

OBSERVATIONS ON THE ECOLOGY OF SOME SANDY BEACHES OF THE SOUTHWEST COAST OF INDIA

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ABSTRACT

The seasonal cycles of organic matter and chlorophyll at some beaches of the Kerala Coast were studied in relation to the abundance of the interstitial fauna at one of the beaches. The faunal abundance showed no definite correlation either with organic matter or with chlorophyll. There was no correlation between organic matter and chlorophyll, which indicates that the occurrence of one is independent of the other. The maximum density of interstitial fauna at the Cochin beach was found to be at the mid-tide level. The most abundant groups on the beach were the ciliates, foraminiferans, nematodes and harpacticoids. Less abundant forms included the gastrotrichs, turbellarians, polychaetes, archiannelids, oligochaetes and isopods.

INTRODUCTION

MUCH of the work on sandy beaches of the Indian coasts has been confined to the taxonomy of different groups of animals (Aiyar and Alikunhi, 1944; Gnanamuthu, 1954; Krishnaswamy, 1957; Rao and Ganapati, 1967). Observations on the ecological features of the interstitial habitat are generally few and these are mainly restricted to grain-size of sand, temperature and salinity of the interstitial waters (Ganapati and Rao, 1962; Govindankutty and Nair, 1966). Recently, an interesting paper on the meiofauna and macrofauna of some beaches at Porto Novo has appeared (McIntyre, 1968).

The present paper which forms first of a series deals with the seasonal cycle of organic matter and chlorophyll in relation to the quantitative variation of the interstitial fauna of some sandy beaches of the Kerala coast, southwest coast of India,

AREAS OF INVESTIGATION

Figure 1 shows the areas from where collections of sand samples were made. These beaches were as follows :

(1) *The Cochin beach.*—This beach forms part of an extensive sandy beach located near the entrance of the Cochin Harbour. It has a steep slope and is exposed to continuous surf action. The lower reaches of the beach are devoid of any vegetation, while the upper reaches have patches of shrubs and grass. During the monsoon (May–August) and post-monsoon (September–December) the beach receives large quantities of aquatic weeds and algal debris which are washed ashore all along this beach. The maximum tidal range at this beach is about 1 m and the grain-size of the sand ranges from 200 to 700 μ , consisting of fine to coarse sand and shell gravel. Exposure at low water is 10–12 meters.

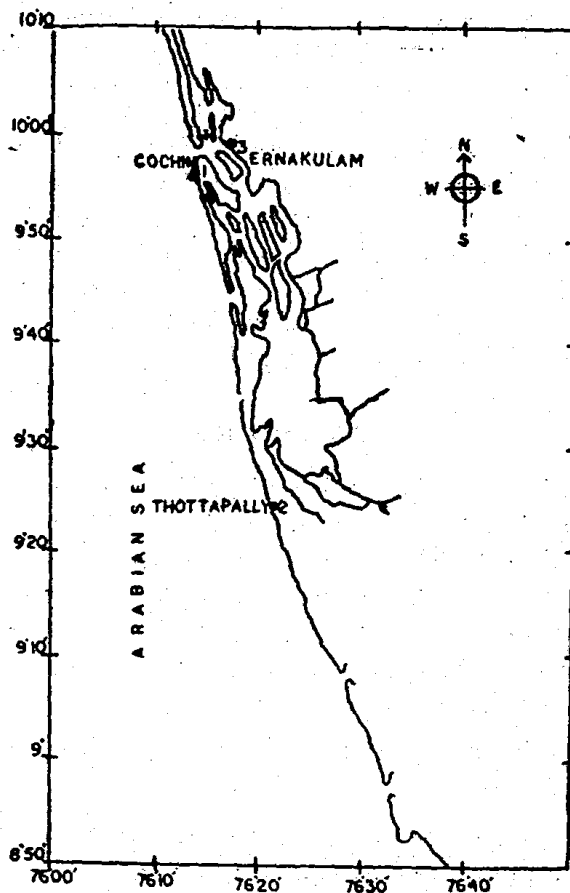


FIG. 1. Map showing the positions of sandy beaches marked as 1, 2 and 3 which were studied.

