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Some Aspects of Wave Dynamics on Coastal Erosion— A Case Study of the Coastal Belt of Sagar Island, Bay of Bengal

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ABSTRACT: The response to wave dynamics on coastal erosion and deposition in the southern sea front of Sagar Island of Sundarban delta, Bay of Bengal, during post- and pre-monsoon periods of 2003 and 2004 was critically studied. Two transects across the beach were selected at the western and eastern parts of the Island. Basic data like measurement of wave height with corresponding wave period, trends of wave crest and swash mark, inter-tidal width of the beach, tidal range and still water depth were collected along two transects during 10 lunar days of which five alternate days in each transect. From these basic data, different wave parameters like wave length, wave steepness, beach face angle, wave form velocity, long shore current, surf scaling factor, wave energy and rate of sediment transport were also derived using some working formulae.

The major findings are as follows:

1. The coastal belt belonging to Sagar Island is a macro-tidal coast. The tidal height varies from 3.008 (post-monsoon) to 3.427 m (pre-monsoon) in the western part and 3.586 (post-monsoon) to 3.814 m (pre-monsoon) in the eastern part of the beach. The inter-tidal width at its western part varies from 264.8 to 319.28 m and 104 to 133.6 m at its eastern part during post- and pre-monsoon periods respectively. Beach slope is <5°. Average wave height varies from 0.464 to 0.520 m at the western part and 0.520 to 0.741 m at the eastern part with corresponding wave periods of 8.393 to 8.41/s and 9.825 to 9.012/s respectively. At the western part, the significant wave height varies from 0.665 (post-monsoon) to 0.768 m (pre-monsoon) while at the eastern part, it varies from 0.953 (post-monsoon) to 1.019 m (pre-monsoon), the average wave length varies from 13.377 to 21.459 m at its western part and 22.06 to 25.975 m at its eastern part for post- and pre-monsoon periods respectively, the average wave steepness varies from 0.036 to 0.024 at western part and 0.037 to 0.03 at eastern part during post- and pre-monsoon periods respectively, the velocity of long shore current varies from 0.174 to 0.229 m/s at western part and 0.705 to 0.295 m/s at eastern part during post- and pre-monsoon periods respectively, wave energy varies from 286.471 to 226.293 Jm^{-2} at western and 687.377 to 313.629 Jm^{-2} at eastern parts during post- and pre-monsoon periods respectively.
2. The eastern part of the island is very vulnerable to erosion. Shoreline transgresses further inland causing devastating land erosion and a great danger to the inhabitants.
3. The beach comprises a mixture of very fine sand and silts with a bimodal grain size distribution having the prominent mode at 2.5 phi with secondary mode at 4.0 phi. The secondary mode becomes more prominent gradually from east to west of the beach indicating evidence of strong long shore current from east to west.
4. Frequent embankment failure, submergence and flooding, beach erosion and siltation at jetties and navigational channels, cyclones and storm surges are all making this area increasingly vulnerable.

Keywords: Bay of Bengal, Coastal Erosion, Sagar Island, Sundarban Delta, Wave Dynamics.

INTRODUCTION

The coastline of West Bengal along the Bay of Bengal is about 350 km long and is dominated by the Ganga delta, which covers around 60% of this coastline. A large portion of the Ganga delta has been abandoned and is now occupied by a dense swamp area designated as Sundarban delta after the tectonically induced river capture of Hooghly resulted from basement faulting in combination with erratic major floods in the region (Elliot, 1978). Several distributaries are beheaded losing link channels to the Ganga and straightened their lower courses in search of a shorter route to the sea. Now, the wide funnel shaped mouths are being attacked by sea waves and destructive tidal currents, which have produced erosive transgression over the sub-aerial part of the sub-delta. However, the Hooghly through the distributary Bhagirathi River is linked with Ganga waters. Sagar Island, a part of Sundarban delta, located at the mouth of the Hooghly estuary, Bay of Bengal, shows a continuous erosion trend for at least over two centuries (Figure 1). The composite deltaic plain of Sundarban originating by braiding of distributary channels of the Ganga-Brahmaputra river system covers parts of India and Bangladesh. The Indian part of Ganga-Brahmaputra composite deltaic coast shows a continuous trend of shoreline retreat at least over the last two centuries (Bandopadhyay *et al.*, 1996). Chakraborty, P. carried out detailed geological and geomorphological mapping of sea front parts of Sagar Island of Hooghly estuary and initiated the study of coastal processes during 1985–86. This was followed up by the monitoring of the coastal processes in 1986–87 by Chakroborty, P. and later on by Chakraborty, S.C., till 1989–90. The work of 1988–89 indicated coastal dune belt retreat to the order of 15.50 m since November, 1985. Further, the eastern part of Sagar beach was lowered by 2.05 m from 1985–86 to September, 1989 and the western part was raised by 1.885 m from December 1985 to September, 1989. From a comparative analysis of the results of pre-monsoon period of 1992 and with that of pre-monsoon period of 1986, Pal (1991–92) indicated accretion in the western and central part of Sagar Island.

The present study is restricted to Sagar Island of India. The effect of shoreline retreat has a vulnerable impact on the coastal structures and its inhabitants. Frequent embankment failures, submergence and flooding, beach erosion and siltation at jetties and navigational channels, cyclone and storm surges are all making this area increasingly disastrous.

The coastal plain is essentially a flat terrain. The marine coastal landforms show dune ridges along with intervening flats bordered by gently sloping beach on one side and a flat beach on the other side (Figure 2).

The area is in the subtropical humid region. There are mainly three seasons viz., i) winter (October to February), the minimum temperature becomes ~9°C, ii) summer (March to June), the maximum temperature becomes as high as ~ 47°C and iii) Monsoon (July to September), the average rainfall ranges from 1013 to 2066 mm. The relative humidity is 60 to 90%.

The area under study is devoid of any natural forest. In the beachfront dune complexes, the natural growth of creepers 'Ipomoea pescaprae', locally called 'Halkalmi' made these dune more stabilized. Casurina plantation has been made to stabilize the dunes. Mangroves, Dhanigrass (local name), Garan and Casurina trees have been planted in the back swamp area.

