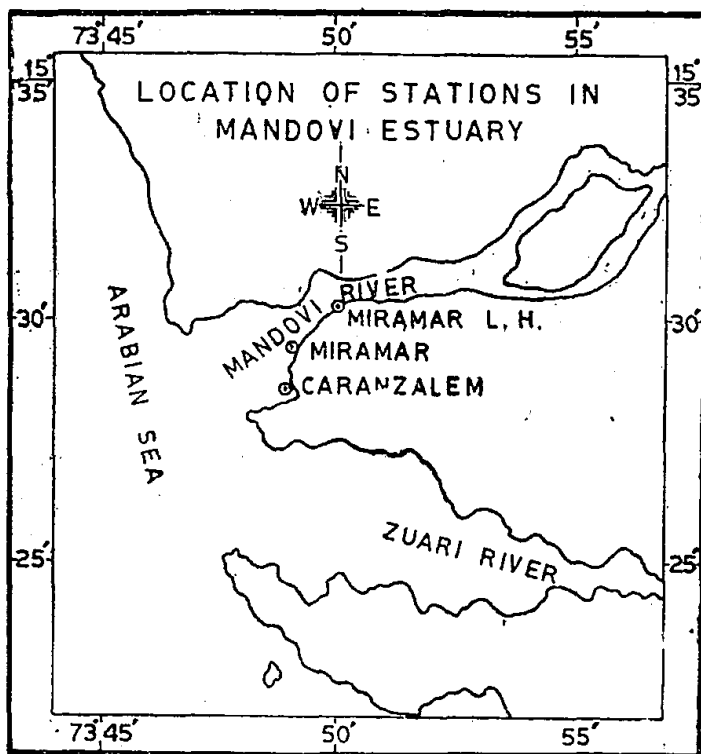


Fig. 1. Mandovi estuary and station positions

### Material and methods

The observations were made fortnightly during low tide in the intertidal region from June to September 1971. All the transects were taken perpendicular to the shore against a reference point, selected near the farthest end of the supralittoral fringe. While measurements relating to beach expanse, and beach profile gradient were made from the reference point, the sand samples were collected from low to high tide mark at every 5 metres by pushing a 0.1m<sup>2</sup> quadrant into the sand upto a depth of 15 cm. They were washed through a 0.5 mm sieve (see, Birket and McIntyre : 1971), preserved in the formalin and brought to the laboratory for further studies. The temperature, 2 cm. below the surface, pH and water table were recorded at all the points from where the samples were collected.

The water tables deeper than 0.75 m were not sampled due to the difficulty in obtaining undisturbed samples. Interstitial water samples were collected for estimation of oxygen and salinity which were analysed immediately after bringing them to the laboratory.

The core samples of sand, upto a depth of 15 cm were obtained with a

plastic corer of 4 cm diameter. Sand grain size composition was studied, using Endecotts Test Sieves with mesh range from 35 to 230. The sand grains were classified as very fine sand from 0.06 to 0.125 mm, fine sand 0.125 to 0.250 mm, and medium sand 0.250 to 0.500 (Inman : 1963).

The macrofauna from sand samples were sorted into different groups and their wet weight was determined, after removing moisture on a filter paper. For estimating the average production and for calculating percentage of occurrence of different faunal groups, only positive stations were taken into account.

## Results

### A. ENVIRONMENTAL PARAMETERS

1. *The beach and the intertidal region.* The beach expanse undergoes changes at all the transects during monsoon months and from reference point to the water margin at low tide, it varies from 35 to 45, 50 to 75 and 30 to 55 metres respectively at Miramar Light House, Miramar and Caranzalem transects. The expanse of intertidal region, and its variations are given in Table 1.

TABLE 1—EXTENT OF THE INTERTIDAL REGION AT THREE TRANSECTS

<i>Transects</i>	<i>Range in mts.</i>	<i>No. of observations</i>	<i>Mean standard error (S.E.)</i>	<i>Std. deviation (S.D.)</i>	<i>Coefficient of variability (C.V.)</i>
1. Miramar Lighthouse	15 to 30	8	21.3±3.6	4.9	22.9
2. Miramar	15 to 45	8	33.8±8.5	11.4	33.8
3. Caranzalem	10 to 25	8	16.9±4.5	6.1	36.0

The seasonal variation in the intertidal region can be compared using coefficient of variability of the expanses (Mayer : 1969). The intertidal region at Caranzalem had the highest variability (CV 36). Miramar, in spite of its greater width, is comparatively less variable (CV 33.8), and the beach at Miramar Light House is most stable (CV 22.9). Table No. 1 also shows that smallest intertidal region is at Caranzalem followed by Miramar Light House. At Miramar the expanse is significantly larger than the other two transects. This intertidal exposure is also influenced by tidal range during monsoon.

Total tidal range between spring tide and neap tide varied from 2.19 to 2.27 metres, whereas the range in the neap tide was 1.28 to 2.26 metres. The range in the spring tide varied from 0.74 to 1.21 metres only.

2. *Sand grain size and beach profile.* Changes in the habitat are well demonstrated by the composition of the particle size of sand. These were studied at each transect and the median diameter sand grain size at low, mid and high tide levels are given in Table 2.

TABLE 2—MEDIAN DIAMETERS OF SAND GRAIN SIZE (mm) AT MIRAMAR LIGHT HOUSE (MLH), MIRAMAR (MIR) AND CARANZALEM (CAR)

<i>Months</i>	<i>Transects</i>	<i>Low tide level</i>	<i>Mid tide level</i>	<i>High tide level</i>
June	MLH	0.210	0.180	0.220
	MIR	0.120	0.240	0.160
	CAR	0.180	0.120	0.180
July	MLH	0.210	0.180	0.220
	MIR	0.200	0.200	0.160
	CAR	0.120	0.090	0.090
August	MLH	0.240	0.310	0.260
	MIR	0.110	0.200	0.220
	CAR	0.180	0.110	0.900
September	MLH	0.160	0.200	0.240
	MIR	0.110	0.270	0.220
	CAR	0.120	0.090	0.110

The Miramar Light House beach had fine sand at all levels and in all the months except in August when at mid and high tide levels, the sand was medium.

At Miramar transect in June, at the low tide level, the sand was very fine and at mid and high tide levels it was fine. In July, it became fine at all levels while in August it was very fine again at low tide level and continued to remain fine at mid and high tide levels. During September, the same position continued except at mid and high level where it became medium.

At Caranzalem, in June, at high and low tide levels, the sand was fine and at mid tide level it was very fine. In July, it was very fine at all the levels. In August, it changed to fine at low tide level, while in September, at all levels the sand was very fine. Thus, at low tide level, sand grain size alternated between fine and very fine, at mid tide it was very fine throughout the season, and at high tide it was fine in June and changed to very fine in July and stayed as such till September.

