

Physico-Chemical Features & Energy Input in 3 Sandy Beaches of West Coast of India

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Erosion of the beaches occurred during the southwest monsoon (June-September) and to a lesser extent during the northeast monsoon (November-December). Accretion occurred during the intervening months. Surf water temperatures were from 24° to 32°C and sand temperatures from 34° to 38°C. Salinity of the surf water was in the range 30 to 34‰ in the pre and post SW monsoon months. During the SW monsoon period the minimum salinity was 16, 20 and 24‰ at Arambol, Bawal and Colva respectively. Nutrient levels in the surf were highest during the SW monsoon months. Particulate organic carbon (POC) in surf water was the main source of energy input for benthic species. Levels of POC in sand and surf chlorophyll were relatively low. Levels of POC in the surf water did not show a consistent trend on the 3 beaches studied compared with a very characteristic seasonal pattern of animal numbers and biomass. This indicates that food availability is not a primary factor in controlling seasonal fluctuations of animal populations of sandy beaches on the west coast of India.

Studies on the ecology and production processes of the sandy beaches of the west coast of India are limited to a few regions¹⁻⁹. These studies have indicated the influence of physico-chemical changes on the abundance of sand macrofauna and a well defined seasonal rhythm in the production of macrofauna in relation to ecological changes. The relation between physico-chemical features of the sand and over-lying waters and the primary production in 3 sandy beaches of the west coast of India have been investigated and the results summarized in this paper.

Materials and Methods

Physico-chemical parameters and primary production of the beaches, viz. Colva, Bawal and Arambol (Fig. 1) were investigated at monthly intervals for 1 yr (1975-1976). Sampling was started in April, June and September 1975 respectively at Colva, Bawal and Arambol. During each collection, a transect was taken from a fixed point at the top of the beach down to low tide level and stations were marked out at 10 m intervals from high to low tide level. Sand temperature, water table depth and interstitial water temperature were recorded at each 10 m station and at 2 stations water samples were collected for the estimation of dissolved oxygen. Surf water samples were collected for determination of particulate organic carbon (POC), chlorophyll, dissolved oxygen and nutrients (PO_4 , NO_2 , NH_4 and NO_3). Sand samples were collected from 3 levels corresponding to high, mid and low tide levels by means of a 15 cm deep corer for the determination of chlorophyll, POC and particle size.

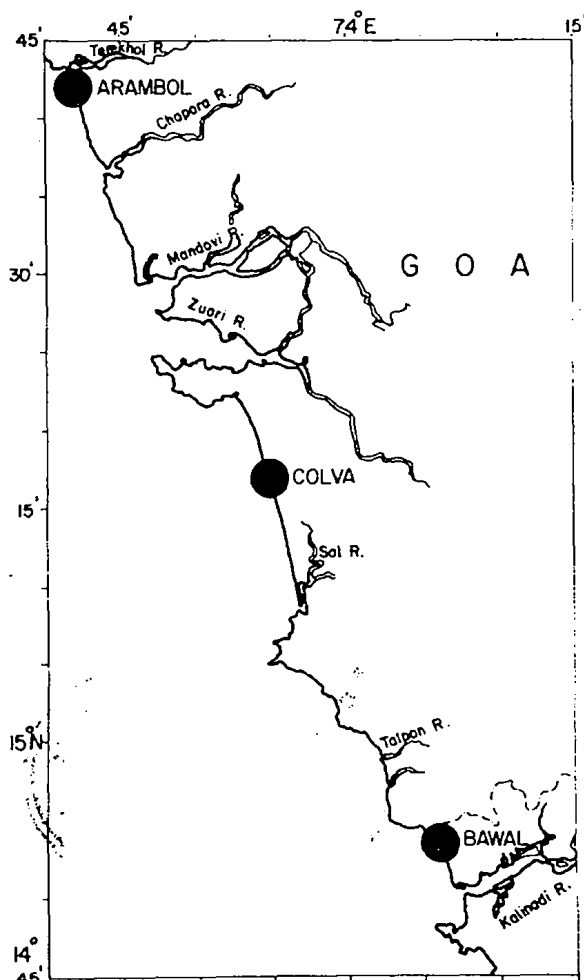


Fig. 1—Sampling sites

Beach profile was measured by conventional survey methods.

