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Sandy Beach at Baina, Goa: Its Ecology & Production

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The beach substratum at Baina was very unstable and the beach was steep throughout. Particle size of sand ranged between 229 and 398·5 µm. Particulate organic carbon in sand was high (3300-16000 µg/g) and that in surf-water was low (410-1730 µg/litre). Temperature and salinity dropped considerably during the monsoon season. NO_3^-N and PO_4P showed a declining trend during this season. Total bacterial population was high in the beach, the peak in nutrient agar (36·7 × 10^3/g dry wt) and in ZoBell 2216 E (40·3 × 10^3/g dry wt) media being recorded in August and November respectively. Coliform population was high (peak, 8·72 × 10^3/g dry wt) in August. Total bacterial population showed a highly significant relation with particulate carbon in sand. Chlorophyll *a* in surf-sand and surf-water was relatively high. Species diversity of macrofauna was small and biomass was poor.

SANDY beaches are being increasingly subjected to pollution in addition to natural physical forces to which they are exposed. Organisms inhabiting this specialized biotope often find it difficult to cope up with the changes occurring in their habitat. This is directly reflected in the reduction of the species diversity and poor production[1]. A detailed study of ecology and nature of production of the beach ecosystem is desirable for the effective monitoring of this ecosystem. In India, studies have been undertaken along sandy beaches, mainly for understanding the influence of physical and chemical factors on the production of macrofauna[2-7]. Information is still incomplete regarding several aspects of the ecology of the sandy beaches that border the extensive east and west coasts of India. Hence, a detailed investigation has been undertaken of the various aspects of production in a sandy beach at Baina, Goa for 1 yr from April 1975.

Materials and Methods

Observations were made monthly during the low water spring tide. Samples were collected from a single transect along the middle of the beach at intervals of 10 m from a fixed reference point above the high water mark to the surf washed zone. During each observation, atmospheric temperature, surf-water and sand temperature were recorded. Water table depth of all the stations were measured. Dissolved oxygen, salinity, chlorophyll *a*, PO_4-P, NO_3^-N, *p*H and CO_2 of surf-water were estimated as per methods given by Strickland and Parsons[8]. Particulate organic carbon in surf-water was also estimated using the procedure outlined by El Wakell and Riley[9].

Macrofauna samples were collected from a 0·1 m² area up to a depth of 15 cm using a quadrat and were seived (0·5 mm mesh width). Samples were preserved in 5% formaldehyde. Biomass was estimated as g/m² wet weight. Surface sand samples, representative of all stations, were collected aseptically and carried to the laboratory in ice for estimating bacterial population. After subjecting the samples to serial dilutions, total populations were enumerated by pour-plate technique in nutrient agar and ZoBell 2216 E media. Most probable number (MPN) of coliforms were estimated using McCready's tables in McConkey's broth. Counts were taken after 48 hr incubation at room temperature (28°C ± 2) and estimated as number/g dry weight sediment.

Core samples up to a depth of 15 cm were taken from high, mid and low tide stations for particle size analysis. Sand chlorophyll *a* and particulate organic carbon were estimated as per standard methods[8,9] from top 2 cm sand collected from low water mark. During each observation, beach profile was measured using standard survey techniques and the distance from berm to fixed point was measured.

Results

Physical and Chemical Factors

Physical characteristics of the beach — Baina is an open sea sandy beach situated south of the Marmugao harbour (lat. 15°24′N, long. 73°48′E). A number of hutments are located in the vicinity of the beach causing considerable human interference. The beach also receives substantial quantities of domestic wastes and sewage every day. Compared to other sandy beaches of Goa[6,7], the expanse of the beach is less, maximum being observed in May (92 m) and the minimum in June (42 m). The intertidal expanse ranges between 20 and 40 m (Fig. 1). The beach slope is steep to very steep throughout the year.