It is observed that the composition of median sand grain size differs from one transect to another and it follows different patterns of changes during monsoon months. These differences at low tide levels are clearly seen in Fig. 2 which shows the cumulative weight percentage of different fractions of sand grain size from June to September. Evidently, these changes in sand grain size are caused by erosion and accretion processes. That these processes are present is inferred from an examination of Fig. 3, where the fortnightly fluctuations of the gradient of intertidal region for all the beaches, have been plotted. At Miramar light house, the gradient from June to end

of July was steep and then it became more gradual. But, at Miramar and Caranzalem, the gradient increased and decreased from month to month.

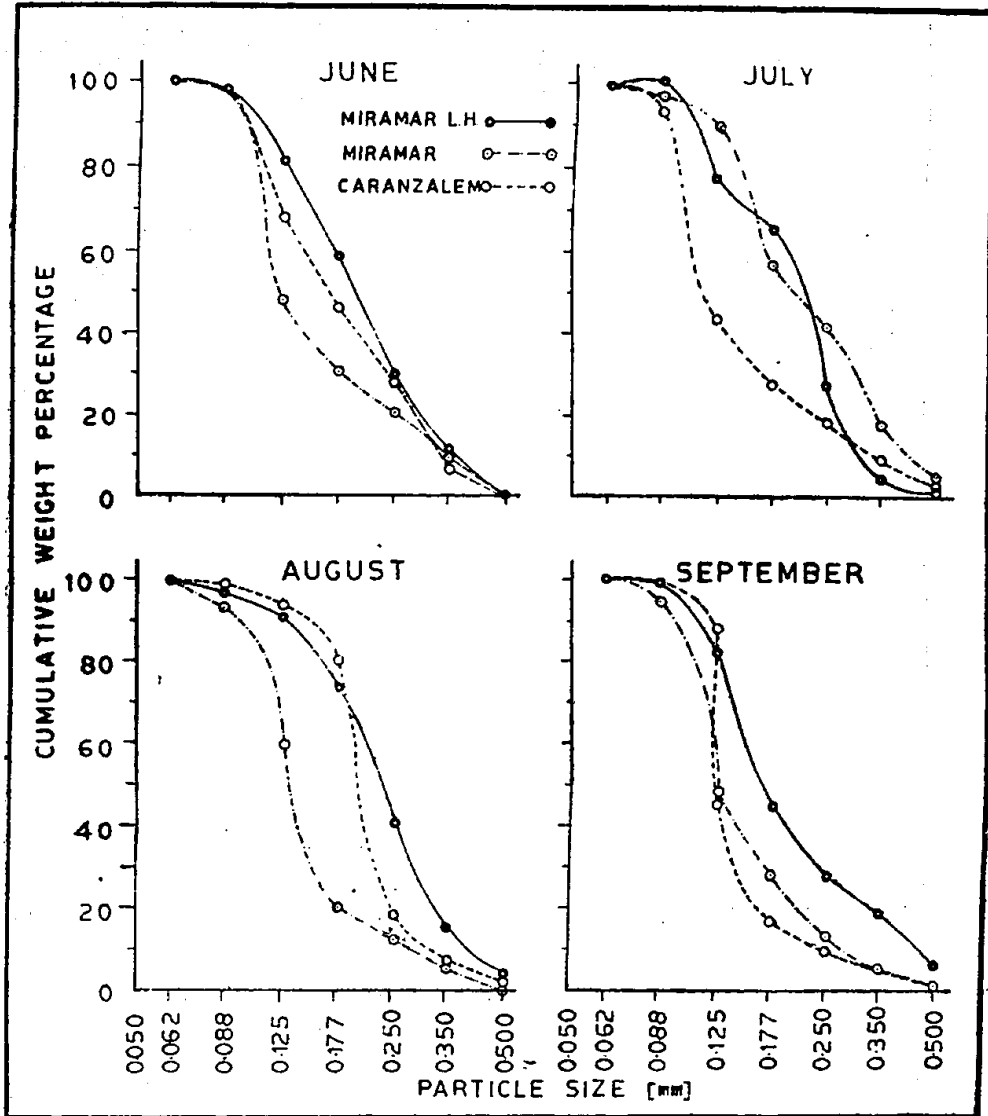


Fig. 2. Cumulative weight percentage of particle size of sand in mm at low tide level along different transects

These two sectors follow an opposite pattern in their sequence of changes, building up at one sector accompanied by erosion at the other.

3. *Physico-chemical factors.* The animal populations and their production is affected by the physico-chemical factors like temperature, salinity, dissolved oxygen and pH. These parameters were studied at each transect and their fortnightly variations from low to high tide level, from June to September, are given in Figs. 4a and 4b.

(a) *Temperature.* The temperature was one of the most variable factors with a range of 9.5°C. Along the three transects, it varied from 25°C to 34.5°C.

Generally, temperature increased from low tide towards high tide; exceptions were seen particularly on the days when it was raining or cloudy, at the

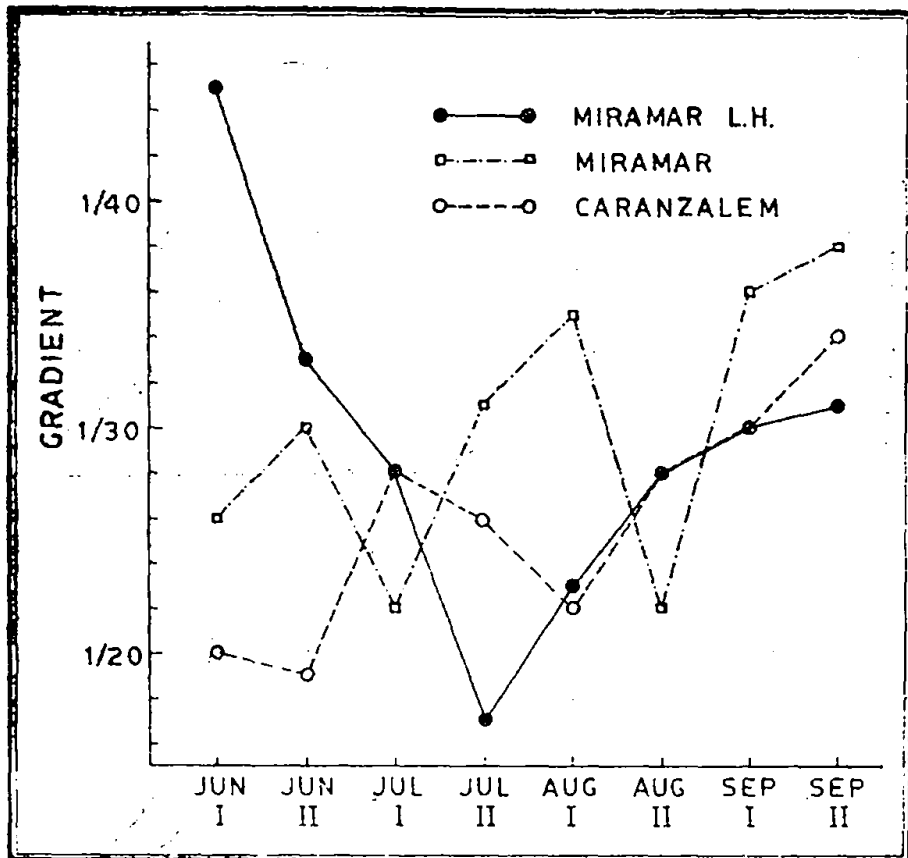


Fig. 3. Fortnightly variations of gradient in the intertidal extent, from June to September 1971.