In the laboratory, sand particle size¹⁰, chlorophyll¹¹ and POC¹² were determined. Nutrients, salinity and dissolved oxygen levels were measured using standard methods¹³. Levels of chlorophyll were expressed in terms of both carbon equivalents¹⁴ and calories¹⁵, and POC in terms of calories using the conversion factor, 1 mg carbon = 10 cal¹⁶.

Results and Discussion

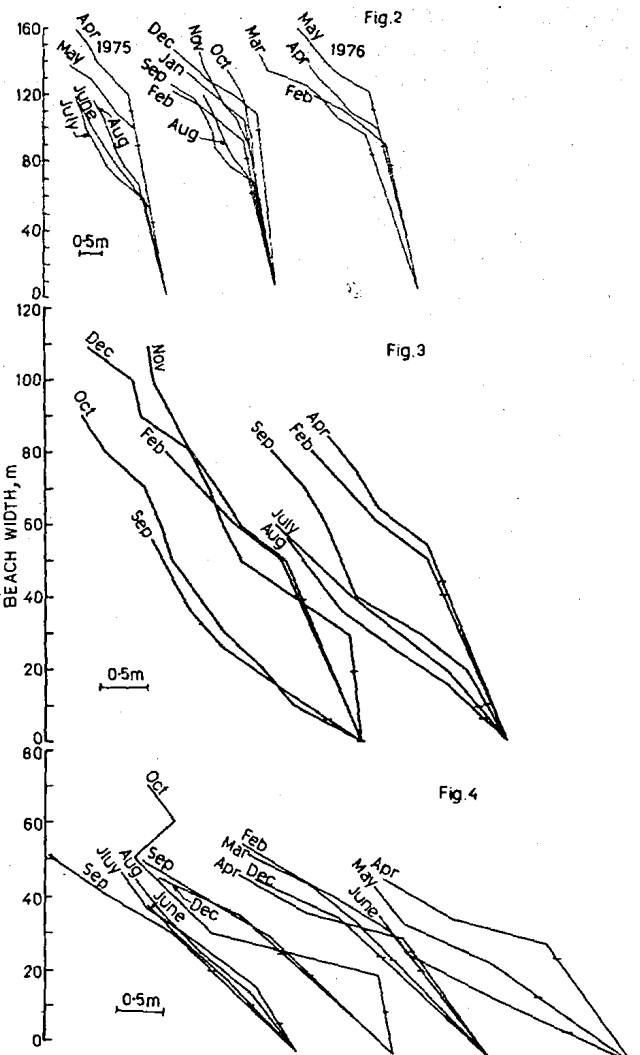
Although the sampling of the 3 beaches was started in different months, the data for each cover a complete annual cycle. The results have, therefore, been rearranged to facilitate comparison.

Colva is a part of an uninterrupted expanse of beach which extends 35 km southwards from Mormugao harbour. The beach has a fairly wide intertidal expanse (40-70 m) and a gentle gradient. Beach profile for Colva (Fig. 2) indicates that it underwent erosion from May to August, and the process was intense in May-June. Some deposition occurred in August which continued till December, being more extensive in September and October. It again underwent erosion in January which continued until February. Between March-May the beach showed successive accretion which was at first more marked on the lower foreshore, but later occurred at all levels. This beach had fine to medium sand with a particle size of 130.5-327.5 μm .

Arambol extends to a distance of 10 km north from the mouth of Chapora river. The changes in beach profile at Arambol (Fig. 3) were similar to those at Colva. Accretion started in September-October but unlike Colva, accretion was intense during November and December. There was some erosion at the lower foreshore level in February, and between February and April there was again some accretion. Compared to April there was massive erosion during July-August and the beach receded by 35 m. The beach showed recovery from September onwards. Arambol like Colva, had a fairly wide beach expanse of 40-90 m and fine sand particle size hardly exceeds 236 μm .

Bawal, just beyond the southern border of Goa (Fig. 1), was a much steeper beach than either Arambol or Colva. The beach expanse was narrow (Fig. 4) in most cases < 60 m with medium to coarse sand. The particle size ranged between 180 and 485.5 μm . Bawal showed a slightly different picture as compared to Colva and Arambol. Erosion began in March-April and continued till June. In June-July there was some accretion at the middle and upper foreshore levels. In October accretion began initially at the upper foreshore level and continued till February.