It is clear from the beach profiles (Fig. 1) that beach erosion started in May and became very active in June. Between April and June, the berm receded by 37 m towards supralittoral region. In July and August, erosion of the beach continued at high tide region thereby further shifting the berm. Filling

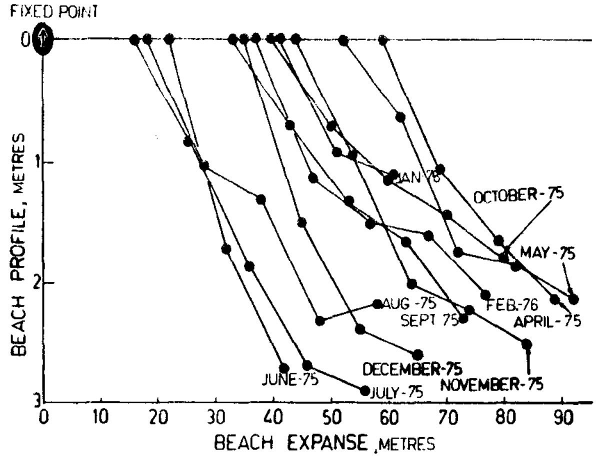

Fig. 1 — Beach profiles for Baina for different months measured from a fixed point

started at a slow pace at the mid and low tide regions in July and extended to high tide region by September and continued actively through October. As a result of this, the beach expanded considerably thereby reducing the steepness. Again in November, erosion of a lower magnitude occurred and this continued through February with some fill occurring in January. But this erosion did not affect the beach expanse to a great extent. A recession of only 9 m of berm was noticed. Thus, the beach substratum was always unstable and the erosion occurring during the early monsoon was severe.

Depth of water table measured during the period of investigation was in agreement with the nature of the beach slope. As the beach was steep throughout the year, water was not recorded at high tide region and very occasionally in the mid tide region, that too, at a greater depth.

Physical features of sand — Particle size analyses showed that the sediment was mainly of medium class, the median size ranging between 229 and 398·5 μm (Fig. 2). Particle size at different tide levels for different months was in agreement with the erosion and accretion phenomena. Variation in the particle size of the same tide level in different months indicated that the beach substratum was not stable.

Surf-sand temperature which was 33°C in May declined during the monsoon season and recorded the lowest (25·1°C) in August. Thereafter, it increased and maintained almost a steady level (27·5°C ± 2) during the other seasons (Fig. 3). Particulate organic carbon content in sand was high throughout the year. It was $<$4000 μg/g during early monsoon period. In all the other months, it was above this level and on several occasions above 10000 μg/g, the maximum being 16,000 μg/g in August (Fig. 4). This high level of carbon in sand suggests that there was some additional source of carbon to the beach.

Seasonal cycle in surf-water — Surf-water temperature was slightly higher than the corresponding sand temperature with some exceptions (Fig. 3), but the general trend was more or less the same. During the monsoon season, temperature dropped and attained 27·6°C in August. It recorded the lowest of the year (26·3°C) in January.

*p*H of surf-water during the monsoon season ranged between 7·6 and 7·9 and in other seasons between 8 and 8·2 (Fig. 5). The corresponding CO_2 values, given in the same figure, showed a CO_2 content of $>$2 μg at/litre during monsoon months except in July and $<$2 μg at/litre in other months except in October. Salinity which was 34·02‰ in May dropped to $<$24‰ during early monsoon months and increased thereafter to reach 31·31‰ in September. During other seasons, it was $\geqslant$32‰ (Fig. 5). Dissolved oxygen content ranged between 4 and 5 ml/litre except in July (5·6 ml/litre) and November (3·8 ml/litre) (Fig. 5).

Phosphate-phosphorus and nitrate-nitrogen showed a similar trend during the late premonsoon and early monsoon periods. PO_4-P which was 3·26 μg at/litre in April showed a declining trend during the monsoon months and touched the lowest value of 0·41 μg at/litre in July. It increased to 1·55 μg at/litre in August and did not show much variation till February, when it recorded a slightly higher value of 2·55 μg at/litre (Fig. 6). NO_3^-N which was 6 at/litre in April, like PO_4-P, declined during the early monsoon season and reached 0·43 μg at/litre in July. Thereafter, it increased progressively to attain the peak of 13·45 μg at/litre in November. In the succeeding months also, it was higher ranging between 10·46 and 12·04 μg at/litre (Fig. 6).

Particulate organic carbon content in surf-water was always lower than the corresponding value in sand (Fig. 4). In June and July, it was 410 μg at/litre and in September it recorded the maximum of 1730 μg at/litre. In February also, it was as low as 480 μg at/litre.