time of observations. Bruce (1928) and Johnson (1965) also studied temperature on intertidal sand flat and found that the temperature regime of intertidal zone is extremely variable, depending upon incident radiation, elevation and stage of tide.

(b) *Oxygen*. The oxygen values ranged at the transects from 1.4 to 6.8 ml/L. Generally, a decreasing trend from low to the high tide level was observed. The high values recorded at some stations may be due to the rain water, high wave action at surf and exposure of the interstitial water to the atmosphere, during collection of samples. The oxygen values at low tide levels were similar to oxygen values at surf.

(c) *Salinity*. The monsoon had most pronounced influence on changes in salinity; the premonsoon marine conditions of salinity were changed to nearly fresh water at Miramar Light House during July and in later part the salinity values increased, again. At all transects, the salinity values decreased from low tide level, except during the rainy period when no such

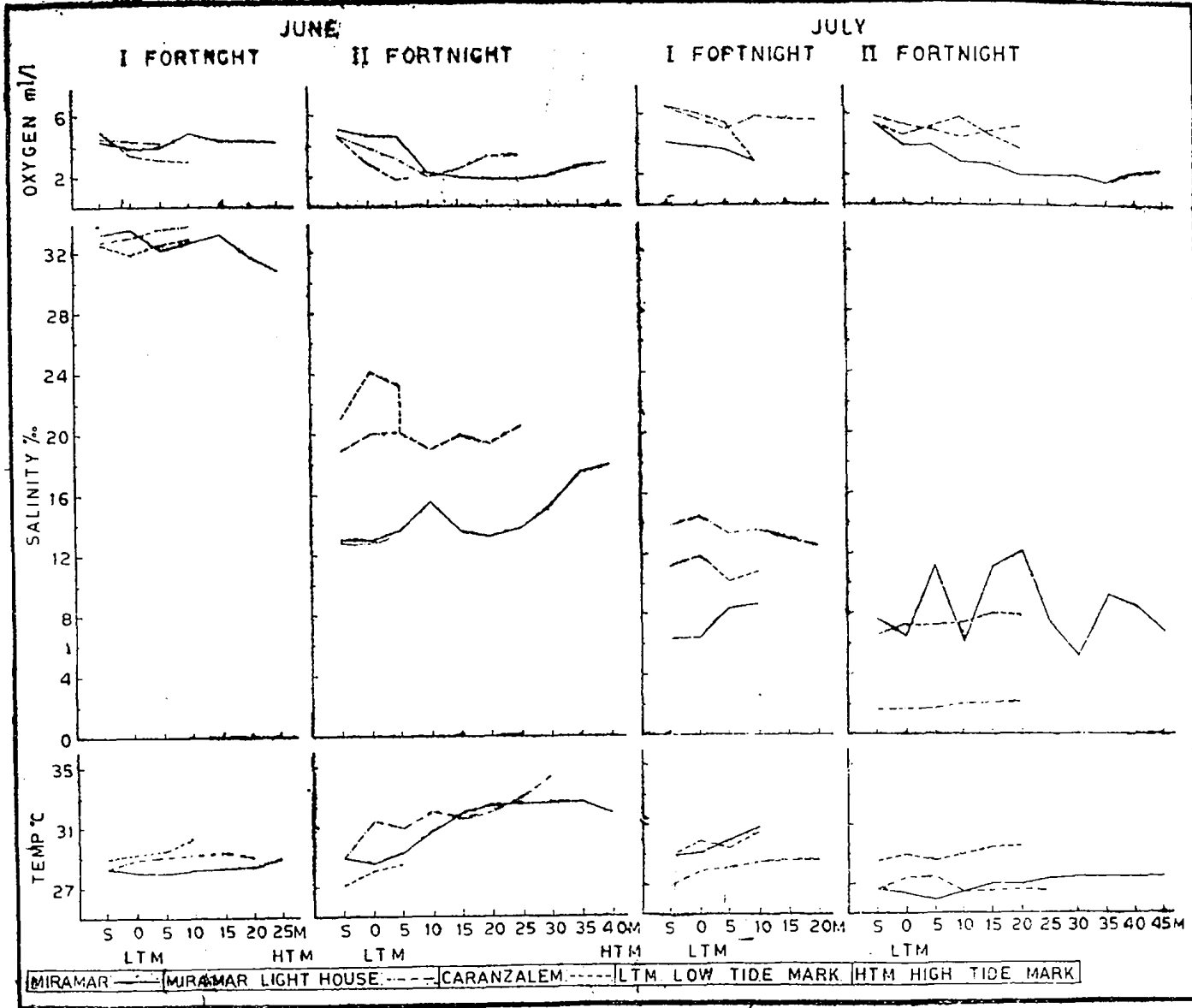


Fig. 4a. Variations of environmental parameters at Miramar Light House, Miramar and Caranzalem for June and July 71: Temperature; salinity and dissolved oxygen.