Temperatures for water and sand varied respectively from 25.4° to 31°C and 25.1° to 30.8°C at Colva; 24.2° to



Figs 2 to 4 - Beach profiles of Colva (2), Arambol (3) and Bawal (4) [Profiles for successive months have been superimposed to demonstrate erosion/accretion and shifting of high water level (bar)]

31.8°C and 27.8° to 36.3°C at Arambol and 24.3° to 31.7°C and 24.4° to 36°C at Bawal. Generally, the sand temperature at low water level and the surf water temperature were almost the same. Relatively low temperatures were recorded during June through August and during November to January. There were marked differences in sand temperatures between high water level and low water level in all the 3 beaches, the difference being related to the beach expanse and the time of collection (Fig. 5). At Bawal, where the beach expanse was usually < 60 m, the difference was never > 3.3°C. At Colva and Arambol, which had a wider intertidal zone, the temperature differences between high and low tide levels were relatively greater. Differences were least in the morning, increased gradually towards noon and were generally highest in the afternoon and evening. Sand temperature at low water was higher than at high water level in the early morning. In the afternoon the situation was reversed.

Seasonal changes in salinity followed the same salinities recorded for the 3 beaches showed some differences which were related to the amount of freshwater inflow. Arambol, which is bounded by the pattern in all the 3 beaches with the levels increasing gradually between July and April then dropping markedly during May to July (Fig. 6). The minimum

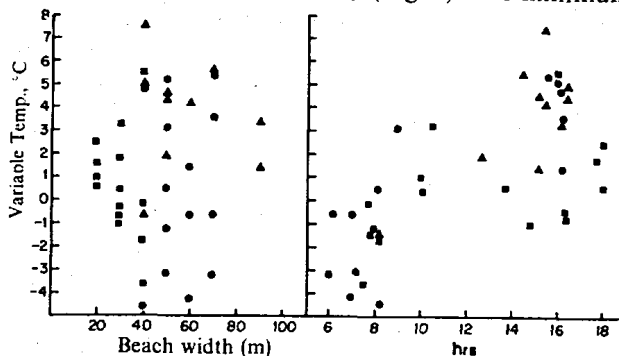


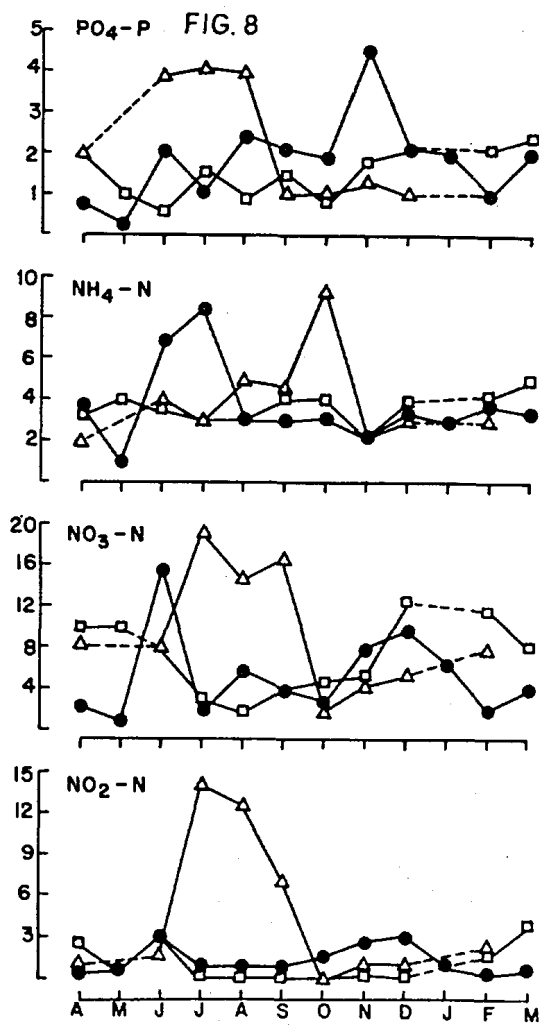
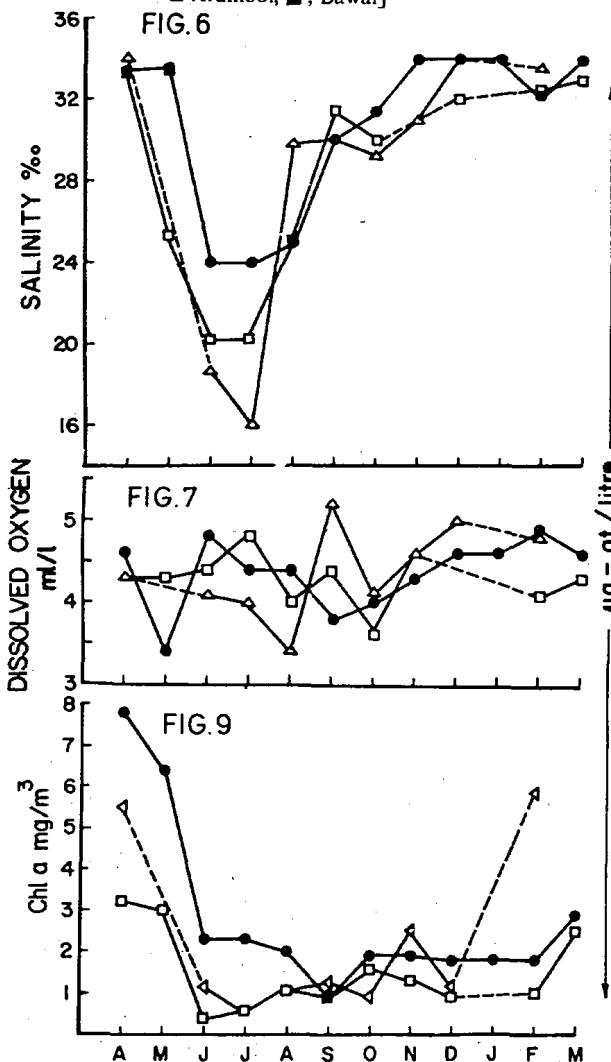
Fig. 5—Variable sand temperature in relation to beach width and time of collection [Positive values: Temperature in HWL > in LWL; Negative values: temperature in LWL > in HWL. ●, Colva; ▲ Arambol, ■, Bawal]

