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Seasonal changes of the sediment size distribution and stability along the beaches of Kerala, south west coast of India

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Mean grain size distribution under different environmental conditions along the coast of Kerala showed considerable spatial variation (0.14-0.96 mm). Standard deviation values indicated a very well sorted class along all the beaches with a lowest value of 0.48 ϕ. Difference in standard deviation values between the stations were significant in all the stations. Samples were nearly symmetrical to negatively skewed with most of the values clustered at -0.01 to -0.10.

Studies on beach sediments along the south west coast of India have been carried out by many researchers[1-15]. Empirical Orthogonal Function (E.O.F) analysis of the sediments from beaches of various morphological set up, at a time is scanty for the Kerala coast[16]. Due to variations in the nature and type of the beaches along Kerala coast, the responses of the individual type of beaches are expected to be different eventhough the monsoonal forcing is more or less the same. In view of this, eight regimes were selected along the Kerala coast (Fig. 1), for field observations, in the vicinity of promontory/headland, barrier beaches, beaches protected by seawalls, open coast beaches, beaches exposed to low and high energy environment and beaches protected by the seasonal occurrence of mud bank. The aim of the present study is to determine statistically the significant variations in grain size distribution of the beach sediments along different beaches of different morphology with the variation of beach volume.

Materials and Methods

Beach profiles and sediment samples were collected from 8 profile locations along the beaches of Kerala (Fig. 1) from March 1990 to March 1991. Sediment samples were collected by scoop sampling. Beach samples subjected to preliminary

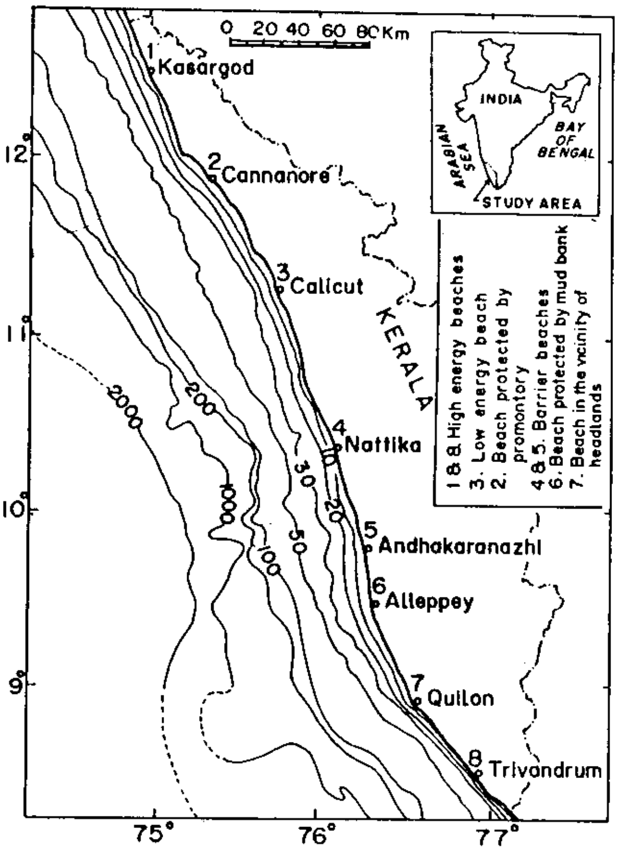

Fig. 1—Location of stations

treatment were sieved for 15 minutes in a mechanical Ro-Tap sieve shaker with a set of standard ASTM sieves at intervals of 0.5 phi. The graphic mean, median, standard deviation and skewness were calculated based on the formula of Folk and Ward. Relative changes in volume of sediments per unit length of the beach (storage volume) at each location were estimated from monthly beach profiles.

Mean grain size data of every sample taken from all stations were together subjected to Empirical Orthogonal Function (E.O.F) analysis to understand the spatio-temporal variability of the sediments in different environments. The size distribution of all the 104 samples from 8 ocations for 13 months were represented in the form of a matrix, L(X, ϕ) of discrete size class with X as the location and ϕ, the grain size class for different months. The matrix was converted to a normalized data matrix, X(X, ϕ) and the eigen functions were obtained.

Results and Discussion

The monthly variation of graphic mean, standard deviation and skewness calculated for the samples from different morphological settings are presented in Figs 2, 3 and 4. The changes in sediment characteristics are associated with corresponding variations in beach profiles, so the variations in grain size could be well explained by the changes in beach profiles. Monthly volume of sediment per meter length of the beach at each stations were estimated and presented in Table 1.

The high energy beach at Kasargod, showed maximum variability in the foreshore region. This beach exhibits cyclic episodes of erosion and accretion in response to the monsoon and fair weather seasons. Storage volume of the beach was maximum (765 m^3 m^{-1}) at the beginning of the study, during March 1990 and showed the least (704 m^3 m^{-1}) in September 1990. After southwest monsoon, the beach built up gradually. By the end of the study period (February 1991), the beach regained to only 738 m^3 m^{-1} in storage volume.