Biological Factors

Bacterial population in sand — Fairly high population was noticed in both nutrient agar and ZoBell 2216 E media in the pre- and postmonsoon periods and low population during the monsoon period. However, an exception to this general trend was seen in August 1975 when the total population in both the media was high. While a major peak in nutrient agar ($36{\cdot}7\times10^3$/g dry wt) occurred in August (Fig. 7), in ZoBell ($40{\cdot}3\times10^3$/g dry wt) it was in November. Apart from this, the corresponding populations in these 2 media for any 1 month varied only slightly suggesting that both terrestrial and marine bacteria enjoy almost equal distribution in the beach. The population in nutrient agar and ZoBell media showed a highly significant relation with particulate carbon in sand (0·1% level of significance), the *r* values calculated were 0·9475 and 0·8889 respectively. For population in nutrient agar, the regression obtained was — population = $0{\cdot}933+20{\cdot}9676\times$carbon and for population in ZoBell, it was — population = $3{\cdot}4205+20{\cdot}8422\times$carbon.

Total population in these 2 media did not show any particular trend either with particulate carbon or with NO_3^-N in surface water.

Coliform population (Fig. 7) was relatively high in the beach sediment. The population which was $3{\cdot}47\times10^3$/g dry wt in April declined to 0·11 and $0{\cdot}19\times10^3$/g dry wt in May and June respectively. It suddenly increased to $8{\cdot}72\times10^3$/g dry wt in