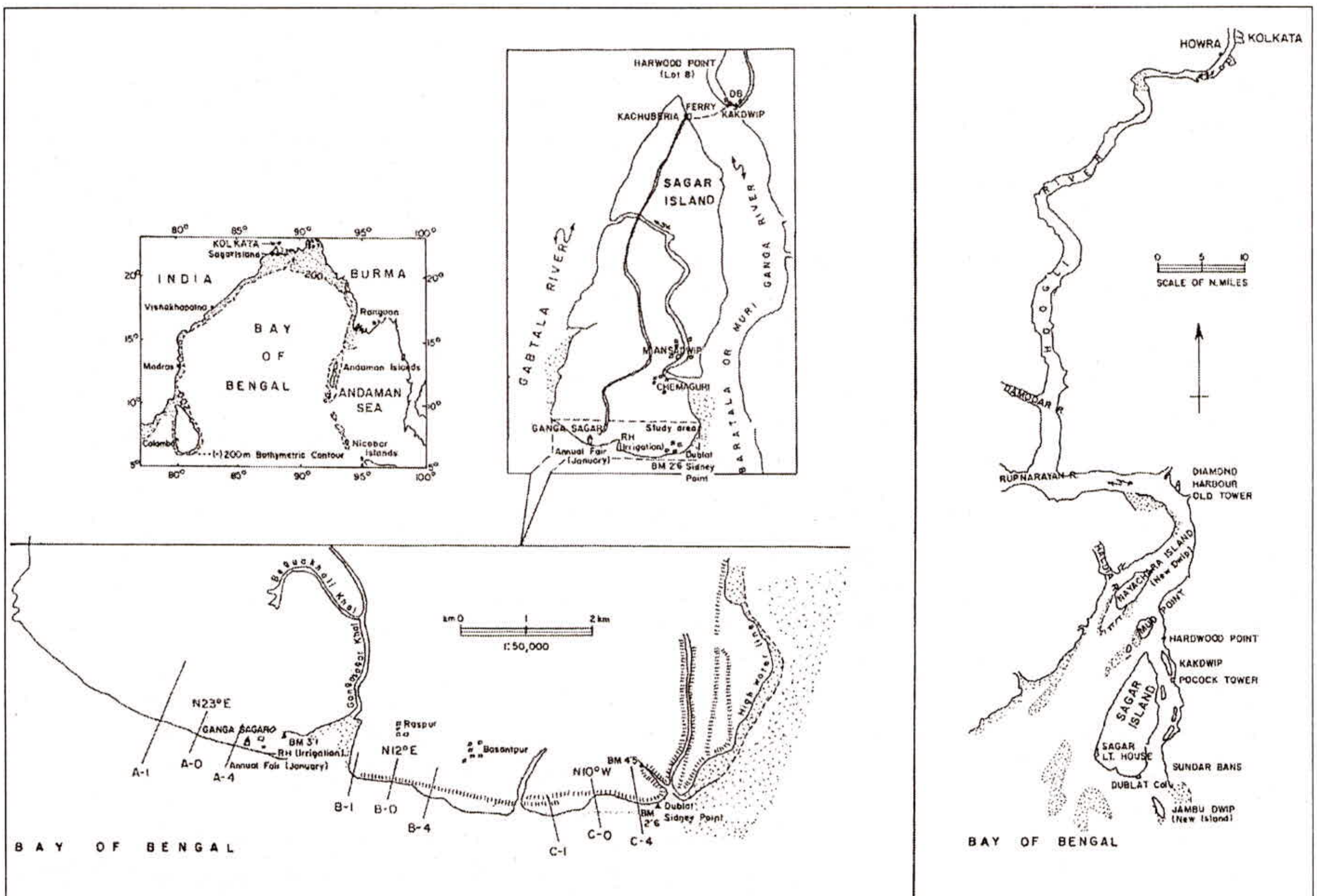


Fig. 1: Location Map

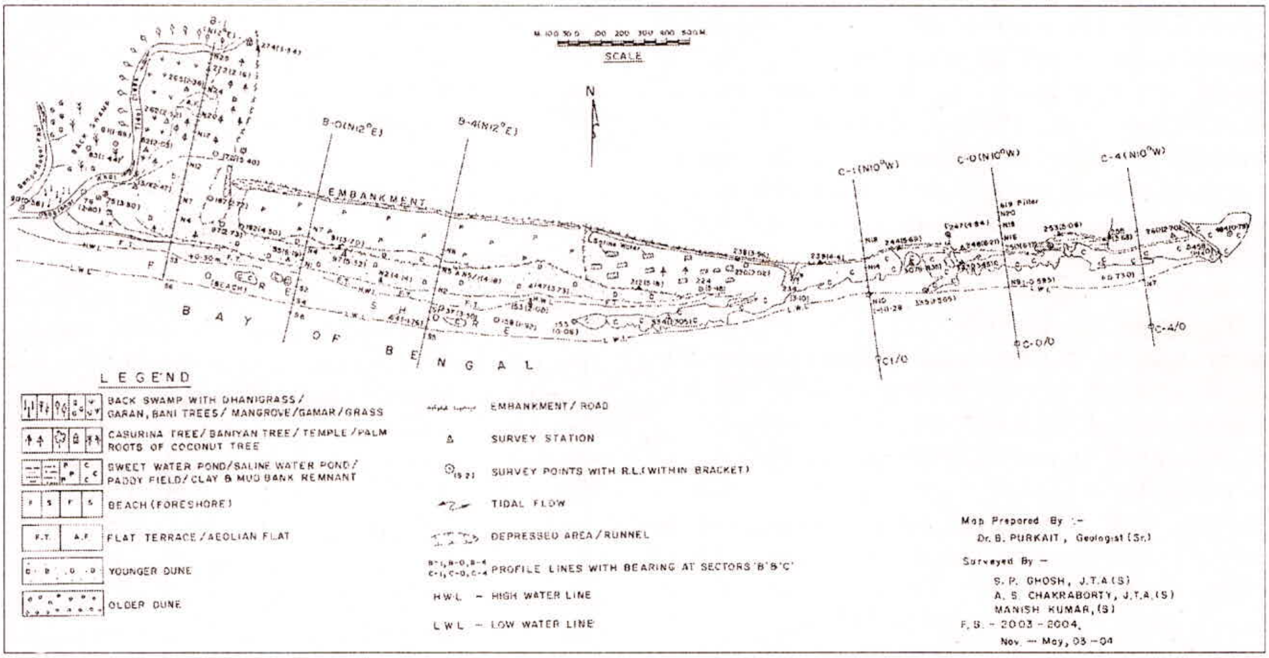


Fig. 2: Geomorphological map of the coastal area of Sagar Island at Central part (Topoban area, sector-B) and eastern part (Dublat area, sector-C), Bay of Bengal, District-24 Parganas (South), West Bengal

The western deltaic distributaries of the Ganges River system are present in the area. These distributaries are Hooghly (Gabtala) river and Muriganga river flowing through the west and east of Sagar Island. In recent years the Sagar Island is shrinking due to the active erosion of the two said rivers.