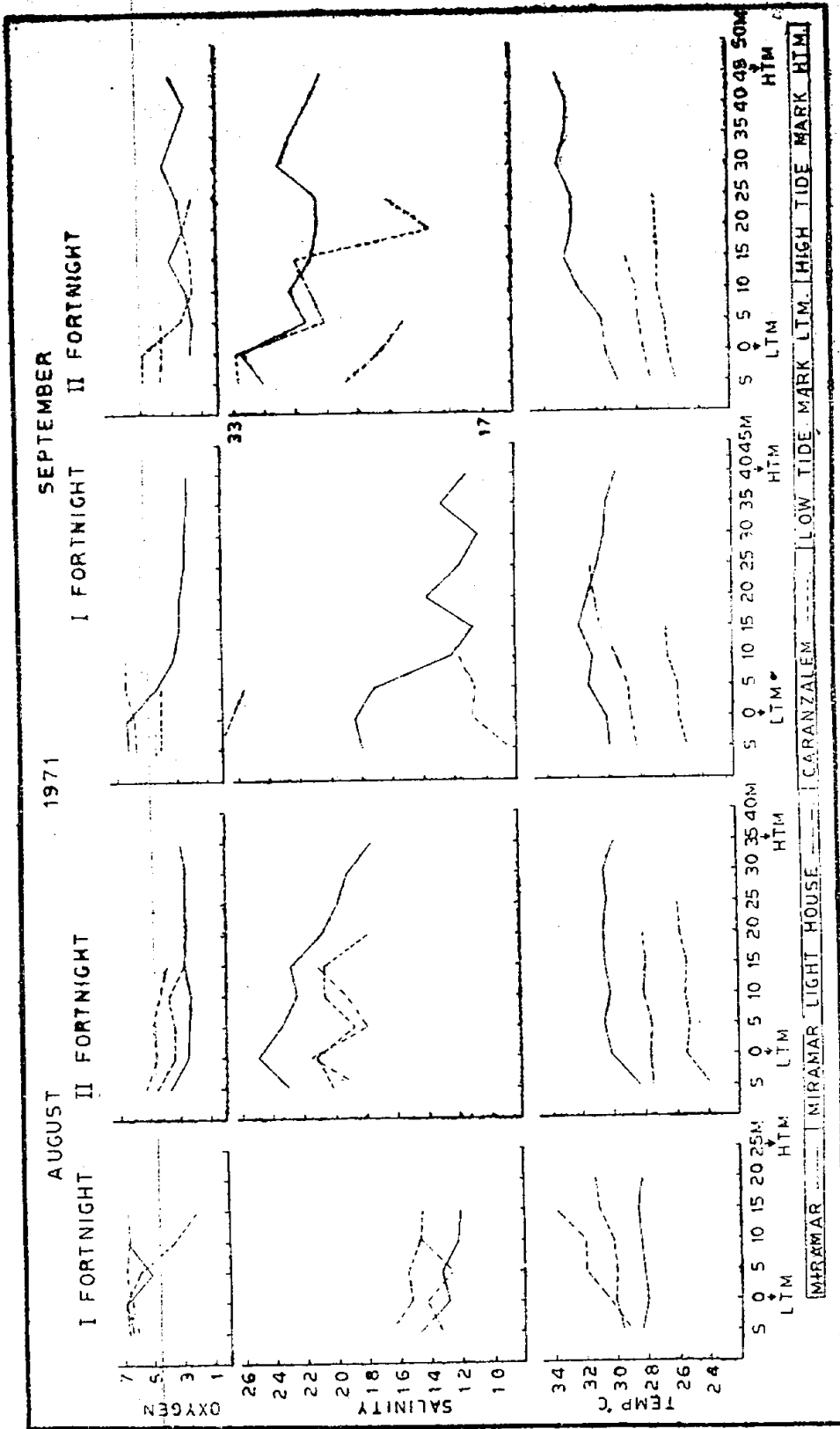


Fig. 4b. Variations of environmental parameters at Miramar Light House, Miramar and Caranzalem for August and September 71, temperature, salinity and dissolved oxygen.



regularity could be observed. The limits of salinity variations for different transects from June to September are given below in Table 3.

TABLE 3— LIMITS OF SALINITY VARIATION AT DIFFERENT TRANSECTS

Month		Miramar Light House (‰)	Miramar (‰)	Caranzalem (‰)
June	Max.	33.5	33.6	33.2
	Min.	18.9	12.8	20.0
July	Max.	14.4	12.0	12.0
	Min.	1.6	6.4	6.7
August	Max.	21.0	25.0	21.0
	Min.	12.8	12.0	14.6
September	Max.	23.6	32.3	32.8
	Min.	8.3	10.2	20.0

Thus the study of environmental parameters shows that the beach extent, intertidal gradient, particle size of sand and salinity ranges are different for all the three transects and these follow different patterns of seasonal changes.

**BIOMASS AND ECOLOGICAL NOTES.** The physico-chemical factors, discussed above, have varied influences on biomass and cause both qualitative and quantitative changes. The quantitative effect, has been studied, fortnightly, in terms of rate of production (gms/m<sup>2</sup>) for different transects and tide levels. The qualitative influences for faunal assemblages have been discussed in the later part.

(a) *Production at different transects.* During the fortnightly observations, taken at each transect, the station at which organisms were found are termed here as positive stations. The percentage of positive stations was 48.3% at Miramar, 45.7% at Caranzalem and 40.4% at Miramar Light House and the total number of positive stations for all the transects, was 63. The total biomass varied at different stations from 0.0 to 13 gms/m<sup>2</sup>. The fortnightly analysis of the overall production pattern pooled for all the transects shows alternate low and high production (Fig. 5A), and it decreased twice, almost to 0.1 gms/m<sup>2</sup> during the season. Though each of the three transects, individually, undergo high and low production, they differ from each other in their amplitude and seasonal succession (Fig. 5B). The Caranzalem transect had almost nil production till first fortnight of July, then it increased to 13 gms/m<sup>2</sup> during first fortnight of August, and again during second fortnight of September, it came down to nil. The Miramar Light House and Miramar, follow a parallel pattern and also have two periods of low and high productions. The summarised picture of the rate of biomass production at each transect,

from June to September, is given in Table 4. During the month of July, production was low at all the transects and overall rate of production, pooled

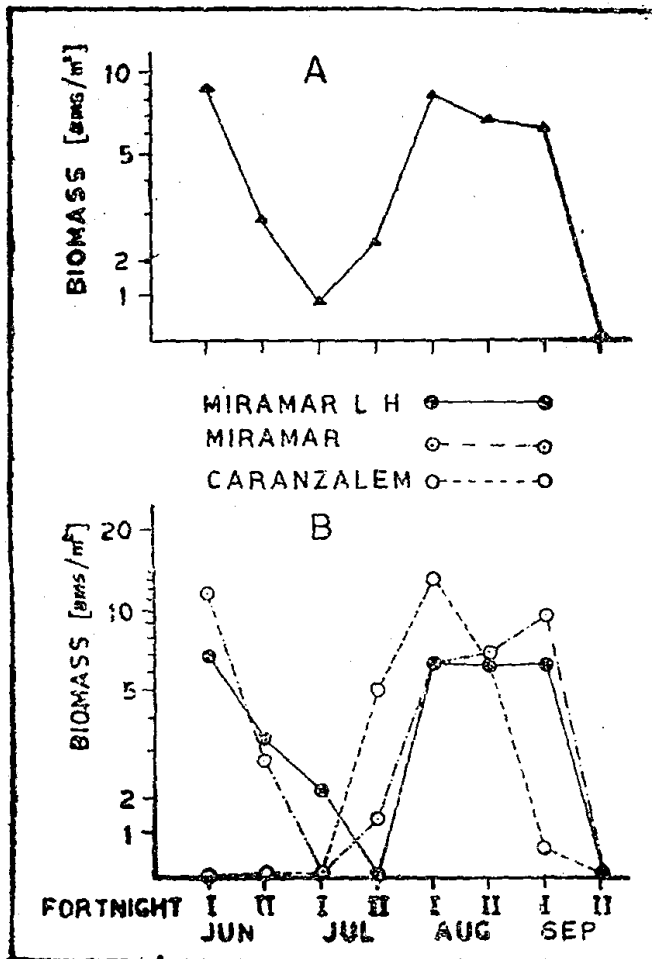


Fig 5 Fortnightly fluctuations in rates of production of macrofauna: (A) pooled for all transects; (B) variations at different transects.