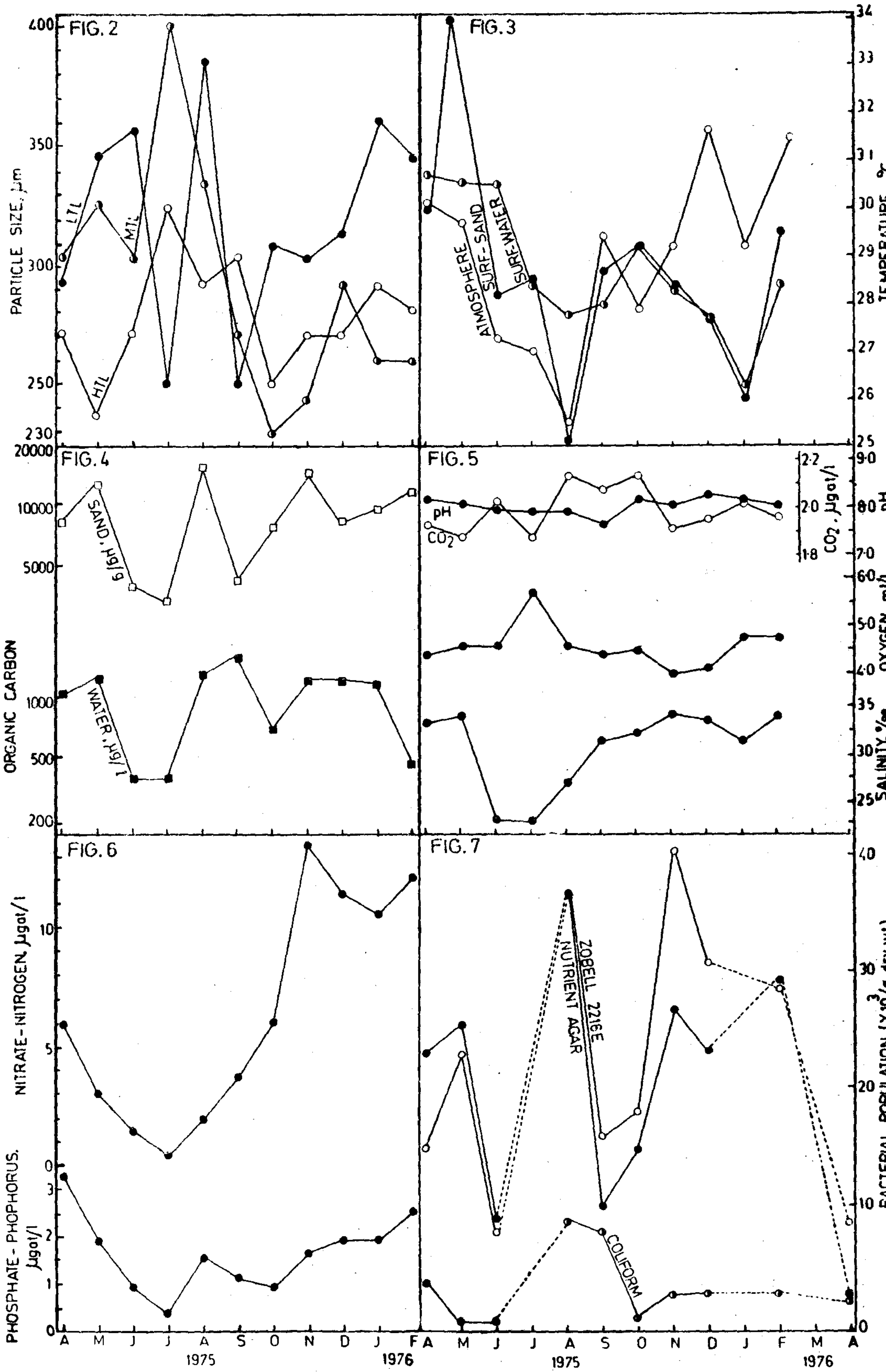

Fig. 2 — Median particle size of sand of different tide levels for different months. Fig. 3 — Temperature of atmosphere, surf-sand and surf-water for different months. Fig. 4 — Particulate organic carbon content in sand and in surf-water for different months. Fig. 5 — Salinity, dissolved oxygen, *p*H and CO_2 of surf-water for different months. Fig. 6 — Phosphate-phosphorus and nitrate-nitrogen content in surf-water for different months. Fig. 7 — Total bacterial population and coliform population in sand for different months

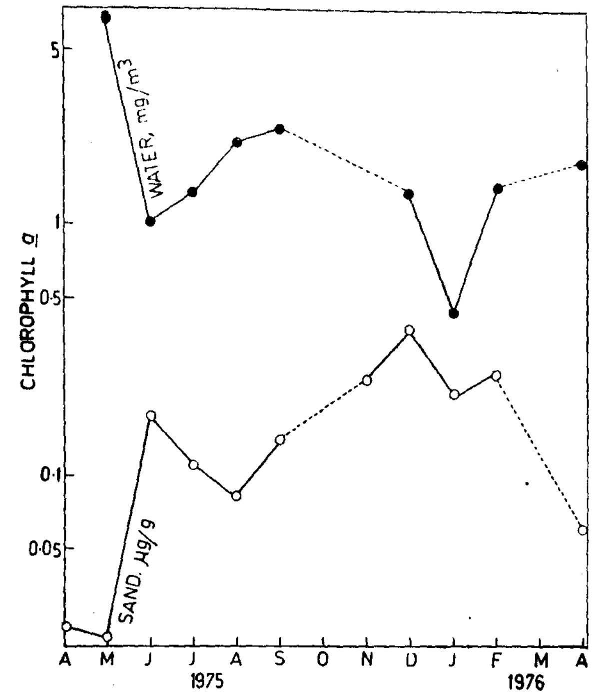

Fig. 8 — Chlorophyll *a* content in surf-water and in surf-sand for different months

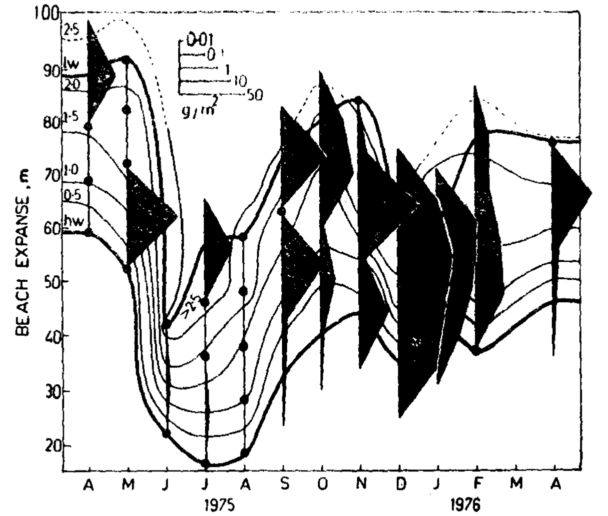

Fig. 9 — Kite diagrams showing biomass of macrofauna at different stations for different months superimposed on beach profile contours [Closed circles indicate absence on the sampling date. hw — high water mark; lw — low water mark]

August and $7{\cdot}83 \times 10^3$/g dry wt in September. During the other months, the population ranged between 2·197 and $2{\cdot}56 \times 10^3$/g dry wt. It was found that coliform, unlike the total population, had no relation with particulate carbon in sand.

Chlorophyll a of surf-water and surf-sand — In general, chlorophyll *a* of surf-water ranged between 1·0264 and 2·3688 mg/m³. A very high chlorophyll content of 6·394 mg/m³ recorded in May and a low content of 0·4352 mg/m³ recorded in January were the only two exceptions (Fig. 8). Chlorophyll, however, showed no relation with either NO_3N or particulate carbon in surf-water.