The mean grain size of the sediment sample, from the low water line is of coarser grade sand size class, moderately sorted and negatively

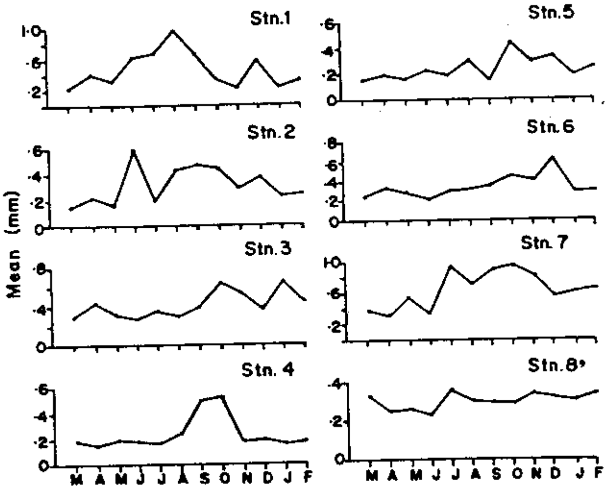

Fig. 2—Monthly variation of mean size

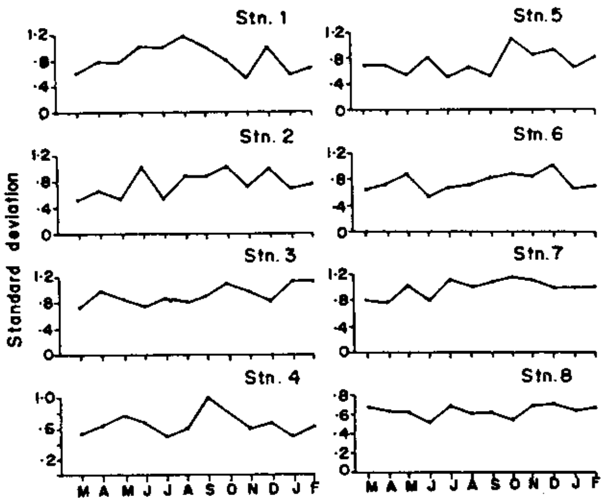

Fig. 3—Monthly variation of standard deviation

Table 1—Monthly volume of beach sediment in cubic metres per metre width

Station No.	Months											
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
1	765.3	758.2	730.9	733.1	735.4	724.7	704.4	712.2	725.0	747.0	741.5	738.1
2	440.1	442.0	438.8	421.5	412.5	421.7	427.3	416.6	430.1	428.5	436.5	437.0
3	1293.1	1302.5	1301.5	1301.9	1292.8	1294.8	1300.0	1295.3	1295.1	1294.8	1301.7	1298.8
4	547.9	547.7	534.3	514.0	515.9	520.9	531.4	540.0	541.8	543.5	544.7	557.0
5	579.2	586.9	554.4	551.6	556.0	554.4	581.2	581.5	579.7	577.4	574.2	588.7
6	895.3	915.2	924.6	934.5	940.2	941.7	936.4	927.3	936.5	945.5	942.6	968.3
7	421.4	425.4	396.9	371.0	385.2	385.2	373.6	380.0	397.9	410.0	406.3	403.9
8	459.9	465.6	447.3	426.5	399.9	413.9	445.2	457.1	466.3	470.5	473.7	477.9