(2) *The Thottapally beach.*—This beach is located about 50 miles south of the Cochin beach, and like the former, forms part of an extensive sandy beach. It is subjected to heavy surf action, especially during the monsoon months. Heavy granite rocks are piled on the beach to act as break-water and to prevent erosion. The lower part of the beach is without any vegetation, while the upper region has scattered shrubs and grass. The slope of the beach is shallow with an exposure of 40 m at low tide. The maximum tidal range is about 1.1 m.

(3) *The Backwater beach.*—This beach is situated on the eastern side of Ernakulam channel. It is an artificial beach of recent origin formed as a result of dredging and sand deposition during the construction of a jetty. This is a small beach and gets exposed only during the low-tide. This beach forms a part of the backwater system in which a number of canals and rivers flow and thus make the condition typically estuarine. The substrate of this beach consists of a mixture of fine sand, silt and clay, with a grain-size of 120–300 μ . During the post-monsoon months, the beach receives large quantities of aquatic weeds washed ashore.

MATERIAL AND METHODS

Sand samples were collected at fortnightly intervals from the topmost layers at four different tidal levels, namely, low-tide mark, mid-tide mark, high-tide mark and from a few meters inside water below low-tide. The sand was scooped into a polythene container for the determination of organic carbon and chlorophyll. For the study of interstitial fauna the sand samples were collected from the Cochin beach only. A cylindrical brass tube of 1.8 cm internal diameter was inserted into the sand upto a depth of 5 cm and the samples thus obtained were transferred to suitable polythene containers. For the determination of organic matter, a weighed quantity of sand samples was heated in a silica crucible at 110° C until a constant weight was obtained. This was then ignited at 600° C in a muffle furnace and the loss in weight was taken as the total organic matter. Organic carbon was calculated from organic matter using the factor 1.8 (Morgans, 1956). Since the method used for the estimation of organic carbon was based on loss due to ignition, it seems probable that the total loss in weight might have included dissociation of calcium carbonate contained in the shell material. This may give rise to an overestimate of available carbon.

Chlorophyll was estimated by grinding about 5.0 g of sand in 90% acetone for 15 minutes, and allowing it to stand in the dark for 10–12 hours. The extract was then decanted off, centrifuged and its volume made

upto 10 c.c. The optical density of the extract was measured at 665 and 750 $m\mu$ in a 4 cm cuvette with 90% acetone in the reference path (Steele and Baird, 1961, 1962, 1968; Parsons, 1966). From the values obtained, the chlorophyll per gram of sand was computed.

The sand samples collected for the study of interstitial fauna by using brass cores were agitated violently in suitable glass containers with filtered sea-water. This was poured through sieves made from cut pieces of bolting nylon of 0.05 mm mesh width. The process was repeated 6-7 times and all the animals retained in the sieve were washed into a petri-dish containing 10% alcohol to anaesthetise the animals. Trial experiments made earlier had shown that generally 6 washings were enough to remove all the animals from the sand. The sample containing the animals thus obtained was divided into a number of sub-samples which were examined in parts under a microscope and each category of animals was listed and counted. The data were pooled to express the total number of animals contained in a 10 ml of sand column.

RESULTS

Organic carbon and chlorophyll.—The relationship between organic carbon and chlorophyll has been shown in Fig. 2. The values plotted in Fig. 2 refer to all tidal levels of the three beaches. It can be seen from the figure that there is no definite correlation between the two. This indicates that the organic carbon is derived mostly from extraneous sources other than the phytoplankton organisms attached to the sand grains. The organic