OBJECTIVES

The objective of this study was to carry out (i) the geomorphological and geological mapping of the coastal belt of Sagar Island, (ii) repeat beach profiling during post- and pre-monsoon periods with a view to bring out the accretion and the denudation sites, (iii) measurement of post- and pre-monsoon wave parameters during 10 lunar days along two fixed profile lines, (iv) observe day to day change of beach profiles during successive lunar days, and (v) sedimentological study of the coastal belt sediments from different geomorphic units, and thus to provide a comprehensive picture of the coastal erosion and deposition in relation to coastal dynamics.

REGIONAL GEOLOGICAL SET-UP

The coastal plain of West Bengal reveals a long history of sedimentation, tectonic settings and marine transgression over the Bengal Basin. Chakraborty and Niyogi (1972) studied the sub-surface stratigraphy around Digha – Contai coast. They established that at depths, from 0 to 140 m m.s.l around Digha coast, sediment sequences from the top represent a marine transgression in recent times i.e., during the post Pleistocene high stand of sea, and these are underlain by sub-aerial —fluviatile deposits and littoral sands dating from the late Pleistocene onwards, and the bottom sediments below fluvial deposits were found in the preceding high stand during the Pleistocene times under lagoonal facies.

In the southern estuarine part of the Ganga delta, the studied area lies between Hooghly River to the west and Saptamukhi River to the east. This coastal tract is a cluster of Islands set in a network with tidal creeks separating the Islands from one another.

METHODOLOGY AND DATA COLLECTION

Plane table mapping on 1 cm = 50 m scale was carried out covering an area of 2.5 sq km of the coastal belt of Sagar Island (Figure 2). Sagar is a high energy, macro-tidal coast. The tidal height varies from 3.008 m (post-monsoon) to 3.814 m (pre-monsoon).

The response to coastal dynamics on the erosion and depositional sites in the Hooghly estuarine, southern sea front of Sagar Island, 24 Parganas (S) district, West Bengal, during post and pre-monsoon periods of 2003 and 2004 was critically studied. Two transects, A-0 and C-0, across the beach were selected at the western and eastern parts of the coast respectively.

Wave-breakers zone was identified adjacent to these transects. Basic data like wave crest heights with corresponding wave period, trend of wave crests, bearing of swash marks, beach face angle, tidal range and inter-tidal widths were measured during 10 lunar days [New moon (NM), NM+1, NM+2, NM+3, NM+8, NM+9, NM+10, NM+11, FM–1, FM (Full moon)], five measurements alternately in each transect during post and pre-monsoon periods. Beach profiles were measured taking R.L. at an interval of 30 m and where there is a break of slope, R.L. was taken at closer interval. Three measuring gauges in each sector were fixed pushing deep into the beach sediments up to their '0'm mark at a considerable interval of ~10 m. in between two gauges before the high tide starts, to measure these basic data.

In each case, measurement of wave crest heights with corresponding periods, bearings of wave crest and swash mark, were started 40 minutes before and continued till 40 minutes after the highest tide time. Wave heights were directly measured with the help of binocular and measuring gauges. Four sets of data from the three measuring gauges were recorded for a period of 10 minutes for wave crest height and in successive10 minutes for wave period in each set of data along with corresponding wave crest trend. Twice the wave crest heights are the wave height. Average wave heights, significant wave heights (average of maximum 1/3 of the wave heights) were calculated. From the significant wave height, wind speed was estimated following Beaufort scale.

The different wave parameters were estimated using some working formulae (Biarman, 1989; Cojan & Renard, 2002 and Paul, 2003).

ANALYTICAL RESULTS

Results of computation of the wave dynamic parameters for post and pre-monsoon periods are shown in Tables 1 A&B. The western part of the beach at sector 'A' (around Kopil Muni's Temple) is more or less stable. South of Dublat at sector 'C' in the southeastern edge of Sagar Island exhibits extensive erosion.

Table 1(A): Post-monsoon Data of Wave Parameter Measurements at Sagar Coastal Belt

		Lunar		*Days*				*Lunar*		*Days*			
Sl. No.	*Parameters*	*New Moon (NM)*	*NM+2*	*NM +8*	*NM+10*	*FM-1*	*Average*	*NM+1*	*NM+3*	*NM+9*	*NM+11*	*Full moon (FM)*	*Average*
1	Date	20.2.04	22.2.04	28.2.04	2.3.04	6.3.04		21.2.04	23.2.04	29.2.04	3.3.04	7.3.04	
2	Inter-tidal width (m)	362	328	194	138	302	264.8	132	142	51	64	131	104
3	R.L difference between HWL &LWL	3.765	4.185	2.19	1.135	3.765	3.008	4.585	4.58	1.93	2.475	4.36	3.586
4	Beach face angle (β) (degree)	0.596	0.731	0.647	0.471	0.714	0.632	1.991	1.848	2.169	2.216	1.907	2.026
5	Swash line bearing (degree)	295–115	105–285	106–286	108–288	108–288		91–271	86–266	95–275	92–272	89–269	
6	Distance of gauges on profile line from fixed point (m)	95,115,152	278,285, 293	341,349, 358	365,371, 379	304,312, 320		372,364, 354	74,29.6, 87.6	334,327, 319	342,335, 329	359,355, 348.8	
7	Mean water depth (m)	0.143	0.25	0.354	0.25	0.417	0.283	0.496	0.55	0.571	0.417	0.546	0.516
8	Mean wave height (H) in m	0.392	0.578	0.629	0.422	0.298	0.464	0.882	0.762	0.842	0.706	0.436	0.726
9	Significant wave height ($H_{1/3}$) in m	0.731	0.787	0.831	0.533	0.443	0.665	1.154	0..978	1.017	1.002	0.615	0.953
10	Mean wave period (sec)	9.817	9.694	5.04	10.218	6.432	8.393	13.792	12.856	0.274	6.432	9.771	9.825
11	Mean wave approach angle (α) in degree	9.25	3.75	1.25	1	12.75	5.6	8.25	5.75	13.25	8	3.75	7.8
12	Velocity of longshore current (m/s)	0.318	0.158	0.028	0.029	0.339	0.174	1.331	0.063	1.039	0.673	0.417	0.704
13	Wave form velocity (C) in m/sec	2.29	2.849	3.106	2.567	2.648	2.692	3.676	3.588	3.723	3.318	3.103	3.482
14	Wave length (L) in m	11.852	15.211	10.818	16.003	13.003	13.377	29.978	29.862	14.846	13.004	22.61	22.06
15	Wave Steepness (H/L)	0.033	0.038	0.058	0.026	0.023	0.036	0.03	0.026	0.057	0.054	0.037	0.037
16	Max. &Min. wave height (m)	0.90, 0.1	1.00, 0.1	0.90, 0.4	0.70, 0.3	0.70, 0.1	0.84, 0.2	1.8, 0.3	1.0, 0.5	1.30, 0.5	1.30, 0.3	0.80, 0.1	1.3, 0.34
17	Surf scaling factor (ϵ)	236.471	0.01	544.954	389.08	0.058	234.115	0.01	36.48	59.999	46.879	25.731	33.82
18	Breakers type	Collapsing	Surging	Collapsing	Collapsing	Surging		Surging	Collapsing	Collapsing	Collapsing	Collapsing	
19	Rate of sediment transport (m/s)	0.058	0.063	0.027	0.008	0.053	0.042	0.418	0.213	0.617	0.235	0.039	0.304
20	Wave energy (E) in Jm^{-2}	191.31	415.55	492.98	221.83	110.687	286.471	969.455	724.386	885.149	621.347	236.55	687.377
21	Transect	A-0						Transect - C-0					