Unlike water chlorophyll, sand chlorophyll recorded the lowest value in May (0·0224 µg/g). In June, this increased to 0·174 µg/g and thereafter showed very little variation till the end of monsoon season. During the postmonsoon period, it attained slightly higher values, ranging between 0·2116 and 0·3824 µg/g. Incidentally, a low chlorophyll value was recorded in April 1976 (0·0601 µg/g). Sand chlorophyll values did not show any relationship with particulate carbon in sand.

Macrofauna and biomass — Kite diagrams superimposed on beach profile contours (Fig. 9) showing biomass at different stations indicate the trend in distribution of macrofauna in the beach. Biomass was almost nil or very poor during the monsoon season. By the end of the season, some improvement was noticeable, especially at the low and mid tide regions. From the beginning of the postmonsoon period, the incidence was fairly good throughout the intertidal region. Peak biomass of the year was recorded at 64 m in November (36·144 g/m²) followed by December at 55 m (19 g/m²). Thereafter, the biomass declined considerably and recorded 1·222, 0·271 and 1·75 g/m² in Jan., Feb. and April 1976 respectively.

Macrofauna of the beach was constituted primarily by 8 species, viz. the wedge clams *Donax incarnatus* Gmelin and *D. spiculum* Reeve, the mole crab *Emerita holthisi* Sankolli, the mysid *Gastrosaccus* sp., the isopod *Eurydice peraticis* Jones, the amphipod *Talorchestia* sp. and the polychaetes *Pisionidens indica* Aiyer and Alikunhi and *Onuphis eremita* Aud and Milne Edw. A few other animals were collected rarely such as the hermit crabs, *Mactra* sp. and some polychaetes. As they were incidental ones, they were not considered as important constituents of the beach macrofauna. Distribution of the 8 species (Nos/m²) and their wet weights (g/m²) for the period of investigation superimposed on profile contours are presented in Figs. 10a-d and 11a-d respectively.

Only young and newly recruited individuals of *Donax incarnatus* and *D. spiculum* were intermittently present in the samples for a short time. The former was present in small numbers in May, September and November through January, mostly confined to mid tide stations (Figs. 10a and 11a). Absence of this species was quite conspicuous in the samples of most of the premonsoon and monsoon seasons. The occurrence of individuals ranging in length between 2 and 4·5 mm having a mean wet weight of 4·5 mg indicates that these are either young or newly recruited ones. Further, they did not show evidence of any growth during any one month to suggest that this species grows to the adult size in this beach.

Specimens of *D. spiculum* ranging in length between 2·5 and 7 mm with a mean wet weight of 1·4 mg were collected only during 3 months (Figs. 10a and 11a). Nevertheless, a fairly large number of young ones (2080/m² ≅ 30·78 g/m²) was collected in November. Like *D. incarnatus*, this species is also represented only by young and newly recruited individuals.

Individuals of *E. holthuisi* were more consistently occurring in the samples in variable numbers. This species was represented by adult, young and newly recruited individuals. During late premonsoon they