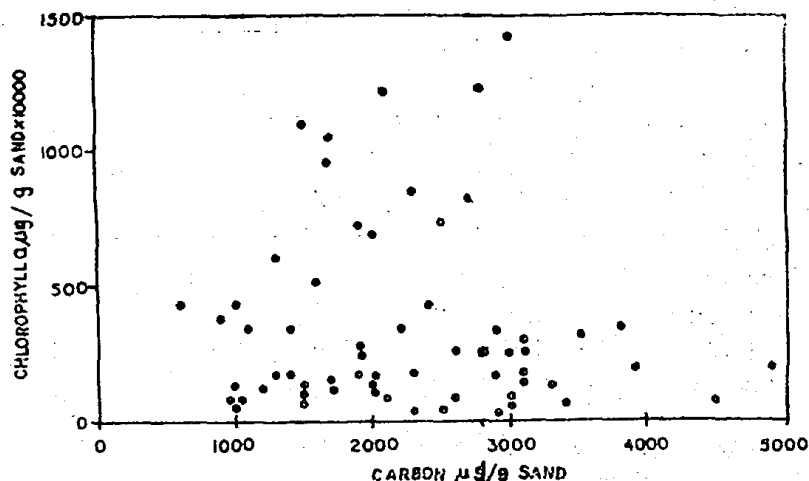


FIG. 2. Scatter diagram showing the relationship between organic carbon and chlorophyll. The points include the values obtained from all the three beaches at different tidal levels.

carbon values, reported from an investigation of sandy beach (Steele and Baird, 1968) from the west coast of Scotland (Loch Ewe), are lower than those obtained in the present studies.

The range in the values of carbon and chlorophyll obtained at the three beaches has been given in Table I, from which it is evident that the organic carbon at the Cochin beach is greater than at the other two beaches, and that the Thottapally beach shows the minimum values. This is probably because of a greater quantity of organic material of terrestrial origin reaching the Cochin beach, for it is situated adjacent to densely populated areas and is subjected to pollution. Similarly, the backwater beach which is amidst human habitation shows high values of organic carbon; but the Thottapally beach which is a relatively cleaner beach, being somewhat away from human influence, is poor in organic matter. A close examination of Table I will reveal that at all the beaches the organic carbon was higher at the low-tide mark and inside water than at the other tidal levels. Since Cochin and Backwater beaches are located near and at the confluence of the estuary respectively, they receive large quantities of organic material and these probably contribute to a higher value of organic carbon.

TABLE I

Range in organic carbon and chlorophyll values at different tidal levels of three beaches under investigation

Organic carbon $\mu\text{g/g sand}$

	Cochin	Thottapally	Backwater
High-tide	1,000-5,900	300-2,700	600-3,500
Mid-tide	1,000-4,600	1,500-3,200	1,300-6,400
Low-tide	1,000-8,400	1,300-3,400	1,600-8,300
Inside water	1,700-6,100	1,500-3,300	1,700-5,900
<i>Chlorophyll ($\mu\text{g/g sand}$)</i>			
High-tide	0-0.017	0-0.122	0.0035-0.142
Mid-tide	0-0.043	0-0.015	0.017-0.123
Low-tide	0-0.031	0-0.055	0-0.131
Inside water	0-0.035	0-0.013	0.15-0.387

At the Cochin beach, high values of organic carbon were obtained at the low-tide level and inside water and low values at the high-tide and mid-tide marks. Marked seasonal fluctuations were noticed at the Cochin beach (Fig. 3). Lowest values were obtained in the monsoon months at all the tidal levels. Except for the mid-tide mark which showed a high carbon content in the pre-monsoon months (January–April), at all other tidal levels, high values were recorded in the post-monsoon months (September–December). At the Thottapally beach, the maximum values of organic carbon were found at the low-tide level. The values inside water were higher than those at high or mid-tide levels. Although no well-defined seasonal cycle of organic carbon was found at this beach, the values at low-tide level and inside water were high during the monsoon and post-monsoon months, while at the high-tide level they showed no regular pattern (Fig. 4).

