International Conference on Estuaries and Coasts
November 9-11, 2003, Hangzhou, China

AN ASSESSMENT OF COASTAL MODIFICAION IN THE LOW – LYING TROPICAL COAST OF NORTHEAST INDIA AND ROLE OF NATURAL AND ARTIFICIAL FORCINGS

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Abstract: The magnitude of erosion in a 30km long west to east extending beach zone from Digha to Dadanpatrabar (Lat. 21º45´N, Long. 87º45´E) in the low-lying, mesotidal tropical coast of bay of Bengal, northeast India has been focused in the paper. The beach is under severe erosional threat for the last few decades both from natural forcings of cyclonic storms, waves, tides and longshore drift and human activities including rampant use of dune fields for construction of hotels, dune destruction for open sea vistas and sand transportation. Certain conservation measures have been recommended including mechanism of dune maintenance by artificial simulation, dune creation and control of coastal water pollution from hotel sewage and fisheries wastewater.

Key words: Coastal dunes, Northeast Indian coast, Coastal erosion, Conservation measures.

1. INTRODUCTION

The west to east extending Digha-Junput tropical sandy beaches of northeastern Indian coast of Bay of Bengal covers a linear stretch of about 45 km and lie between the Hugli-Subarnarekha estuarine systems respectively in the east and west (Fig. 1). The elevation of the coast in the southernmost region is <3m above the sea level (Umitsu, 1987, 1993). The beach material is generally siliciclastic, quartzo-feldspathic in composition with well sorted, medium to fine sand (Friedman and Sanders, 1978). The estuarine mud in many places, mixing with the beach sand creates mixed flats. A major portion of the mud is carried to the offshore that constantly keeps the coastal water turbid. The Digha beach, about 8 km long on the west of this coastal stretch, is dominated by sedimentation from the Subarnarekha river, whereas, the eastern-most 6 km long Junput beach gets its major silt contribution from the Hugli estuary. It is ubiquitous that the modern estuary-related beaches have a range of textural gradients and morphologies controlled by fluvial, tidal and wave regime (Wright and Coleman, 1973; Kuehl et al., 1997). High discharge from the rivers, particularly during the monsoon months in this tropical coast results in deposition near the mouth of the rivers with significant subaqueous growth compared to that of its subaerial counterpart (cf. King, 1961; Wright and Nittrouer, 1995). Depending on the present state of erosion-accretion, the entire Digha-Junput stretch is divisible into two parts having contrasting characteristics: (i) Digha to western portion of the Dadanpatrabar sector chiefly under erosional regime and (ii) eastern portion of Dadanpatrabar to Junput sector belonging chiefly to accretional regime (Chakraborti, 1990).