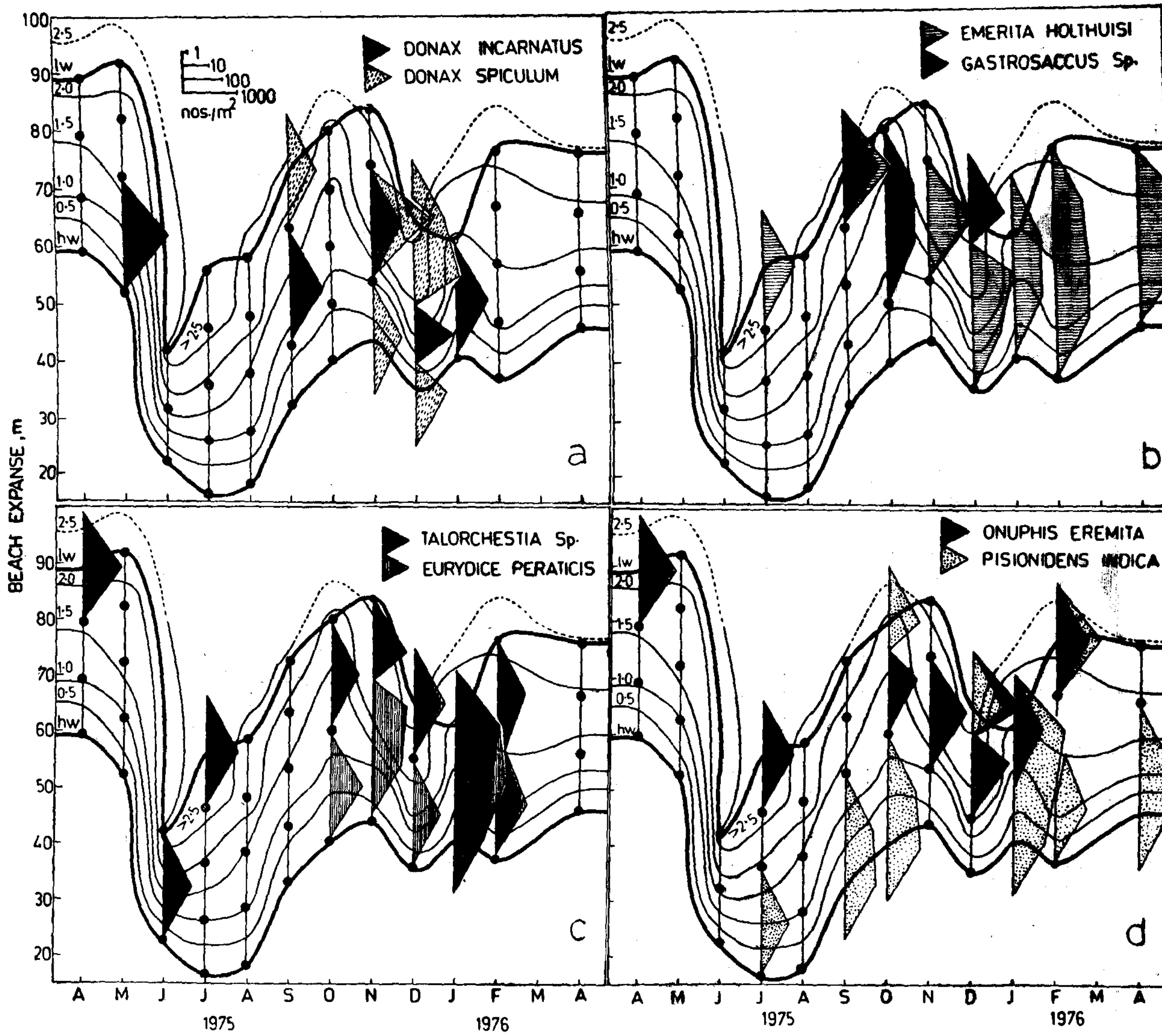

Fig. 10 (a-d) — Kite diagrams showing distribution and abundance of macrofaunal elements for different months superimposed on beach profile contours [Closed circles indicate the absence on the sampling date]

were not collected and during monsoon they were distributed only at the low tide levels. Newly recruited individuals made their appearance in July ($20/m^2 \equiv 0{\cdot}111$ g/m^2) and in September ($270/m^2 \equiv 3{\cdot}65$ g/m^2) (Figs. 10b and 11b). During post and early premonsoon periods, they were widely distributed along the intertidal belt having more numbers at the low and mid tide regions. Berried and adult specimens were more abundant during the postmonsoon months. They ranged in length between 8·9 and 11·3 mm and the mean wet weight was 740 mg. Young individuals were invariably present in all the samples. During February and April 1976 also, newly recruited ones were dominant in the collections. Their presence in the beach almost throughout the year suggests that this species is one of the regular inhabitants of the beach.

Sporadic occurrence of *Gastrosaccus* sp. in small numbers was observed in the beach. Specimens belonging to this species were collected mainly from low tide region from September through December. Owing to their small size and negligible weight, their contribution to total biomass was insignificant. A maximum number of $50/m^2 \equiv 0{\cdot}187$ g/m^2 was collected from the low tide station in September (Figs. 10b and 11b).