for all the transects was 2.2 gms/m<sup>2</sup>. During the month of August, high rate of production occurred at all the transects and highest ratio of 8.1 gms/m<sup>2</sup>

TABLE 4 — BIOMASS PRODUCTION (in gms/m<sup>2</sup>) FROM JUNE TO SEPTEMBER IN THREE SECTORS

(n = number of observations)

Month	Miramar Light House		Miramar		Caranzalem		Pooled for all transects	
	gms/m <sup>2</sup>	n	gms/m <sup>2</sup>	n	gms/m <sup>2</sup>	n	gms/m <sup>2</sup>	n
June	5.5	7	5.1	11	—	—	5.3	18
July	1.1	5	1.2	9	4.0	5	2.2	19
August	6.5	3	7.0	5	8.1	4	7.2	12
September	3.3	2	7.6	5	0.2	7	3.2	14
Average June-Sept.	4.1		4.7		2.8		4.2	

was recorded at Caranzalem, whereas, pooled rate of production was 7.2 gms/m<sup>2</sup>. Again in the month of September, production changed at all the transects and the overall production decreased.

(b) *Production at different tidal levels.* Out of a total of 139 stations sampled, only 63 were positive and supported populations. The occurrence of biomass in grams per square metre has been computed for each tide level (Table 5).

**LOW TIDE LEVEL.** Miramar transect was most productive at low tide level with an overall average of 4.9 gms/m<sup>2</sup> while the highest rate recorded at one

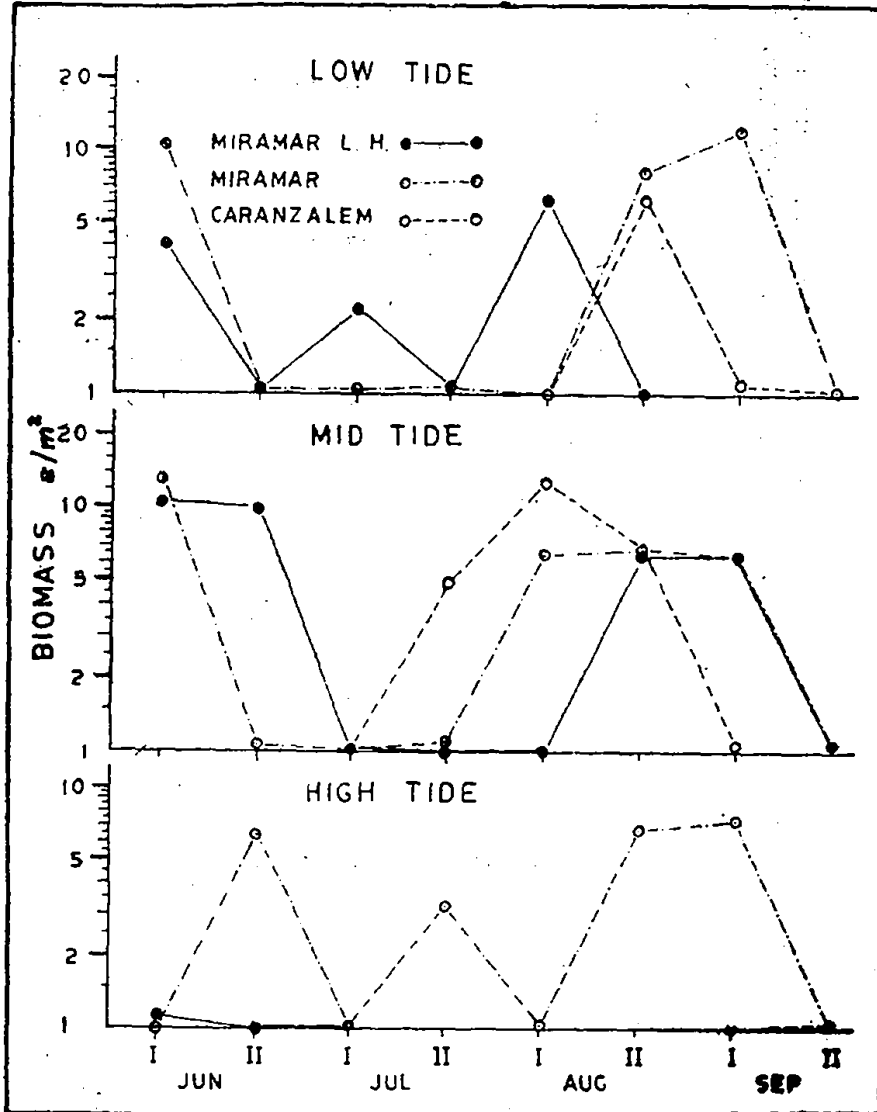


Fig. 6. Production of macrofauna at different tide levels for the transects—Miramar Light House, Miramar and Caranzalem.

station of this transect was 12.1 gms/m<sup>2</sup>. Both Miramar Light House and Caranzalem, had low biomass values (Table 5) but the number of positive stations was higher at Miramar Light House. At the latter transect no bio-

TABLE 5—FORTNIGHTLY BIOMASS PRODUCTION (gms/m<sup>2</sup>) AT DIFFERENT TIDE LEVELS ALONG THREE TRANSECTS, MIRAMAR LIGHT HOUSE (MLH), MIRAMAR (MIR), CARANZALEM (CAR)

	June		July		August		September		Average		
	I	II	I	II	I	II	I	II	June to September	Total No. of observations	
	g/m <sup>2</sup>	g/m <sup>2</sup>	g/m <sup>2</sup>	g/m <sup>2</sup>	g/m <sup>2</sup>	g/m <sup>2</sup>	g/m <sup>2</sup>	g/m <sup>2</sup>	g/m <sup>2</sup>	g/m <sup>2</sup>	
Low tide											
MLH	4.2	0.1	2.2	0.2	6.5	—	—	—	—	2.9	9
MIR	10.3	0.4	0.3	0.1	—	8.3	12.1	—	—	4.9	11
CAR	—	—	—	—	—	6.5	0.6	0.06	—	2.7	5
Mid tide											
MLH	9.4	10	—	0.05	—	6.5	6.5	0.6	—	7.1	6
MIR	13.3	0.6	0.2	0.6	6.5	6.7	6.5	0.01	—	3.4	10
CAR	—	—	0.05	5.0	13.0	6.5	0.6	0.8	—	4.0	10
High tide											
MLH	0.95	0.1	—	—	—	—	—	—	—	0.5	2
MIR	6.6	6.6	0.1	3.3	—	6.9	7.2	—	—	4.9	9
CAR	—	—	—	—	—	—	—	0.2	—	0.02	1

mass occurred from second fortnight of August through September, whereas, at Caranzalem, biomass values were nil from June through first fortnight of August. From second fortnight of August through September small quantities of biomass were recorded.