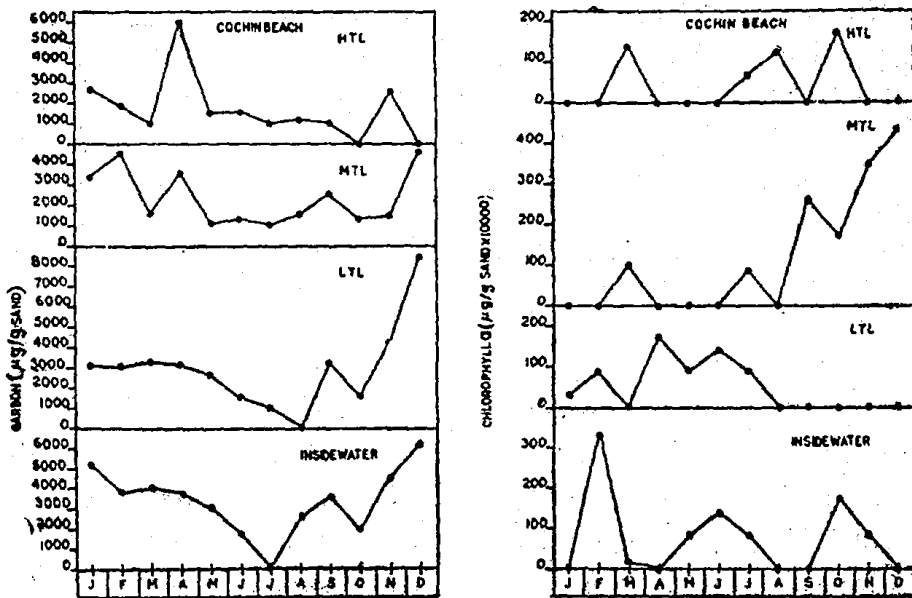


FIG. 3. Organic carbon and chlorophyll at different tidal levels of the Cochin beach.

Marked seasonal fluctuations in the organic carbon were noticed at the Backwater beach (Fig. 5). At mid-tide, low-tide and inside water, high values were found in the pre-monsoon months, while at the high-tide, slightly higher organic content was found during the post-monsoon months. At all tidal levels, minimum values were obtained during the monsoon period. A decrease in the organic carbon values during the monsoon months may be because of its washout by the rain-water.

Like carbon, the chlorophyll values at all the three beaches showed fluctuations in different seasons (Figs. 3, 4 and 5). At the Cochin beach no definite seasonal pattern was noticed in the distribution of chlorophyll at various tidal levels except that the values at the mid-tide level were high from August to December. Similarly, at the Thottapally beach, two peaks

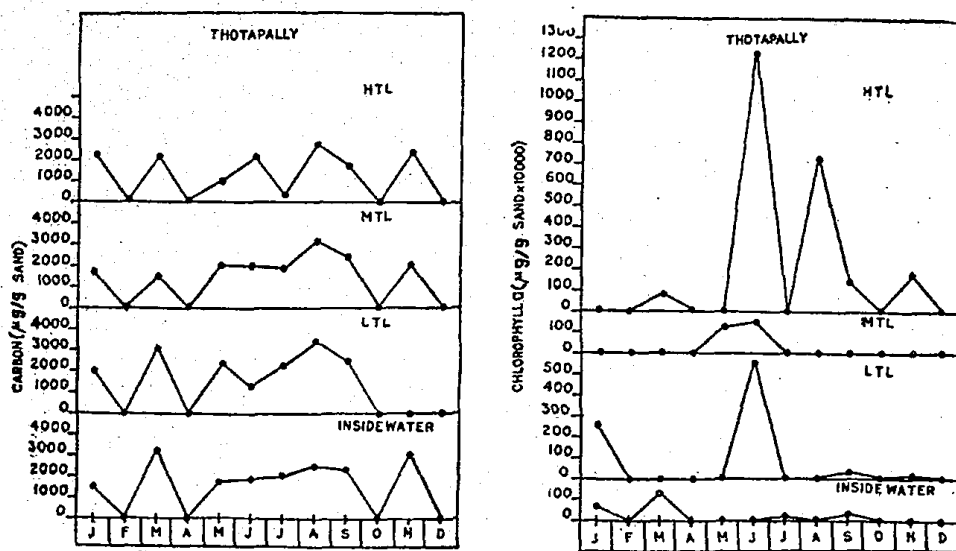


FIG. 4. Organic carbon and chlorophyll at different tidal levels of the Thottapally beach.