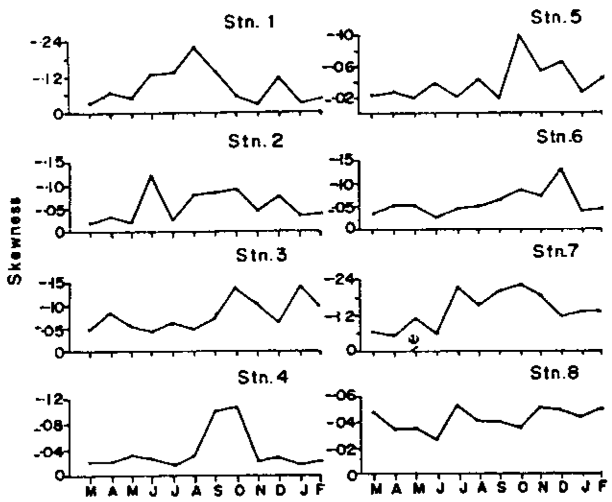

Fig. 4—Monthly variation of skewness

skewed. Mean size of the beach sand (Fig. 2), varies between fine to coarser grade (0.22 mm to 0.94 mm). Standard deviation values (Fig. 3), revealed that majority of the water line samples were moderately sorted and displayed best sorting with an average value of 0.82 ϕ. In August, the sorting value was maximum (1.15 ϕ) and the mean grain size was coarsest (0.93 mm). This indicates that erosion was active till August. The samples were negatively skewed to nearly symmetrical with most of the values clustered around -0.02, -0.11 and -0.21 (Fig. 4). However, during the rest of the months, it was symmetrically skewed with values around -0.21. Coarsest material occurred during August, coincided with the erosion during the south-west monsoon period. The skewness directly relates to the erosional/accretional pattern of the beach[18]. The negative skewness values observed most of the time, indicated the erosional phase of the beach. The symmetrical skewness seen during September to November indicated the accretional phase of the beach.

The beach at Trivandrum is an open beach exposed to high wave energy. It lost 67 m^3 m^{-1} of the material during monsoon period. The erosion was rapid while the accretion was gradual and steady by taking about 4 to 5 months to recover the material lost during the south west monsoon. There is considerable building up showing a value of 478 m^3 m^{-1} to its initial volume of 466 m^3m^{-1} before the onset of monsoon.

Average value of the mean grain size (Fig. 2) showed the presence of medium size sand (0.25 mm - 0.36 mm) except in June where fine sand class was present (0.23 mm). Maximum grain size in July showed the severe erosion during this month. Sorting values (Fig. 3) showed moderately well sorted to moderately sorted nature during south west monsoon. And was symmetrically skewed (Fig. 4) through the entire period of study indicating the dynamically stable nature of the beach.

The beach at Calicut, an open coast low energy beach, frequently sheltered by the occurence of mud bank is wide and sandy with least variability compared to the rest of the beaches. Changes in storage volume of this beach are of 10 m^3 m^{-1} during the south west monsoon and 5 m^3 m^{-1} during the north east monsoon. The beach regained it's initial storage volume of 1302 m^3 m^{-1} (April 1990) by the end of January 1991. Mean size of the beach sediment (Fig. 2), is composed of medium grade sand (0.26 mm to 0.40 mm) with moderate sorting and symmetrical skewness except during October, November and January, when coarse material is present. During January (0.64 mm) the material is coarsest. Coarser size class during October and November along with high sorted (Fig. 3) and negatively skewed nature (Fig. 4) shows that the beach undergoes erosion during these months which is also evident from a reduced storage volume of 1295 m^3 m^{-1} during November. Low values of the medium grain size during south west monsoon along with small volume changes are caused by the calm conditions provided by the dampening of waves under the influence of the Calicut mud bank.

Payyambalam beach at Cannanore in the vicinity of Ezhimala promontory is a straight long beach with seawall at the backshore. Erosion is maximum during July when the storage volume is least (412.5 m^3m^{-1}). Over the period of one year the beach almost regained its initial storage volume of 442 m^3 m^{-1} by March 1990. Average mean size (Fig. 2), of the beach sand was 0.29 mm which belonged to medium grade sand size. Coarsest size sand was observed in June (0.58 mm) coinciding with high energy environment under the influence of south west monsoon. In August and October the sediments showed poorly sorting nature (Fig. 3), while during the rest of the year they were moderately well sorted to moderately sorted. During monsoon months the sediment was negatively skewed (Fig. 4) while during the rest of the period it was symmetrically skewed indicating an erosion during June.

Nattika beach is an open straight beach backed by seawall well inside the backshore. Beach had maximum material in the beginning of March 1990 (548 m^3 m^{-1}) with a rapid erosion during the onset of the south west monsoon. Beach lost about 34 m^3 m^{-1} of the material within two months of south west monsoon (June and July). It took about six months for the beach to recover its lost material reaching 544.7 m^3 m^{-1} by January 1991. Also the beach continued to accrede to a storage volume of 557.0 m^3 m^{-1} in February 1991. This beach did not show any erosion during north east monsoon.

Average beach grain size (Fig. 2) showed fine sand class (0.15 mm to 0.26 mm) except during September (medium sand class, 0.48 mm) and during October when coarser sands (0.52 mm). Sorting values (Fig. 3), are well sorted class during monsoon and moderately sorted during other seasons. Negatively skewed sediment in October (post-monsoon period) (Fig. 4) and symmetrically skewed nature during the other seasons indicated the erosional and accretional characteristics of the beach.

Andhakaranazhi beach is a barrier type beach. Before the onset of south west monsoon, the beach had a storage volume of 587 m^3m^{-1} (April) which rapidly decreased to 35 m^3 m^{-1} during June under the action of high monsoonal waves. The accretion is also rapid and the beach regained its material by the end of October 1991 (582 m^3m^{-1}). During November-December (north-east monsoon) the loss of beach material is 7 m^3m^{-1}. Beach regained this material by the end of February.