rivers Chapora and Tiracol, showed most dilution (minimum sal., 16‰). Bawal, which has an irrigation channel flowing across the beach, showed intermediate levels (minimum sal., 20‰) and Colva, where the only freshwater influx is through a small creek, showed the least dilution (minimum sal., 24‰).

Fluctuations in dissolved oxygen in the surf water (Fig. 7) were small and no seasonal variation was evident. Dissolved oxygen in the interstitial water at mid and high water levels varied from < 1 to 3 ml/litre, but it was usually around 2 ml/litre. No consistent decrease in dissolved oxygen with distance from low water level was apparent, since interstitial dissolved oxygen levels would depend on porosity, capillary suction, standing crop, and the rate of community metabolism.

pH of the surf water varied from 7.7 to 8.3 at Colva, 7.6 to 8.2 at Arambol and 7.7 to 8.2 at Bawal.

Levels of nutrients (PO_4 , NO_3 , NO_2 and NH_4) in the surf water (Fig. 8) showed peak values during June to September with a much smaller secondary peak during



Figs. 6 to 9—Seasonal changes in the salinity (6); oxygen (7); nutrients (8) and chl a (9) of surf waters [●, Colva; ▲, Arambol and □, Bawal].

November to January. Incessant rains and fresh water drainage would result in the increase in nutrients during June to September. Low utilization of nutrients for primary production during November to January (see low chlorophyll values in Fig. 9) could account for the secondary peak.

Chl *a* in the surf water of Colva (Fig. 9) showed a seasonal rhythm in phytoplankton production, with peak levels in summer (6-8 $\mu\text{g/litre}$) which declined to a minimum (0.9 $\mu\text{g/litre}$) in September and stabilised at intermediate levels (about 2 $\mu\text{g/litre}$) during October to February. A similar seasonal cycle occurred at both