Table 1(B): Pre-monsoon Data of Wave Parameter Measurements at Sagar Coastal Belt

		Lunar days						*Lunar days*					
Sl. No.	*Parameters*	*New Moon (NM)*	*NM+2*	*NM +8*	*NM+10*	*FM-1*	*Average*	*NM+1*	*NM+3*	*NM+9*	*NM+11*	*Full Moon (FM)*	*Average*
1.	Date	20.4.04	22.4.04	28.4.04	30.4.04	4.5.04		21.4.04	23.4.04	29.4.04	1.5.04	5.5.04	
2.	Inter-tidal width (m)	409	360	199	240.4	388	319.28	150	158	52	128	180	133.6
3.	R.L difference between HWL &LWL	4.495	4.065	1.805	2.285	4.485	3.427	4.36	4.385	1.525	3.205	5.595	3.814
4.	Beach face angle (β) (degree)	0.63	0.647	0.358	0.545	0.662	0.568	1.666	1.59	1.681	0.025	1.781	1.349
5.	Swash line bearing (degree)	104–284	109.5–289.5	100–280	95–275	105–285		93.5–273.5	99–279	95–275	86–266	92–272	
6.	Distance of gauges on profile line from fixed point (m)	226,233, 242	257,259.60 282.6	335,344, 357	331.4,340.8, 348.8	263,269, 277		363,358, 351	351,341, 336	302,297, 290	327,321, 314	358,350, 342	
7.	Mean water depth (m)	0.575	0.675	0.475	0.688	0.988	0.68	0.808	0.558	0.983	0.708	1.142	0.84
8.	Mean wave height (H) in m	0.436	0.531	0.479	0.547	0.606	0.52	0.556	0.621	0.851	0.787	0.891	0.741
9.	Significant wave height ($H_{1/3}$) in m	0.664	0.737	0.611	0.731	1.095	0.768	0.777	0.856	1.108	1.146	1.208	1.019
10.	Mean wave period (sec)	9.385	8.585	8.375	7.866	7.841	8.41	9.667	8.403	10.143	6.888	9.959	9.012
11.	Mean wave approach angle (α) in degree	7.5	1.5	7.25	2.25	3.75	4.45	3.75	5.25	4.5	1.5	2.25	3.45
12.	Velocity of longshore current (m/s)	0.793	0.05	0.129	0.058	0.116	0.229	0.36	0.417	0.457	0.002	0.238	0.295
13.	Wave form velocity (C) in m/sec	3.149	3.44	3.059	3.48	3.954	3.416	3.658	3.401	4.241	3.83	4.466	3.919
14.	Wave length (L) in m	22.29	22.092	18.079	20.428	24.405	21.459	27.222	19.666	31.503	18.157	33.329	25.975
15.	Wave Steepness (H/L)	0.02	0.024	0.026	0.027	0.025	0.024	0.02	0.032	0.027	0.043	0.027	0.03
16.	Max. &Min. wave height (m)	1.00,0.10	1.10,0.10	0.90, 0.2	1.10,0.20	1.20, 0.1		1.00, 0.1	1.20, 0.1	1.60, 0.2	1.40, 0.2	1.60, 0.2	
17.	Surf scaling factor (ϵ)	246.384	312.314	96.435	494.908	370.608	304.13	43.545	61.463	62.476	385346.36	59.116	77114.6
18.	Breakers type	Collapsing	Collapsing	Collapsing	Collapsing	Collapsing		Collapsing	Collapsing	Collapsing	Collapsing	Collapsing	
19.	Rate of sediment transport (m/s)	0.08	0.026	0.09	0.01	0.009	0.043	0.075	0.122	0.056	0.014	0.033	0.06
20.	Wave energy (E) in Jr^{-2}	237.782	353.482	286.941	374.23	459.49	342.385	386.938	482.524	906.154	775.96.	994.996	709.314
21.	Transect A-0							Transect C-0					

DISCUSSION

(A) Beach Mapping

Broadly three geomorphic units have been delineated (Figure 2): (i) Beach proper (foreshore), (ii) Backshore shore with coastal aeolian dunes, and (iii) Back swamp.

The western part of the beach of the studied area (at sector-A) is dominantly of fine sands with patchy occurrence of small scale ripple marks whereas the eastern part of the beach (at sector - C) is dominated by the occurrence of remnants of mud bank with roots of coconut trees and mud balls. The beach in this area is relatively narrow and steeper than the western part. Ridges, flat terraces and runnels are developed almost parallel to the beach at sector-A, indicating presence of longshore currents. The beach is gradually becoming narrower from sectors 'A' to 'C' with increasing coastal erosion.

The coastal dunes border the beach. The dunes are of fore-dune type and low in heights (~1 m). The isolated occurrences of such dunes, at places, probably indicate wide fluctuation of wind speed. Significant wave heights were selected from these measurement data from each of the two transects to predict the corresponding wind speed. The wind speed as estimated is light (1.6–3.3 m/s) to moderate (5.5–7.9 m/s) as per Beaufort scale. Some older dunes occur further inland. These are longitudinal type with relatively more in height (~ 3 m) and length (~10 m). All these dunes are composed of fine sands. Casurina plantation has been made to stabilize the dunes. However, recently developed coastal fore-dunes are getting stabilized by the natural growth of a variety of creeping tress 'Ipomoea pescaprae', locally called 'Halkalmi'.