Contributions of other 2 crustaceans, viz. the amphipod *Talorchestia* sp. and the isopod *E. peraticis* to the biomass of the beach were also insignificant on account of their negligible weight. Among them, the former enjoyed a wider distribution in the beach than the latter as evident from Figs. 10c and 11c. While the isopod was present in small numbers in samples of the post and early premonsoon seasons, the amphipod was represented in the samples of all the 3 seasons but their occurrence was irregular during premonsoon and monsoon periods. The isopod inhabited mainly the mid tide stations and a maximum of $400/m^2 \equiv 0{\cdot}5$ g/m^2 was collected in Jan. 1976. The amphipod, on the other hand, was occurring more frequently at the low tide stations and was distributed all along the intertidal region in January ($220/m^2 \equiv 0{\cdot}175$ g/m^2). From their distribution pattern, it appears

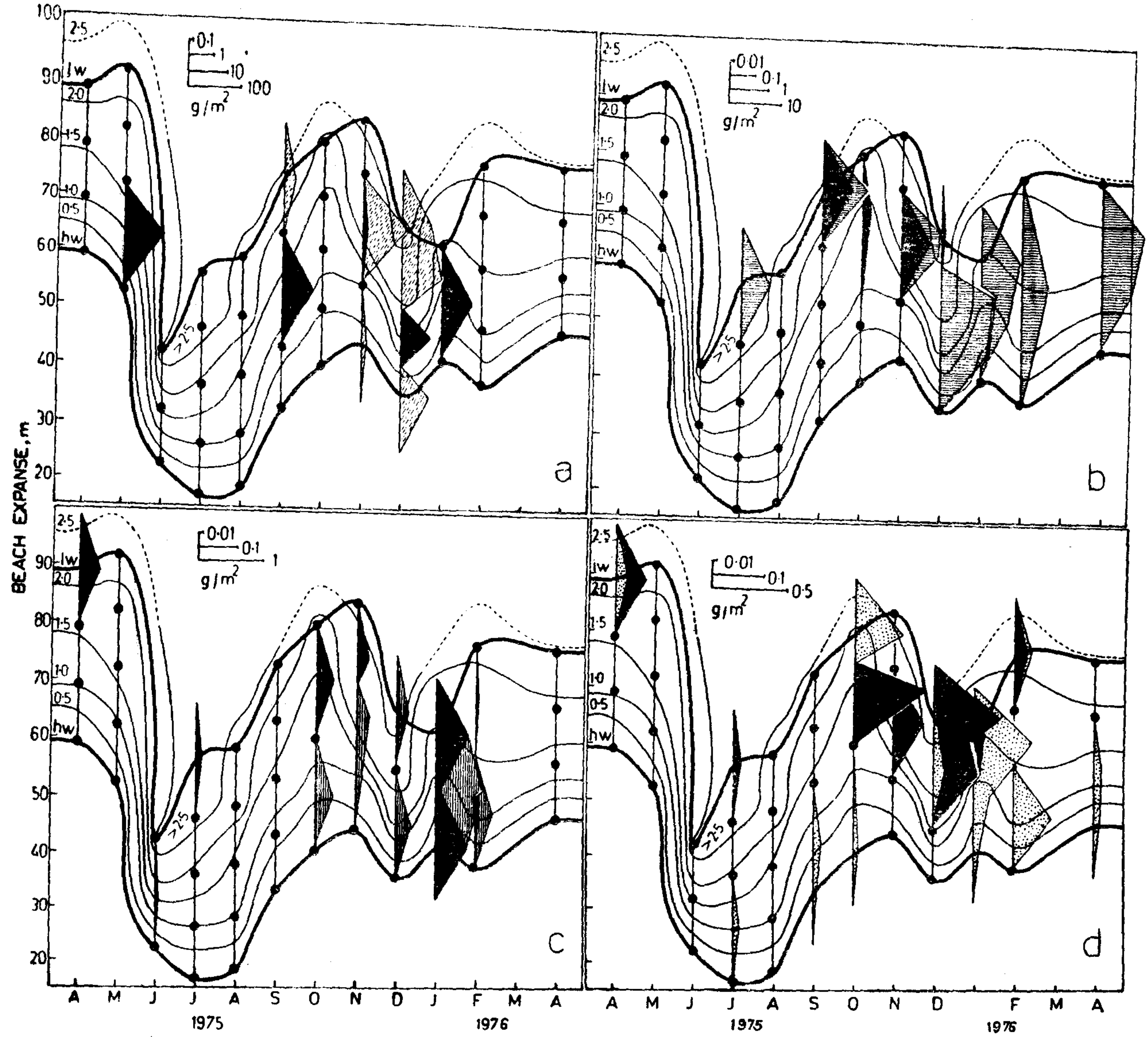
Fig. 11(a-d) — Kite diagrams showing biomass of macrofaunal elements for different months [Symbols as in Figs. 10a-d]

that the amphipod is a permanent element of the beach fauna.