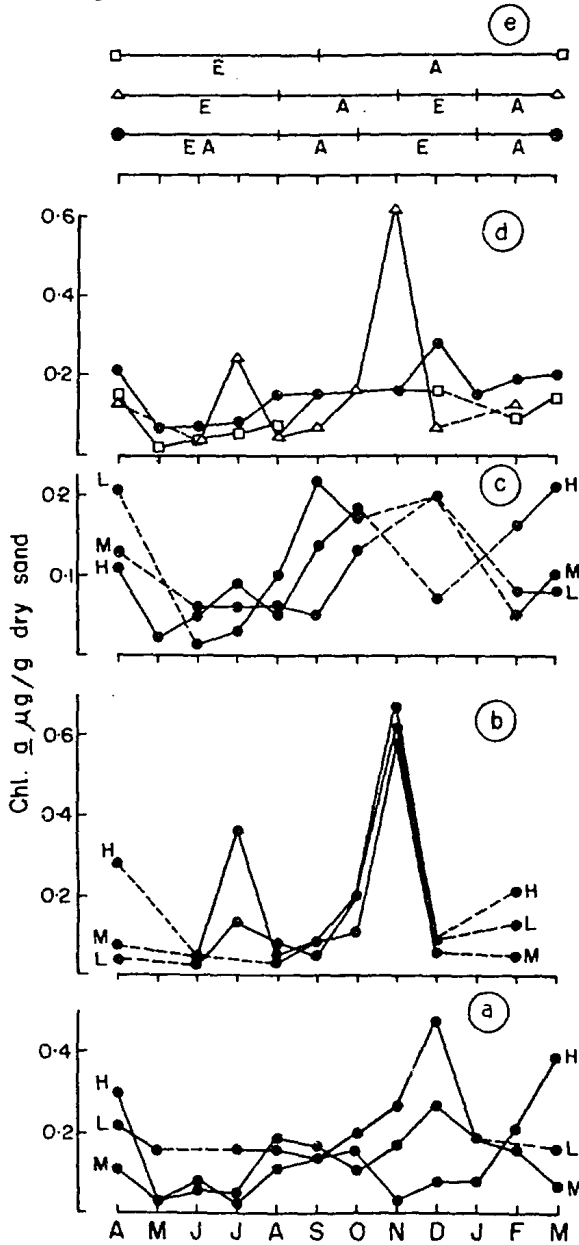


Fig. 10—Seasonal changes in sand chlorophyll [(a) Colva; (b) Arambol (c) Bawal: H-HWL, M-MWL, L-LWL. (d) Mean Chlorophyll values from 3 tide levels: ●, Colva; Δ, Arambol, □, Bawal. (e) Periods of erosion, E and accretion, A]

Arambol and Bawal, the only exception being 2 minor peaks - one at Bawal in October and the other at Arambol in November. These levels are similar to those reported for sandy beaches of Kerala².

Comparison of nutrients and chl *a* indicates that although nutrient levels were very high during the SW monsoon months (June-September), the standing crop of phytoplankton was low, which would result from the very turbulent conditions during the SW monsoon period. Increased phytoplankton production from December onwards was after the secondary peak of nutrients and attained a maximum value in March-April, when nutrients became low.

Levels of chl *a* in sand (Fig. 10) were up to 10 times higher than those reported for sandy beaches in Kerala². At all the 3 beaches seasonal changes in the sand chlorophyll were similar to those in the surf waters. In addition to this general trend there were particularly high levels of sand chlorophyll at Arambol in July and November and at Colva in December which were not paralleled by high levels in the surf water. The reason for these peaks is not clear. The