The back swamp area is muddy in nature, partly washed out occasionally by seawater. Tidal creeks are developed within this back swamp area. Mangroves, Dhanigrass (local name), Garan and Casurina trees have been planted.

(B) Beach Profiles

Both post- and pre-monsoon beach profiles (Figures 3 & 4) were surveyed with respect to some fixed points in two sectors (A & C). Each sector has been divided into 3 transects e.g., 'A' has been divided into A-1, A-0 and A-4 transects from west to east. Similarly 'C' into C-1, C-0, and C-4, with an inter-transect gap of about 600 m.

A comparison was made between pre- and post monsoon beach profiles to delineate the area of accretion and denudation. From this comparative study, the following observations were noted:

1. At A-1, addition of sediments was noted in the upper foreshore region during pre-monsoon period. There is no appreciable change in the dune area. However, in the coastal 1st row of dunes bordering the coast, erosion was noted during pre-monsoon period followed by addition of sediment in the 2nd row of dunes further inland (Figure 3).
2. At transect A-0, the central part of the beach (between high water level and low water level) is eroded away during pre-monsoon period. The eroded materials are transported landward to coastal dunes causing deposition but further inland, erosion took place during pre-monsoon period (Figure 3).
3. At A-4, erosion in the lower part of the beach is followed by the deposition in the upper part of the beach during pre-monsoon period. This is followed by deposition in the dune area (Figure 3).
4. At C-1, erosion at the lower part of the beach is followed by the deposition of sediments in the upper part of the beach during pre-monsoon period (Figure 4).
5. At C-0, erosion in the central part of the beach is followed by the addition of sediments in the upper part of the beach during pre-monsoon period Figure 4).
6. At C-4, erosion all along the beach is very conspicuous during the pre-monsoon period (Figure 4).

From the comparative study of the beach profiles, the day- to-day change of beach profiles on macro scale was observed (Figures 5A&B). It is noted that the erosion takes place in the central part of the beach indicating that this part acts as a pumping station from where sediments are sometimes transported further inland forming coastal aeolian dunes and sometimes transported further offshore area forming offshore sand bars or sand ridges.

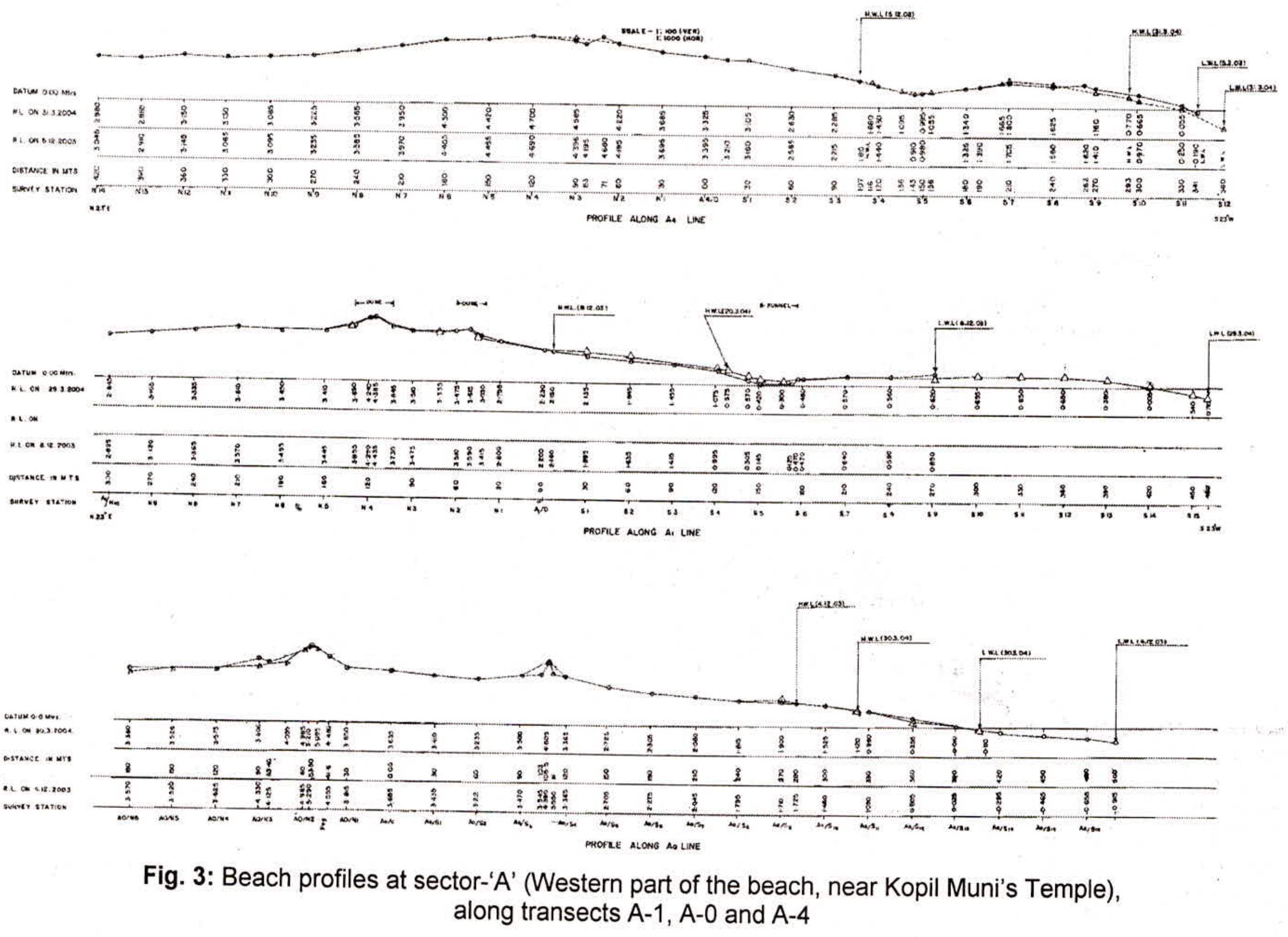


Fig. 3: Beach profiles at sector-'A' (Western part of the beach, near Kopil Muni's Temple), along transects A-1, A-0 and A-4