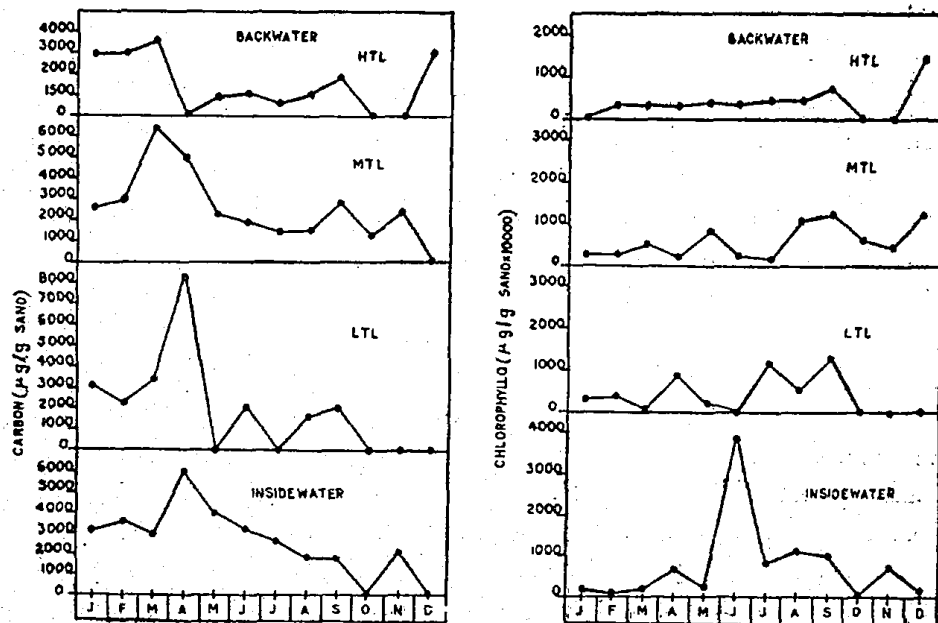


FIG. 5. Organic carbon and chlorophyll at different tidal levels of the Backwater beach.

of chlorophyll occurred in June and August, otherwise the values for the rest of the year were very low (Fig. 4). The backwater beach, on the other hand, showed a fairly well-defined cycle of chlorophyll. The values were generally high during the monsoon and post-monsoon seasons and rather low during the pre-monsoon months. High values were obtained inside water, especially in the month of June. The Backwater beach had a higher chlorophyll content than those of the other two beaches. This may be because it has a much finer sand than the other two beaches, and this may possibly lead to a greater retention of plant material because of poor drainage. High values of chlorophyll during the monsoon and post-monsoon period, at all the three beaches, are probably because of large quantities of aquatic weeds being washed ashore on these beaches. The canals and irrigation channels opening into the backwater system develop a luxuriant growth of weeds like *Salvinia* and *Eichornia* during the monsoon period. In the post-monsoon months, when the salinity of these channels increases, these weeds get dislodged and with the outgoing tides are deposited on the beaches where they disintegrate. On one instance as many as 400 *Salvinia* and *Eichornia* plants were seen within one square meter at the Cochin beach. Probably their settlement and final decay on the beaches has a profound influence on both chlorophyll and organic matter of the beaches.

The Thottapally beach being away from the estuarine influence is subjected to far less accumulation of aquatic weeds, and this might explain the lower chlorophyll and organic contents recorded at this beach.

There seems to be at times sporadic high peaks, otherwise there is very little seasonal variation in the organic carbon and chlorophyll at all the beaches. Since the organic carbon and chlorophyll are mainly influenced by external forces like rainfall, land drainage, etc., the fluctuations of the values may not remain consistent year after year.

INTERSTITIAL FAUNA

As noted earlier, the interstitial fauna were studied only at the Cochin beach. The total abundance of the animals on this beach showed a marked seasonal variation at different tidal levels (Fig. 6). The maximum number of animals appeared in the pre-monsoon period. A gradual decline in the fauna occurred during the monsoon months, which was followed by a consistent increase in the post-monsoon period (Table II). It may also be of interest to note that the sampling of the fauna was only confined to the top 5 cm layer of sand. It is therefore possible that the decline in fauna

noticed during the monsoon months may be because of their vertical migration to deeper layers. However, the ciliates recorded the maximum numbers, followed by foraminiferans, nematodes, harpacticoids, gastrotrichs, turbellarians, polychaetes, archiannelids, oligochaetes and isopods (Fig. 7). The nematodes were the most abundant metazoan group. Occasionally molluscs, kinorhynch, ostracods, eggs and developmental stages of insects, nauplii and copepodite stages were also found. Even though the numerical abundance of ciliates and foraminiferans was greatest, nematodes and harpacticoids, being larger in size, contributed to the highest biomass.