**MID TIDE LEVEL.** The mid tide level was most productive amongst the three tide levels; highest average rate of 7.1 gms/m<sup>2</sup> occurred at Miramar Light House. The rate at Caranzalem was 4.0 gms/m<sup>2</sup> and at Miramar it was 3.4 gms/m<sup>2</sup>. Though at Miramar the average biomass values were low, all the stations were productive from June to September indicating that production had continued throughout the period of investigation. But at Caranzalem the biomass during June was nil, followed by high values from second fortnight of July and these decreased again in September.

**HIGH TIDE LEVEL.** The high tide level was least productive. Only at twelve stations biomass occurred; out of this, only one was at Caranzalem, two were at Miramar Light House and nine were at Miramar. Further, the production at high tide level at the Miramar Light House and Caranzalem was below 0.5 gms/m<sup>2</sup> and at Miramar it was 4.9 gms/m<sup>2</sup>. The monthly changes in the rates of biomass production pooled for all transects at different tide levels have been computed (Table 6).

TABLE 6—BIOMASS VARIATIONS POOLED FOR ALL TRANSECTS AT DIFFERENT TIDE LEVELS FROM JUNE TO SEPTEMBER  
(in gms/m<sup>2</sup>)

Months	Low tide	Mid tide	High tide
June	3.75	8.66	4.18
July	0.69	3.49	2.54
August	6.87	7.66	6.90
September	5.18	1.97	3.62

It is observed that at all tide levels from June to July the production rates decreased and at low tide the rate was only 0.69 gms/m<sup>2</sup>. In August, an increase in values is seen at all levels. Highest rate of 7.6 gms/m<sup>2</sup> for this month occurred at mid tide level. In September production decreased and the lowest biomass value of 1.97 gms/m<sup>2</sup> was recorded at mid tide level. It is thus seen that monthly variation in production occurred at all the tide levels, but were most pronounced at mid tide level and in spite of the fluctuations mid tide level was most productive for the period June to September.

#### Ecological Notes

The differential rates of biomass production discussed above depend to a great extent on the faunal elements which are distributed at different tide levels during different months (see Table 7). The table shows the distribution of dominant groups of animals according to the particle size. Details of

TABLE 7—DISTRIBUTION OF FAUNA AT DIFFERENT TIDE LEVELS IN RELATION TO MEDIAN SAND GRAIN SIZE

Beaches	Tide level	June		July		August		September	
		Animals present	Median sand grain size (in mm)	Animals present	Median sand grain size (in mm)	Animals present	Median sand grain size (in mm)	Animals present	Median sand grain size (in mm)
MIRAMAR LIGHT HOUSE	LOW	Donax sp.	0.210	Eurydice sp.	0.210	Eurydice sp.	0.240	Megalopa of Emerita sp. Eurydice sp.	0.160
	MID	Donax sp. Emerita sp.	0.180	Eurydice sp.	0.180	Emerita sp. Eurydice sp.	0.310	Eurydice sp.	0.200
	HIGH	—	0.220	—	0.220	Megalopa larvae of Attergattis sp.	0.260	—	0.240
MIRAMAR	LOW	Donax sp. Nereis sp. Onuphis sp.	0.120	Eurydice sp. Amphipod (unidentified)	0.220	Onuphis sp. Eurydice sp. Donax sp.	0.110	Matuta sp. Caprella sp. Eurydice sp.	0.110
	MID	Amphipod (unidentified) Eurydice sp.	0.240	Eurydice sp.	0.200	Emerita sp. Donax sp. Dotilla sp.	0.200	Eurydice sp.	0.270
	HIGH	Ocypoda sp.	0.160	Ocypoda sp.	0.160	—	0.220	—	0.220
CARANZA-LEM	LOW	Caprella sp.	0.180	Emerita sp. Lumbrineris sp. Dotilla sp.	0.120	Nereis sp. Microneis sp. Lumbrineris sp.	0.180	Lumbrineris sp. Nereis sp. Emerita sp. Matuta sp.	0.120
	MID	—	0.120	Dotilla sp.	0.090	Mysidacea	0.110	Nereis sp.	0.090
	HIGH	—	0.180	—	0.090	—	0.090	Mysidacea	0.110

different groups and species distribution in relation to grain size and environmental features are given below :

1. CRUSTACEA. Crustaceans were found at 68.1% of stations sampled and were the most dominant group. These were represented mostly by crabs, their larval stages, and few other groups described below :

- (a) *Emerita sp.* A few of genus *Emerita* occurred at 10.6% of the stations. At Miramar Light House, they were found at mid tide level during June and August, whereas at Caranzalem they occurred at low tide level in July and September. The median sand grain size at these stations was 0.120 to 0.310 mm with salinity and temperature ranges from 10.9 to 33‰ and 25.5 to 32°C respectively.
- (b) *Dotilla sp.* This occurred at Miramar and Caranzalem during the months of July and August in fine and very fine sand (0.090 and 0.200 mm) at mid and the low tide levels. It occurred at 6.4% of the stations sampled with salinity ranging from 10.2 to 12.9‰ and the temperature from 29.8 to 30.0°C.
- (c) *Ocypoda sp.* Occurred at 4.3% stations at Miramar and Miramar Light House around the high tide level during the months of June and July in fine sand of particle size 0.160 mm. The salinity and the temperature observed at these stations varied from 18.9 to 30.8‰ and 29 to 31°C respectively.
- (d) *Matuta sp.* These species occurred at 4.3% stations at low tide level, in the month of September, at Miramar and Caranzalem in very fine sand (0.110 to 0.120 mm). The salinity varied from 12.9 to 26.2‰ and the temperature from 25.5 to 28.0°C.
- (e) Mysidaceae. This group was observed at Caranzalem only during the months of August and September at 4.3% of the stations sampled. Mysids favoured mid and high tide levels with very fine sand (0.110 mm). The salinity and temperature range at these stations was from 14.7 to 25.4‰ and 25.5-30.2°C, respectively.
- (f) Megalopa of *Emerita* and *Attergattis*. The Megalopa of *Emerita* occurred only once in September at low tide at Miramar Light House where the sand was very fine (0.160 mm), the salinity and temperature values were 14.4‰ and 30.2°C, respectively. The Megalopa of *Attergattis* spp. occurred only once at high tide level in medium sand (0.260 mm) at Miramar Light House in August at 14.6‰ salinity and 32.0°C temperature.
- (g) Isopods. Isopods were represented by *Eurydice* species only. They were found at 25.4% stations, thus this single genus was most predominant in the entire collection. During June it occurred at Miramar only at one station at mid tide level; from July through September it was found at mid tide and low tide levels at Miramar Light House and Miramar. It was associated with fine and medium sand (0.110 to