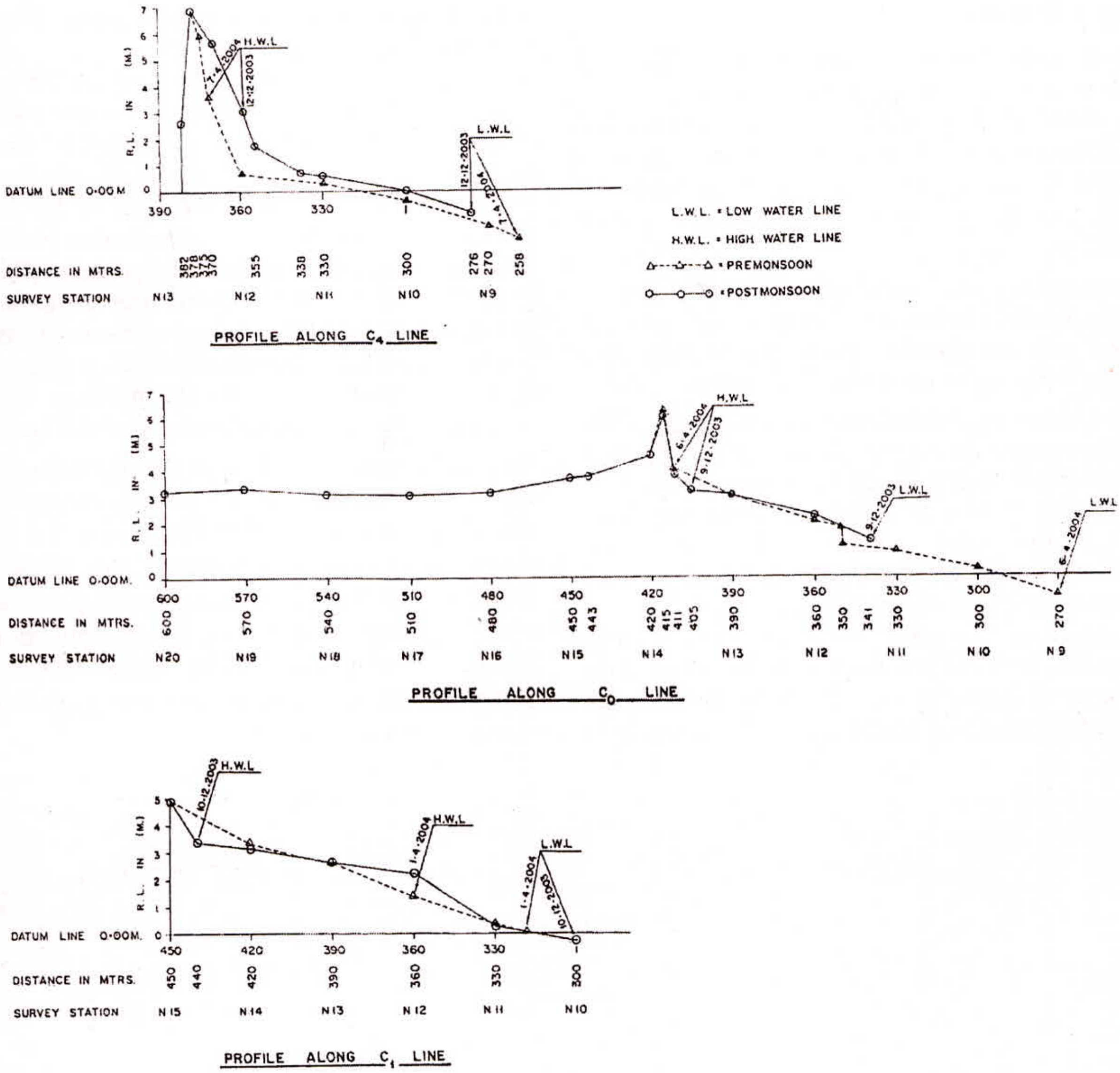
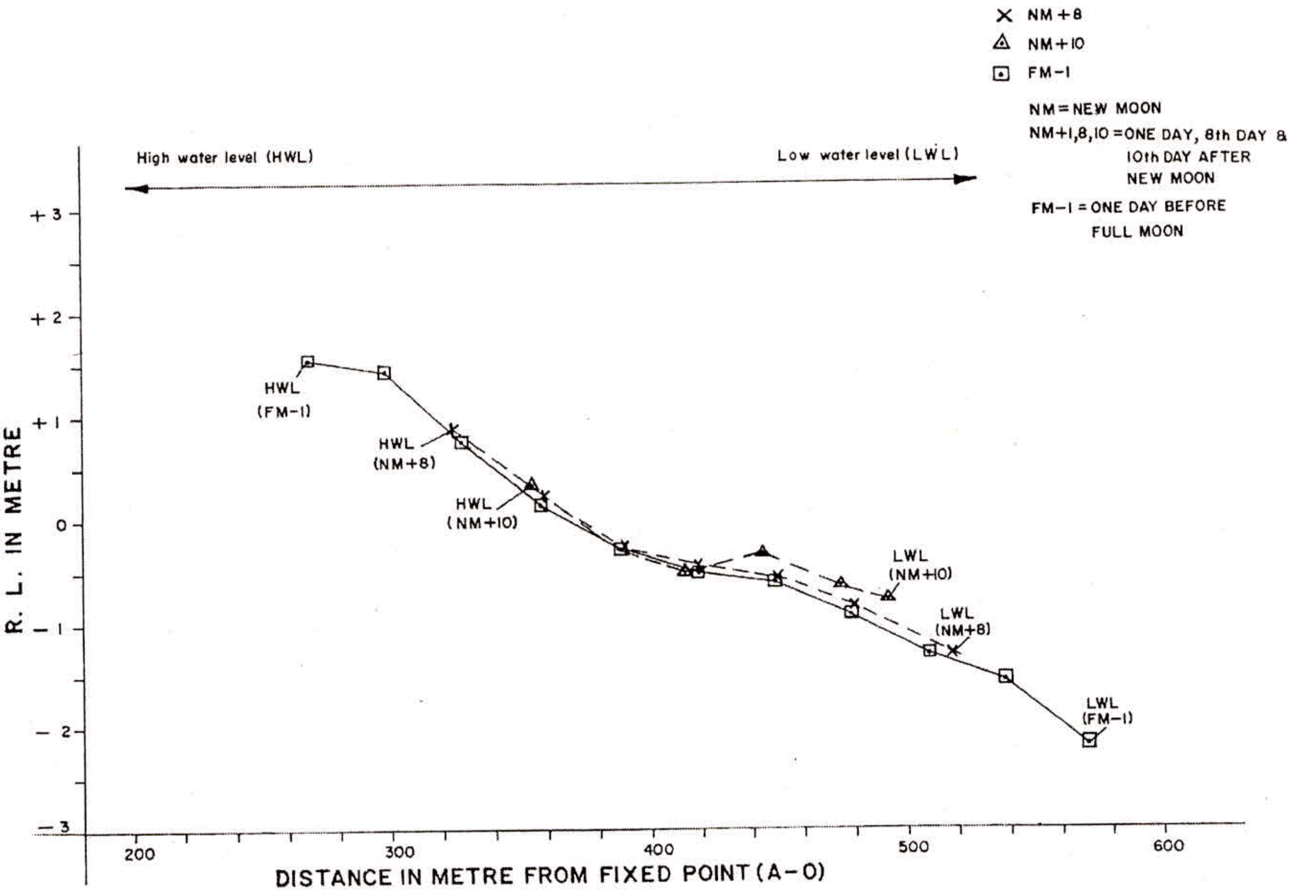