TABLE II

Total number of animals at the Cochin beach at different tidal levels [The three seasons indicated are of four months each, pre-monsoon (January–April), monsoon (May–August), post-monsoon (September–December)]

	Pre-monsoon	Monsoon	Post-monsoon
High water-mark	683	765	753
Mid-water-mark	1,163	845	1,210
Low-tide mark	955	650	755
Average	934	753	906

An examination of Fig. 7 will reveal that, although the various categories of animals were found throughout the year, their maximum abundance was restricted to a particular tidal zone. Thus, isopods were present all the year round at the high water-mark, and in some months at the mid-tide level, but they were totally absent at the low-tide level. Foraminiferans, ciliates and nematodes appeared in large numbers throughout the year, but showed maximum abundance in the pre-monsoon and post-monsoon periods. Although they were found at all tidal levels, the abundance of foraminiferans and nematodes was greater at the high and mid-tide marks, while ciliates occurred in maximum numbers at the low and mid-tide levels. Turbellarians and gastrotrichs occurred in moderate numbers throughout the year, with a maximum in monsoon and post-monsoon months. They were most abundant at mid and low-tide marks,

There was no consistency in the occurrence of oligochaetes, which were randomly distributed at all the tidal levels. Harpacticoids occurred throughout the year at all tidal levels with a maximum in the monsoon and post-monsoon months at the low-tide mark. Isopods occurred in small numbers in the monsoon and post-monsoon months. They were rarely seen during the pre-monsoon months.

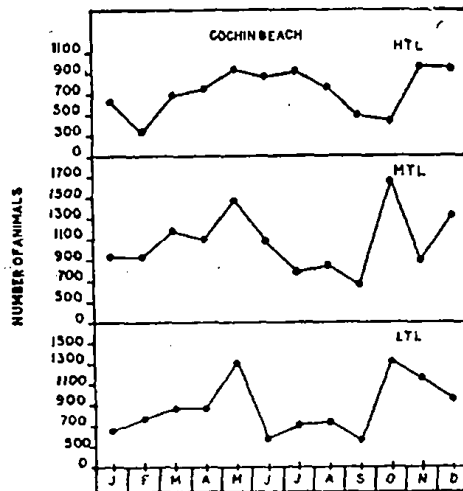


FIG. 6. Seasonal abundance of interstitial fauna at different tidal levels of the Cochin beach.

DISCUSSION

The total composition of the interstitial fauna at the Cochin beach during the year under investigation has been compared with some earlier informations which has been given in Table III. It can be seen from the table that the density of fauna at the Cochin beach is greater than what has been reported from the same beach earlier (Govindankutty and Nair, 1966). It is also greater than that of Palm beach, Andhra coast (Ganapati and Rao, 1962).

The factor which may affect the population density of the interstitial fauna is the changing nature of the beach profile. Some observations made in recent years have indicated that the beaches of the Kerala coast are subjected to severe erosion and that their profile changes drastically during the monsoon months. This factor alone may greatly change the composition of the fauna from year to year. However, as compared to the Palm beach of the Andhra coast the fauna at the Cochin beach is markedly high. Boaden (1963) reported a density of 1,250 animals per litre of sand

in between low and mid-tide marks, upto a depth of 5 cm, in a North Wales beach. Such a low density of animals at that beach may be because of the difference in the grain-size of the sand, for it is well known that the size of the sand grains has a marked influence on the distribution of animals inhabiting the interstitial spaces of sand (Wieser, 1959). From an investigation of sandy beaches at Porto Novo, southeast India, McIntyre (1968) reported a meiofauna density of 19,600/100 cm² at mid-tide, which is much higher than the density of fauna found at the Cochin beach.