0.310 mm). Salinity at these stations varied from 6.4 to 33.6‰. It indicates that the species is predominantly euryhaline. The temperature range was between 28°–32°C. *Eurydice* spp. was dominant at low and mid tide level and was found to tolerate wide fluctuations in environmental factors. Trevallion *et al.* (1970) found this spp. dominant at low tide level at Shertallai Beach in Kerala while Panikkar and Rajan (1970) reported this from all the three tide levels throughout the year at Cochin beaches. Rao and Ganapathi (1968) found Isopods in coarse and medium sand at all levels.

- (h) Amphipods. Amphipods were represented at 8.6% stations. They occurred predominantly at low tide level but extend upto mid tide. Unidentified amphipods were found in the months of June and July only at mid tide and low tide levels at Miramar and were associated mainly with medium sand (0.200 to 0.240 mm). The salinity at these stations varied from 12.9 to 33.6‰; temperature from 28.3 to 29.0°C, oxygen 3.9 to 6.8 ml/L. and pH from 7.8-8.9.
- (d) *Caprella* spp. *Caprella* species occurred at 4.1% of stations at low tide level during June and September at Caranzalem and Miramar in fine sand (0.110 to 0.180). The salinity at these stations varied from 8.9 to 30.8‰, temperature from 28.0 to 30.1°C, oxygen from 2.0 to 4.4 ml/L and pH was from 7.6 to 9.2. Amphipods have also been reported in very small numbers on Waltair coast in coarse sand at low tide level (Rao and Ganapathi : 1968).

2. PELYCYPDS. Pelycypods were represented by *Donax* sp. only and were found in the wash zone at 10.6% of stations. They occurred at Miramar Light House and Miramar in June and August at low and mid tide levels in fine and medium sand (0.110 to 0.210 mm). Salinity at these stations varied from 12.9 to 33.6‰, temperature 28 to 31°C, oxygen 2.8 to 6.2 ml/L and pH from 8.2 to 9.2. *Donax* sp. has also been reported from the wash zone from Shertallai beach by Trevallion *et al.* (1970).

3. POLYCHAETES. Polychaetes were widely distributed and occurred at 21.3% stations, and were represented by four genera. Generally they occurred at low tide levels, except once when they were recorded at mid tide level. They were found in very fine sand and withstood wide salinity variations from 11.2 to 33.6‰. The temperature at these stations varied from 25.2 to 30.1°C, pH from 8.6 to 9.1, and oxygen from 3.1 to 6.5 ml/L. At Shertallai beach near Cochin, the Polychaetes occurred mainly, at low tide level, (Trevallion *et al.* : 1970). Rao and Ganapathi (1968) have reported polychaetes from low and mid water levels at the Waltair beach, whereas Panikkar and Rajan (1970) reported their occurrence at all levels from Cochin beach, but their abundance decreased from low tide to high tide.

(a) *Nereis* sp. These occurred at 8.5% of stations at mid and low tide levels. In June it was recorded at Miramar. In August and September it



occurred at Caranzalem at low and mid-tide levels and was associated mostly with fine and very fine sand grain size from 0.090 to 0.180 mm. Salinity at these stations varied from 15.3 to 32.2‰ and temperature from 25.5 to 30.1°C.

(b) *Micronereis spp.* These species occurred only at 2.1% of positive stations and were found at Caranzalem beach in fine sand (0.180 mm) at low tide level. The salinity recorded at the stations of occurrence was 12.9‰ and the temperature was 28°C.

(c) *Onuphis spp.* It was occurred at 4.3% stations only at Miramar at low tide level in June and August, in very fine sand (0.110 to 0.120 mm). The salinity varied from 12.9 to 33.6‰ and the temperature was 28°C.

(d) *Lumbrinereis spp.* It was found at 6.4% stations and occurred regularly at Caranzalem beach at low tide level from July to September and was associated with fine and very fine sand of grain size 0.180 mm. The salinity range was between 11.2 to 26.2‰, and the temperature varied from 25.5 to 30.2°C.

### Discussion and conclusions

In India Estuarine beaches have been studied at Porto Novo : two of these beaches were situated within the estuary of the river Vellar and had relatively muddy substrata. Trevallion *et al.* (1970) studied beaches at Cochin and Shertallai and compared the fauna with Mozambique (MacNae and Kalk : 1962) and exposed beaches in Madagascar (Pichon : 1967).

The present investigation is a study of an estuarine beach, the parts of which in spite of their physical continuity differ in the ecology and biomass production, particularly during monsoon season. The tides and the circulation pattern affect these sectors differently resulting in changes in profile and the expanse of the intertidal region and the particle size of the sand. The intertidal region fluctuates at all the sectors, the least changes were noticed at Miramar Light House. Miramar had the widest expanse, the mean exposure being 33.8 m. Due to this, more stable production is expected in this sector

The comparatively stable premonsoon conditions are altered in the month of June, by erosion processes, as can be seen by sharp and continuous increase in gradient of the beach profile (Fig. 3).

At Miramar Light House transect the changes started in June. The intertidal gradient became steeper, this process continued till the end of July when accretion started again and progressed slowly to attain premonsoon condition. At the other two transects, Miramar and Caranzalem, the changes were of lesser magnitude and broadly follow opposite pattern; when one beach is building up, the other gets eroded. In September, at all the three beaches building up processes are visible. These simultaneous changes which differ in pattern and intensity at each transect also modify the habitat differently.

At low tide level the process appears to continue vigorously and the substratum is in a state of continuous shifting. This probably explains the low production of biomass at low tide level along all the three transects and results in an ecological situation where the mid tide level has highest production. Changes in production rates due to changes in ecology of habitat have also been discussed by Vanucci (1969). In some months at certain transects along with accretion processes, the gradient is steep and the water table at high tide level is deeper. In such cases the biomass production becomes nil or almost negligible. This appears to have been one of the reasons for almost nil production at high tide level at Caranzalem. At Miramar Light House also the gradient is steep and production is negligible at high tide level throughout the season. These observations present a generalised pattern that the continuous active shifting of sand also changes its composition. This change in turn alters the physico-chemical conditions and ecology of the intertidal environment, therefore the composition and growth rates of the intertidal communities are modified.