Fig. 4: Beach profiles at sector-'C' (Easternmost part of the beach, Dublat area), along transects C-1, C-0 and C-4.)

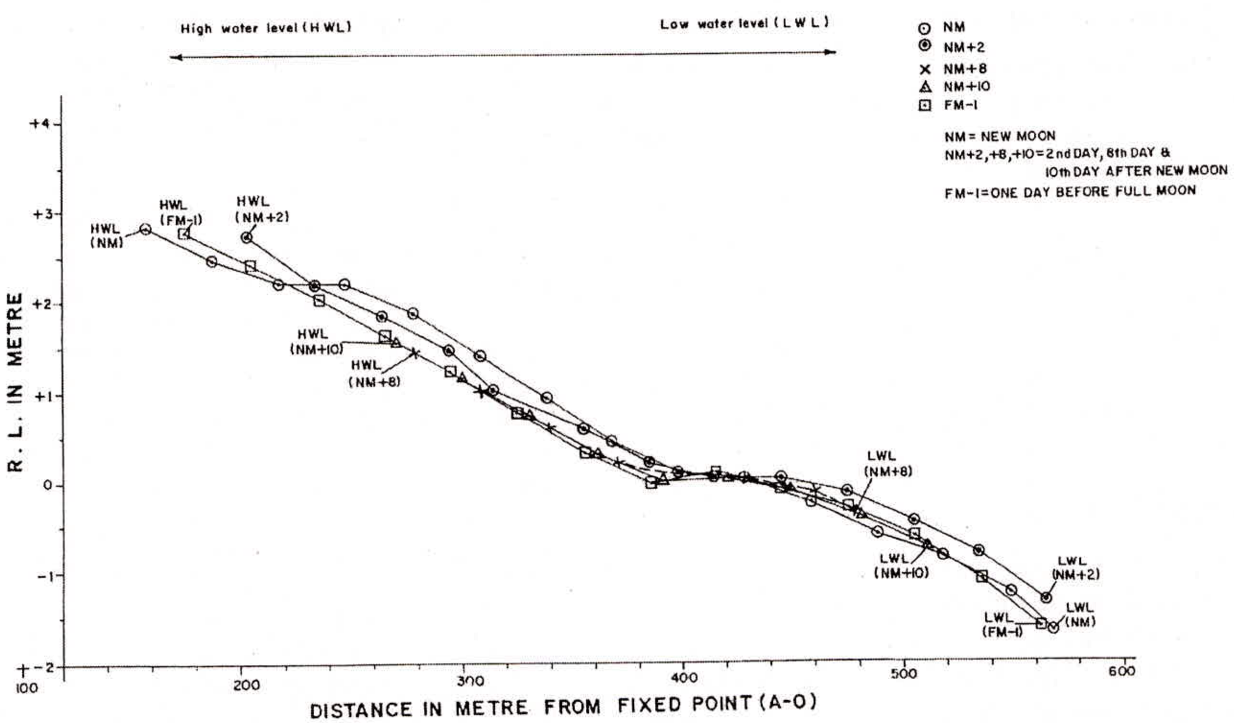
(C) Wave Parameter Measurement and Coastal Dynamics

Different wave parameters were measured in two sectors (Figure 1) along transects A-0 (western part of the beach near Kopil Muni's Temple) and C-0 (eastern part of the beach), during 10 lunar days (NM, NM+1, NM+2, NM+3, NM+8, NM+9, NM+10, NM+11, FM-1 and FM; NM = New Moon, NM+1, 2, …, 11=1st day after new moon, 2nd day after new moon etc., FM = Full moon, FM-1= One day before full moon) of which 5 sets in A-0 transect and 5 sets in C-0 transect.

At transect C-0, the beach is narrow (52 to 158 m inter-tidal width) as compared to transect A-0 (199 to 409 m inter-tidal width). Beach slope at C-0 varies from 1.5903° to 1.6805° whereas at A°, it varies from 0.35846° to 0.647°. Though the beach slope at C-0 transect is steeper than that of A-0 transect, overall the beach is gentle (< 5°). The beach erosion is very conspicuous in the eastern part of the beach i.e., in sector 'C' (along profiles C-1, C-0, C-4) resulting in the transgression of shoreline landward exposing the mud bank remnants with roots of palm and coconut trees of earlier plantation. However, the western part of the beach at sector-A (along profiles A-1, A-0, A-4), the beach is relatively stable. This can be correlated with the different magnitudes of wave dynamic parameters. The average wave steepness at C-0 is 0.0365 whereas at A-0, it is 0.0245. Average wave energy at C-0 as measured is 500.503 Jm^{-2} and at A-0, it is 256.382 Jm^{-2}. Erosion is also noted at sector 'C' resulting exposure of mud bank remnants and scattered occurrences of mud balls.