Average grain size (Fig. 2), showed medium grade sand size class. During monsoon period, fine (0.16 mm - 0.22 mm) to medium sand classes (0.30 mm) were observed and maximum medium grade sand class (0.44 mm) is present in October indicated the eroding phase of the beach during October to November. Sediments are well sorted (Fig. 3) in July and September indicating beach accretion. It is negatively skewed in October and symmetrically skewed during the other seasons (Fig. 4) showing there is not much change in storage volume. The symmetrically skewed nature of the sediment during most of the time shows almost stable characteristics of the beach.

The Alleppey beach is a wide and long beach protected by the mud bank during the south west monsoon period. Storage volume showed that the beach continuously accreted from March (895 m^3m^{-1}) to August (942 m^3m^{-1}). During north-east monsoon (October) the beach volume reduced by 15 m^3m^{-1}.

The mean grain size (0.27 mm – 0.46 mm Fig. 2), did not show much significant changes till October, indicated stable nature of the beach during the south-west monsoon. During the north east monsoon season, grain size values decrease from 0.46 mm (October) to 0.41 mm (November). In December, sediment is coarser (0.62 mm). During June, sediments belonged to fine sand class (0.22 mm) indicates the depositional phase of the beach. It is moderately well sorted (Fig. 3) during the south west monsoon season, poorly sorted and negatively skewed in December and symmetrically skewed in the other seasons (Fig. 4). The poorly sorted distribution along with negative skewness during the north-east monsoon indicated an erosional trend. However the symmetrical skewness during the rest of the period indicated accretional nature of the beach. The results corroborated the earlier studies done in this beach by Hameed[17].

The Quilon beach, south of Thankasseri headland, is a narrow beach. During the south-west monsoon, the beach eroded 54 m^3 m^{-1} of the beach material from it's initial storage volume of 425 m^3 m^{-1} in April 1990. Average grain size, (Fig. 2) showed the presence of coarse sand (>5 mm). From March to June, the sand size showed medium sand size class (0.30 mm – 0.38 mm) except in May (0.53 mm). Coarser grain size were on peak during the south-west monsoon (July, 0.95 mm) and north-east monsoon (October, 0.96 mm) seasons. Medium sand was present in the other seasons. During July to August, sediment is poorly sorted (Fig. 3). Sediment samples are negatively skewed (Fig. 4) except during April and June.

The E.O.F analysis of the mean grain size data showed that the first function accounted for 92.1% of the mean square value while the second and third functions accounted for 3.9% and 1.6% respectively.

The first spatial eigen function (U1) of the mean grain size (Fig. 5) showed that, of all the beaches under study, the beaches at Kasargod and Quilon have had the highest mean grain size whereas the beaches at Nattika and Trivandrum have the least grain size values. In general, the sediments were medium sand class except at Kasargod and Quilon of coarse sized.

Corresponding temporal eigen function (VI) indicated the overall behaviour of the beaches examined in terms of its grain size. Cyclic behaviour of the beaches in terms of sediment size (Fig. 5), indicated that the beaches almost restored back it's average grain size over a period of one year.

Second spatial eigen function (U2) of the mean grain size reflected the deviation in the grain size at a given station from the mean. It also followed a similar trend as that of the first eigen function

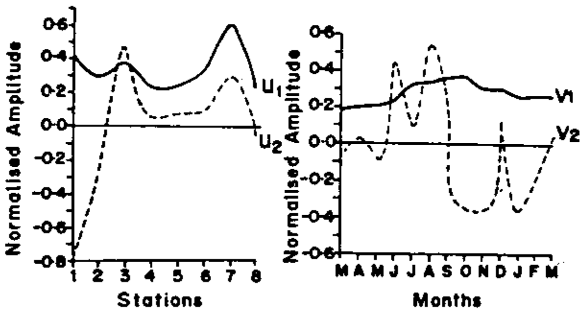

Fig. 5—Spatial and temporal distribution of eigen functions

indicating that the maximum variability of the mean grain size was seen at Kasargod and Quilon while at Nattika, Andhakaranazhi, Alleppey and Trivandrum it showed least variability.

Second temporal function (V2) presents the seasonal pattern of the mean grain size changes of the beach from March to May, followed by a gradual decrease upto May. The sudden increase in size as depicted by the peak during June implicated the high energy environment, associated with the south west monsoonal wave climate. Higher grain size during December indicated the comparatively high wave energy during north east monsoon. Grain size decreases during January and increases during February-March, showes the accretional phase of the beaches. Grain size is maximum during August. From August till November the mean grain size continuously decreased indicating the depositional phase of the beach. The response of the beach sediments to the south west monsoonal forces could be clearly seen by way of sudden increase in the mean grain size.

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