In the intertidal region during 24 hour period the temperature, pH, oxygen and salinity fluctuate differently from low tide to high tide level. Pamatmat (1968) had also recorded similar fluctuations in their characters. The high oxygen values recorded in this study may be due to the contact of interstitial water with the atmosphere at the time of the collection of water samples and may also be due to the very intensive wave action in the intertidal region. The oxygen values reduced significantly from low to high tide level, similarly increases in temperature from low to high tide level were seen, but the pH followed an uneven pattern and salinity decreased from low towards high tide level, except on the days when there was heavy rain at the time of observations as was the case in June and in July during the second fortnight. Salinity fluctuations were recorded at all the three transects but maximum freshwater influence and lowest salinity was seen only at Miramar Light House, while salinity values were always comparatively higher at Miramar and Caranzalem. During the periods of absence of rainfall for a few days, the salinity became considerably higher at Caranzalem as compared with Miramar Light House.

The changes in beach profile, particle size of sand and environmental parameters, brought about changes in overall biomass productions along three transects during the season. The high rate of production in June becomes less than  $1 \text{ g/m}^2$  in second week of July; it was built up again in August to a level comparable to June and again in September it reduced to almost nil. However production at each of these three sectors varied during the monsoons but followed a different pattern of seasonal changes.

The present investigation indicates that at the mouth of the Mandovi estuary, adjacent sections of the same beach are subjected to varying environmental influences and their ecology and rates of production are different. These in turn also influence the benthic ecology of the estuarine areas. The

presence of ecological variations and the pattern of changes in adjacent parts of an intertidal beach at the mouth of an estuary is an isolated case in Mandovi Estuary or is a generalized pattern, cannot be stated from this study alone and calls for investigations in the other tropical estuaries.

### Summary

1. The beach situated along the left bank of the Mandovi estuary, at a point opposite to its confluence with the Arabian sea has physical continuity from Miramar Light House to Caranzalem but it has three sectors as represented by Miramar Light House, Miramar and Caranzalem which differ in their environmental features.
2. The intertidal extent during monsoons was smallest at Miramar Light House with  $16.9 \pm 4.5$  m, followed by Caranzalem where the extent was  $12.3 \pm 3.6$  m. The intertidal region along these two transects was significantly smaller than that of Miramar, where the extent was  $33.8 \pm 8.5$  m. At Miramar Light House the coefficient of variability of the intertidal expanse was smallest (CV—4.9) indicating that at this transect the magnitude of fluctuations of the intertidal expanse was lowest.
3. The strong diurnal type of tides accompanied by the monsoon eurrents and heavy rainfall change the beach gradient, particle size of the sand and beach ecology. The magnitude of the changes and their seasonal patterns are different at three transects.
4. The salinity changes are pronounced and the premonsoon marine conditions change to almost freshwater state. At Miramar light house the lowest salinity recorded was  $1.6 \text{ ‰}$ . At Caranzalem, during short spells of dry weather, salinity registered sharp increases indicating heavy influx of seawater whereas at Miramar Light House fresh water influence was persistent throughout the season.
5. Ecological differences also influenced the biomass production at three transects. The average rate of biomass values for the period June to September was  $4.7 \text{ g/m}^2$  at Miramar, followed by  $4.1 \text{ g/m}^2$  at Miramar Light House and the lowest rate  $2.8 \text{ g/m}^2$  was found at Caranzalem.
6. The rate of production of macrofauna varied at different tide levels. The mid tide level was most productive amongst the three and at this level highest mean rate of production of  $7.1 \text{ gms/m}^2$  was recorded at Miramar Light House.
7. In Mandovi estuary the existence of these sharp differences in ecology and rates of production of macrofauna in intertidal region on adjoining sectors of a beach is an isolated case or it is a generalised phenomenon of estuaries is not known and needs further investigations. Understanding of this phenomenon is very essential for optimum utilisation of the production potentialities of the estuary.

The authors express their gratitude to Dr. N. K. Panikkar, Director, National Institute of Oceanography, Panaji, Goa, for his guidance, facilities and encouragement. The valuable constructive criticism by Shri R. Jayaraman during the period of investigation is gratefully acknowledged. Our thanks are due to Shri Victor Rajamanickam and other colleagues for help.

#### REFERENCES

- BIRKETT, L. and MCINTYRE, A. D., (1971), *Method for the Study of Marine Benthos*, IBP Handbook No. 16. *Treatment and Sorting of Samples*, Blackwell Scientific Publications, Oxford and Edinburgh, 157.
- BRUCE, J. R., (1928a), Physical factors on the sandy beach. Part I—Tidal, climatic and edaphic, *J. Mar. Biol. Ass. U.K.*, 15 : 535-552.
- INMAN, D. L., (1963), *Submarine Geology, Sediments : Physical Properties and Mechanics of Sedimentation*, Harper and Row, New York, 104.
- JOHNSON, R. G., (1965), Temperature variation in the infaunal environment of a sandflat, *Limnol. Oceanog.*, 10 : 114-120.
- MACNAE, W. and KALK, M., (1962), The fauna and flora of sandflats at Inhaca Island, Mozambique, *J. Anim. Ecol.*, 31 : 93-128.
- MCINTYRE, A. D., (1968), The microfauna and macrofauna of some tropical beaches, *J. Zool. Lond.*, 156: 377-392.
- MAYR, E., (1969), *Principles of Sys. Zool.*, McGraw-Hill Book Co., New York.
- PAMATMAT, M. M., (1965), Ecology and Metabolism of a Benthic community on an Intertidal sandflat, *Int., Revue ges. Hydrobiol.*, 53(2) : 211-298.
- PANIKKAR, B. M. and RAJAN, S., (1970), Observations on the ecology of some sandy beaches of the south-west coast of India, *Proc. Ind. Acad. Sci.*, LXXI (6), Sec. B.
- PICHON, M., (1967), Contribution a l'etude des peuplements de la zone intertidal sur sables fins et sables vaseux non fixes dans la region de Tulear, *Recl. Trav. Str. mar. Eudonm (Fasc. hors. ser. Suppl. 7)* 57-100.
- RAO, G. C. and GANAPATHI, P. N. (1968), The interstitial fauna inhabiting the beach sands of Waltair coast, *Proc. Indian Acad. Sci.*, 34B (2).
- TREVALLIION, A., ANSELL, A. D., SIVADAS, P. and NARAYANAN, B., (1970), A preliminary account of two sandy beaches in south west India, *Mar. Biol.* 6 : 268-279.
- VANNUCCI, M., (1969), What is known about production potential of coastal lagoons. *Lagunas Costeras, un simposio Mem. Simp. Intern. Lagunas Costeras*, UNAMUNESCO Nov. 28-30, 1967, Mexico, D. F. : 457-478.