(a)



(b)

Fig. 5: Day to day change of beach profiles along transect A-0 during lunar days. A. Post-monsoon period, B. Pre-monsoon period

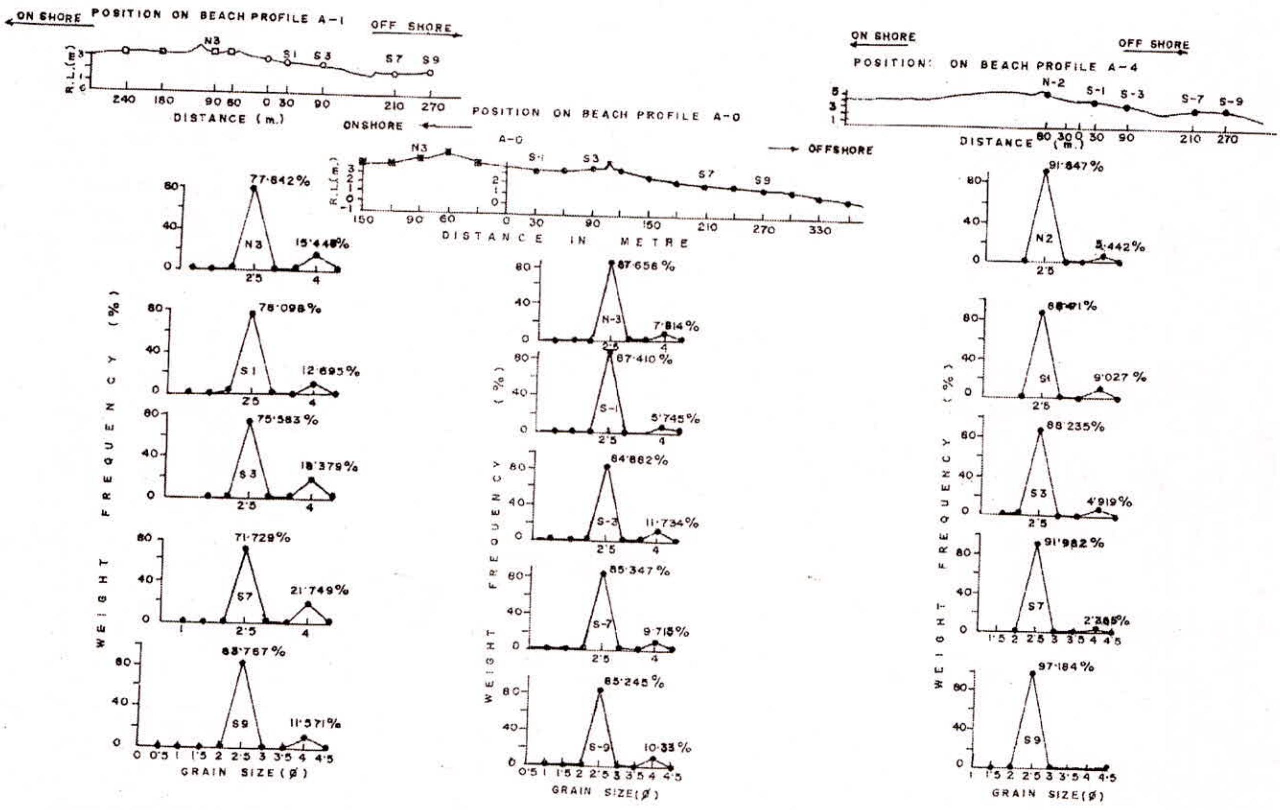


Fig. 6: Grain size distribution patterns at different positions on the beach profiles along transects A-1, A-0, and A-4, showing the development of secondary mode with gradual increase of weight frequency % from east (A-4) to central (A-0) to west (A-1). Increasing of weight frequency of secondary modes indicates the presence of strong long shore current from east to west of the beach at this sector

(D) Sedimentological Study

From the field observation and sedimentological studies at the western part of the beach, it is observed that there is strong longshore current in this area that help develop small creeks/runnels within the beach. Sediments are very fine sands and silts with a bimodal distribution pattern having the prominent mode at 2.5 phi with secondary mode at 4.0 phi. The secondary mode becomes more prominent gradually from east to west of the beach with increasing weight frequency % along sector-A (A-4 to A-0 to A-1) (Figure 6). It also supports the evidence of strong longshore current in this sector from east to west of the beach.

CONCLUSIONS

From the critical review of the wave dynamic phenomena at the coastal belt of the Sagar Island, the following observations are made:

1. Sagar Island, a part of Sundarban delta at the mouth of the Hooghly estuary, Bay of Bengal, is a tectonically controlled, composite deltaic plain originating by braiding of distributaries channels of the Ganga-Bramaputra River system.
2. Sagar is a macro-tidal coast. The tidal height varies from 3.008 (post-monsoon) to 3.427 m (pre-monsoon) in the western part and from 3.586 (post-monsoon) to 3.814 m (pre-monsoon) in the eastern part of the beach. The inter-tidal width at its western part varies from 264.8 to 319.28 m during post- and pre-monsoon periods respectively and 104 to 133.6 m at its eastern part during post and pre-monsoon periods respectively. Beach slope is less than 5°. Average wave height varies from 0.464 to 0.520 m at the western part and 0.520 to 0.741 m at the eastern part of the beach with corresponding wave periods of 8.393 to 8.41/s and 9.825 to 9.012/s at its western and eastern parts respectively. At the western part, the significant wave height varies from 0.665 (post-monsoon) to 0.768 m (pre-monsoon) while at the eastern part, it varies from 0.953 (post-monsoon) to 1.019 m (pre-monsoon), the average wave length varies from 13.377 to 21.459 m at its western part and 22.06 to 25.975 m at its eastern part for post and pre-monsoon periods respectively, the average wave steepness varies from 0.036 to 0.024 at western part and 0.037 to 0.03 at eastern part during post and pre-monsoon periods respectively, the velocity of longshore current varies from 0.174 to 0.229 m/s at western part and 0.705 to 0.295 m/s at

eastern part during post and pre-monsoon periods respectively, wave energy varies 286.471 to 226.293 Jm^{-2} at western and 687.377 to 313.629 Jm^{-2} at eastern parts during post and pre-monsoon periods respectively.

3. The study indicates that the eastern part (C-0) of the island (and also the extreme western part i.e., further west of sector A-0) is very vulnerable to erosion. Shoreline transgresses further inland causing devastating land erosion and a great danger to the inhabitants.
4. From the comparative study of the beach profiles, the day- to-day change of beach profiles on macro scale was observed. It is noted that the erosion takes place in the central part of the beach indicating that this part acts as a pumping station from where sediments are sometimes transported further inland forming coastal aeolian dunes and sometimes transported further offshore area forming offshore sand bars or sand ridges. The mechanism of such a sediment transport might provide clues to the formation of coastal aeolian dunes or new offshore bars.
5. Sediments are a mixture of very fine sand and silts with a bimodal distribution pattern having the prominent mode at 2.5 phi with secondary mode at 4.0 phi. The secondary mode becomes more prominent gradually from east to west of the beach with increasing weight frequency % along sector-A. It supports the evidence of strong long shore current in this sector from east to west of the beach.
6. Frequent embankment failure, submergence and flooding, beach erosion and siltation at jetties and navigational channels, cyclones and storm surges are all making this area increasingly vulnerable.

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