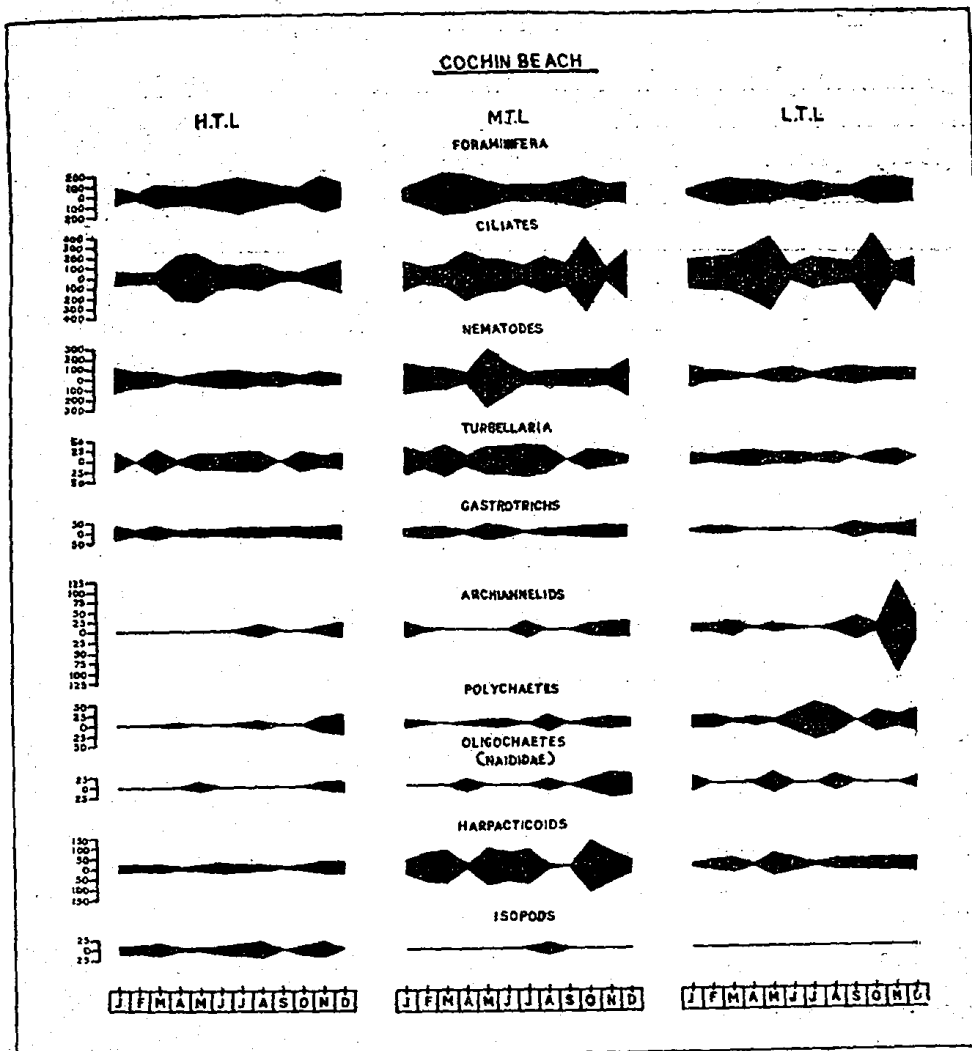


Fig. 7. Diagrammatic representation of the seasonal abundance of various groups of animals at different tidal levels of the Cochin beach,

The Cochin beach is in many respects different from the other beaches. In the temperate region (Loch Ewe beach of the west coast of Scotland) the relationship between chlorophyll and carbon has been found to be direct which indicates that the phytoplankton organisms attached to sand particles contribute largely to the organic carbon (Steele and Baird, 1968). At the Cochin beach the chlorophyll has no direct relationship with carbon, signifying that one is independent of the other. No definite correlation between the abundance of interstitial fauna and the peaks in the organic

TABLE III

Average number of animals in 15 c.c. sand sample at the Cochin beach during present observations and during 1963-64 reported by Govindankutty and Nair (1966) [The numerical values reported from Palm beach (Andhra) by Ganapati and Rao (1962) have also been included]