Although the polychaetes, *O. eremita* and *P. indica* were absent in the samples of some months, they like the amphipod, were represented in all the seasons, the latter more abundantly and enjoying a wider distribution. During the postmonsoon period, both the species occurred consistently and abundantly in the beach. Even then, in terms of biomass, their contribution was small. While *O. eremita* was collected mainly from mid and low tide regions, *P. indica* was sampled from mid and high tide regions. A maximum of 480/m^2 weighing 0·298 g/m^2 of the former was collected from 65 m in December and 590/m^2 $\equiv$ 0·198 g/m^2 of the latter from 61 m in January (Figs. 10d and 11d). These 2 species also seem to be persistent elements of the beach fauna.

Discussion

Stability of the beach substratum influences to a very great extent the production of sandy beaches[6,7]. Baina beach was steep all through the year and was not stable in any month on account of erosion or accretion. During the monsoon season owing to severe erosion, the beach became very steep, the beach expanse was reduced considerably and the berm shifted landwards, thus making the substratum not suitable for the inhabitants. Erosion has been reported from May to June and accretion from September through March on the same beach[10]. However, erosion of a lower magnitude was observed from November through February during the present study.

Besides the changes taking place to the beach substratum, significant changes in other physical and chemical conditions occur in the beach during the monsoon season and these also play an important role in limiting the production of the beach[5-7]. There was a sudden drop in salinity and temperature and a slight reduction in *p*H and nutrient content in the beach during the monsoon season. These also contributed to the adverse conditions for the survival of the beach communities.

A notable difference noticed during the present study as compared to earlier works[5-7] has been the high content of particulate organic carbon in sand. This is well in agreement with sediments adjacent to sewage outfalls which are rich in organic matter[11]. More or less an identical condition exists in Baina. As mentioned earlier, large quantities of domestic wastes accumulate in the beach day by day and these probably provide additional source of carbon to the beach sediments. A relatively lower content in surf-water may partly be due to its distribution in surf-water and partly to the circulation which carries it away from the shore.

Bacterial population in intertidal sediments has been shown to have a close relation with sediment organic carbon[12]. The bacterial population in Baina beach proliferated utilizing the nitrogen available and the carbon which was present in plenty. In fact, the population would have shown remarkable increase had the nitrogen not been a limiting factor. However, it showed a very close relation with carbon in sand. Unfortunately, the total nitrogen in sand was not estimated and hence it is not possible to say to what extent nitrogen in sand would have limited the bacterial population. The relatively high population of coliforms in the beach may be due to the domestic waste accumulation which is seen in sewage discharging localities[11].

A close relationship exists between chlorophyll *a* and particulate organic carbon in sand[13]. This type of relation cannot be expected in a beach like Baina where there is surplus carbon and limited nutrient source. But incidentally, both sand and water chlorophyll were slightly higher than that in the other nearby sandy beaches investigated[14].

Continuous human interference as well as domestic sewage discharge will reduce the diversity of species[1]. Exactly, the same condition exists in Baina. Of the sandy beaches of India investigated so far[2-7,15], Baina alone has such a limited species diversity. Only 4 species were found to inhabit the beach permanently and they too were collected in small numbers only. This indicates that many of the organisms which are permanently inhabiting the neighbouring sandy beaches[6,7,15] could not adjust themselves to the changed physical conditions that are brought about mainly by human activities in this beach. This was another important factor, which along with other prevailing adverse physical conditions, brought down the macrofauna population of the beach. Indeed, the wedge clams, which are permanent elements of the macrofauna of the beaches along the west coast of India[5-7] were recruited to the beach population during postmonsoon season when the breeding of these species is at its peak in Goa[6]. But they were not growing to any appreciable size in the beach. On the contrary, the mole crab which is another important element of sandy fauna of Indian beaches[5-7] was found to occur in the beach almost throughout the year and completing its life cycle. Though these crabs were present in small numbers, their breeding and settlement in this beach correspond with the nearby Sancoale beach[7,16].

Thus, it is clear that the conditions existing in Baina sandy beach are somewhat different from other sandy beaches along the coasts of India and that these are not favourable for the fauna. The steepness of the beach and the unstable beach substratum all through the year coupled with the changes occurring in the physical and chemical conditions during monsoon season played the vital role in limiting production of the beach. Besides these, the human activities in the beach disturbed the beach inhabitants. The impact of all these were felt directly on the macrofaunal elements and hence Baina sandy beach had a reduced species diversity and recorded a poorer biomass than other sandy beaches studied so far in India.

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