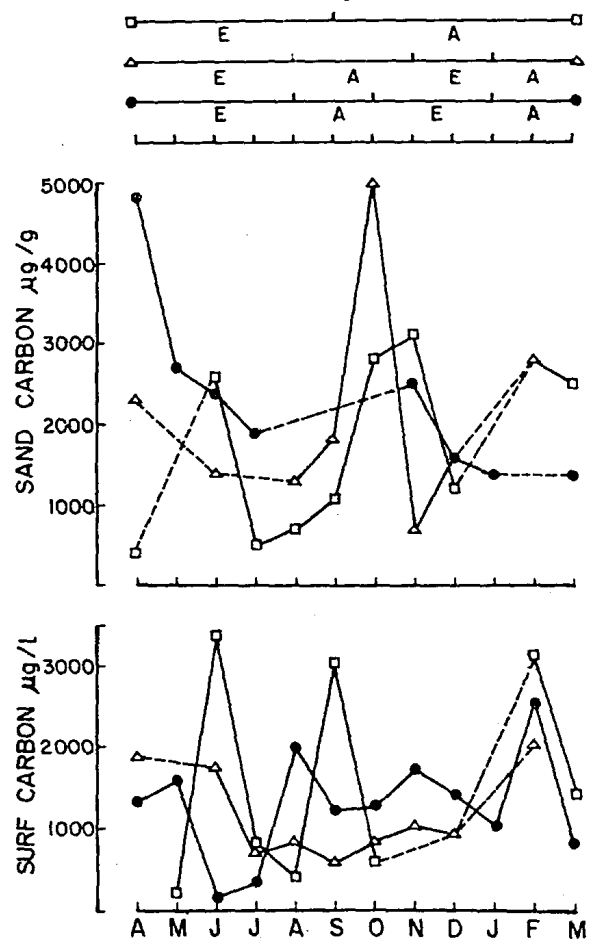


Fig. 11—Seasonal changes in particulate organic carbon in surf and in sand [Sand carbon values are mean values from the 3 tide level values. ●, Colva; Δ, Arambol; □, Bawal. Erosion, E and accretion, A]

Table 1—Caloric Equivalents of Chl *a* and POC in Surf and Sand
 [Figures represent range values with mean in parentheses]

Location	Surf				Sand			
	Chl <i>a</i> µg/l	Equ. calories g cal	POC µg/l	Equ. calories g cal	Chl <i>a</i> µg/g	Equ. calories g cal	POC µg/g	Equ. calories g cal
Colva	0.9-7.8	0.4-3 (1.2)	140-2550	1.4-25.5 (13)	0.07-0.28	0.03-0.11 (0.06)	1400-4800	14-48 (23)
Arambol	0.6-5.9	0.2-2.4 (0.9)	590-2040	5.9-20.4 (11.72)	0.04-0.63	0.02-0.25 (0.07)	700-5000	7-50 (17)
Bawal	0.4-3.2	0.2-1.3 (0.5)	210-3380	2.1-33.8 (13.91)	0.02-0.16	0.01-0.06 (0.04)	400-2800	4-28 (16)

seasonal changes were generally similar at the 3 tide levels. Levels in high tide sand at Bawal and Colva between December and March were an exception.

The consistent feature in POC in the surf at all the 3 beaches was the peak in February and relatively high values in premonsoon months (Fig. 11). At Colva and Arambol the pattern of changes in POC was similar to chlorophyll. At Bawal, however, there were peaks in surf carbon levels during June and September. Levels were within the range reported for other beaches in south India^{2, 17}. There was a significant relationship between chl *a* and POC in surf water at Arambol ($r = 0.75$) but not at Colva ($r = 0.02$) or Bawal ($r = 0.5$).

Levels of organic carbon in sand (Fig. 11) were generally low during the SW monsoon period with a marked peak at all the 3 beaches between October and December. In all cases the relationship between chl *a* and organic carbon levels was not significant (Colva, $r = 0.03$; Bawal, $r = 0.08$; Arambol, $r = -0.23$). These organic carbon levels were 5 to 8 times higher than those reported for Shertallai and Cochin beaches in Kerala² and for Calangute beach, Goa⁶.

Seasonal changes in the diversity and production of macrofauna have been described for a number of Indian beaches^{2,6,18} and fluctuations in abundance have been attributed to changes in beach stability and salinity levels which are associated with the annual monsoonal cycle. The results presented in this paper support the same general conclusions.

Levels of carbon in sand reported for Baina beach, Goa⁹, were higher than those reported in the present paper, but these high levels resulted from the large quantity of organic pollution on Baina beach. In comparison with levels of carbon in sediment from muddy areas, where the fauna are predominantly deposit feeders, the levels of carbon in sand reported here are relatively low^{19,20}, and may represent a minor contribution to energy input. The animal communities characteristic of Indian sandy beaches of the type

described here are predominantly suspension feeders^{2,6} and the main source of energy input will be the particulate matter in the surf water. Table 1 indicates the energy available as particulate food for suspension feeders. In estuarine situations, there may be a high input of particulate organic carbon from aquatic and terrestrial macrophytes which is not related to primary productivity. On some beaches fish offal discarded by local fishermen and human excrement may make a significant contribution to the particulate carbon levels.

On all the Indian beaches studied so far, including the present 3, a very marked and consistent drop in numbers and biomass of beach populations occurs during the monsoon^{2,5,6,9}. However, the values for food availability measured as POC in the surf water show variable trends with increasing values during the monsoon at some beaches (Bawal, Cochin and Shertallai) and decreasing values at others, (Arambol and Colva). Thus it may be suggested that food availability is not a primary factor in controlling the fluctuations of animal populations on tropical sandy beaches of the type described.

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