	Cochin beach 1967			Cochin beach 1963-64			Palm beach Andhra Coast (1958-59)
	HTL	MTL	LTL	HTL	MTL	LTL	MTL
January	94	141	99	12	24	10	8
February	52	139	115	12	27	12	12
March	103	171	130	20	30	15	10
April	112	165	130	20	35	18	16
May	141	222	196	21	32	15	21
June	130	163	87	9	20	12	24
July	138	117	105	10	25	28	31
August	115	127	111	10	18	30	18
September	75	99	87	11	19	29	11
October	67	250	199	12	15	26	8
November	145	135	174	11	16	20	9
December	144	199	145	13	18	12	7

matter and chlorophyll found at the Cochin beach is again quite suggestive. Both at the high and mid-tide marks the highest concentration of organic contents precedes the maximum occurrence of sand fauna. Another source of organic material in the sand seems to be the microbes (bacteria). Pearse *et al.* (1942) reported an average bacterial population of 648,000, 147,000 and 45,000/cm³ of sand at high, mid and low-tide marks respectively at the North Carolina beach. Copepods, nematodes and some groups of ciliates are well known to feed directly on bacteria (Pennak, 1951; Wieser, 1960), and therefore, the importance of bacteria as a major source of food for the interstitial group of animals cannot be ignored.

The significance of soluble organic material in the sea-water has been greatly emphasised in the trophic chains of a sandy beach ecosystem and the link of this seems to be through bacteria (McIntyre *et al.*, 1968). Since no estimate of bacterial population has been made from the Cochin beach it is difficult to assess the contribution of the microbes in the food chain. However, the beach being greatly subjected to human influence and considerable pollution, the bacterial population would seem to be high.

A recent study of the sandy beaches at Etterick Bay yielded an average of 1,191 diatoms per mm² of sand grain surface (Meadows and Anderson, 1968). The diatoms occurring in the marine sandy beaches contributing to the organic carbon and chlorophyll form another source of food for the interstitial fauna.

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REFERENCES

- Aiyar, R. G. and Alikunhi, K. H. *Proc. natn. Inst. Sci. India*, 1944, 10, 113-40.
- Boaden, P. J. S. *J. mar. biol. Ass. U.K.*, 1963, 43, 79-96.
- Ganapati, P. N. and Rao, G.C. *J. mar. biol. Ass., India*, 1962, 4, 44-57.
- Gnanamuthu, C. P. *Ann. Mag. nat. Hist.*, 1954, 12, 257-74.
- Govindankutty, A. G. and Nair, N. B. *Hydrobiologia*, 1966, 28, 101-22.
- Krishnaswamy, S. *University of Madras*, 1957, 1, pp. 168.

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- McIntyre, A. D. .. *J. Zool. Lond.*, 1968, **156**, 377-92.
- , Munro, A. L. D. and Steele, J. H. .. *Proc. Symposium on Marine Food Chains*, Denmark, 1968, No. 2 (mimeo), pp. 23.
- Meadows, P. S. and Anderson, J. G. .. *J. mar. biol. Ass. U.K.*, 1968, **48**, 161-75.
- Morgans, J. F. C. .. *J. Anim. Ecol.*, 1956, **25**, 367-87.
- Pearse, A. S., Humm, H. J. and Wharton, G. W. .. *Ecol. Monogr.*, 1942, **12**, 135-90.
- Parsons, T. R. .. *Monographs on Oceanographic Methodology*, UNESCO, 1966, pp. 19-36.
- Pennak, R. W. .. *Année Biol.*, 1951, **27**, 449-79.
- Rao, G. C. and Ganapati, P. N. .. *Proc. Ind. Acad. Sci.*, 1967, **55**, 10-15.
- Steele, J. H. and Baird, I. E. .. *Limnol. Oceanogr.*, 1961, **6**, 68-78.
- .. *Ibid.*, 1962, **7**, 42-47.
- .. *Ibid.*, 1968, **13**, 14-25.
- Wieser, W. .. *Ibid.*, 1959, **4**, 181-94.
- .. *Ibid.*, 1960, **5**, 121-37.