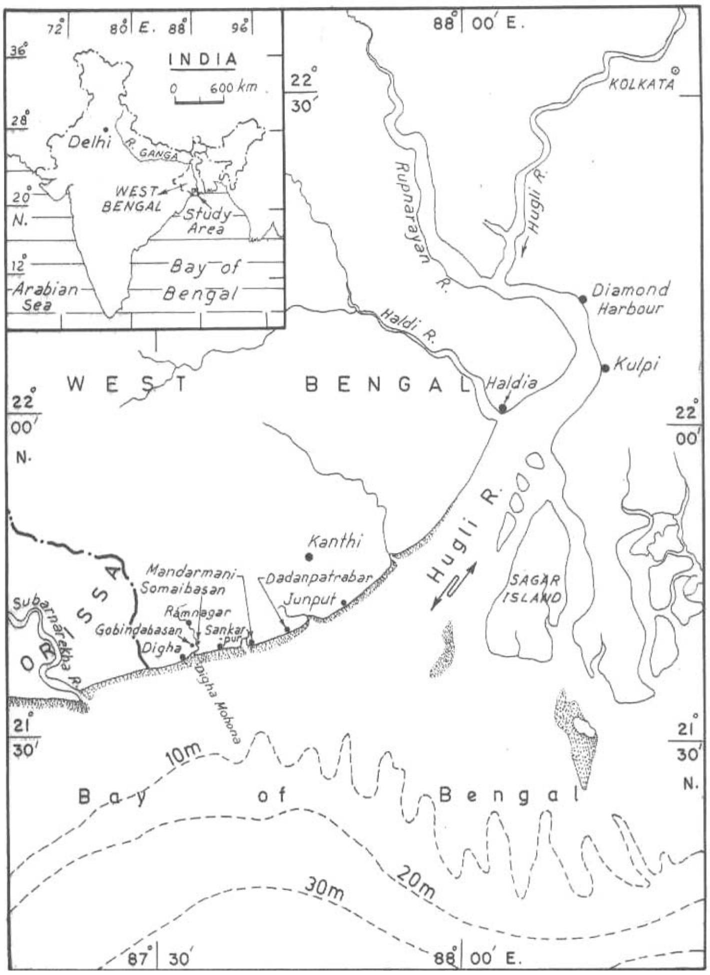

Fig. 1 Map of the study area citing important locations in the beach

The geological history of the coast is relatively short and the coast is still in its formative state. Its present day manifestation is the result of fluvio-tidal and coastal processes resulting from the onlapping sequence of Flandrian transgression, > 5900 yrs B.P. and offlapping sequence of delta progradation till the stabilization of the sea level at around 3000 yrs B.P. (Leader, 1982; Bearman, 1989; Chakrabarti, 1990). C_{14}-dating of the coast showed that this stretch of the beach was just 2920 ± 160 yrs old. The bathymetric chart reveals that the general offshore gradient is 1: 003. However, off Digha Mohona the gradient is gentler 1: 001. This present paper focuses on the magnitude of erosion in the western 30 km stretch of the beach from Digha to west of Dadanpatrabar under the influence of both natural and man-made activities and has suggested some measures for its restoration and protection.

2. BEACH MORPHOLOGY

The beach has a linear almost east-west extension of variable width. The present day backshore is 50-70 m wide with multiple trains of dunes followed seaward by a 400-500 m wide intertidal foreshore and an inshore of 500-700 m before it merges into the deeper offshore zone. Morphodynamically, the beach has a dissipative profile (Short, 1983) with high compaction of sediments and a gently sloping gradient towards the sea (Table 1).

The backshore beach is girdled by a number of dune trains with undulating topography. The southernmost dune train lies along the lower marine terrace. The higher terrace occurs farther north and stands as the basement for the earlier landward dunes. The older dunes reveal crestal flattening and appear as remnants in the backdune area. The mature dune field is fronted in some places by neodune field with mounds and arcuate embryonic dune forms. These dunes together with a part of the mature dunes are covered with halophytic creepers and herbs. The vegetation buffers act as a natural barrier of the coast against storm surges. When the sea recedes, the dunes move forward and change their place.

The foreshore beach is generally flat, slightly concave upward to gently undulating, often with upper and lower beach faces (Table 1). Surface sedimentary structures include backwash ripples, rhomboid marks, crescentic-, wave- and interference ripples of ladder-back types, current crescents, rill marks and swash marks (Komar, 1976). Shell and mica concentration zones are quite frequent. Cut-out trenches reveal alternation of seaward dipping cross-beds and parallel beds reflecting deposition from low tide and high tide respectively. The transition zone, in between and foreshore and backshore, changes its position in time and space depending on the fluctuation of high water spring and neap tides. This zone is charecterised by a spectrum of surficial and internal, sedimentary and biogenic structures (Bhattacharya, 2001).

Table 1 Characteristics of the dissipative beach of the study area

Parameters	Characteristics
Gradient	Low; 1:50 to 1:70 Beach face with minor surface features; uniform along shore
Grainsize	Medium to fine sand (Mz = 2.58-2.94 phi)
Sorting	Well sorted (σ_1 = 0.38-4.72 phi)
Profile	Gentle with minor undulations; often with upper and lower beach faces
Upper beach face structure	Occasionally with beach cusps; eroded faces of cusps with parallel laminations
Lower beach face structure	Typified by backwash features like back-wash ripples (upper flow regime); small-scale current- and wave ripples along with other wave and current generated sedimentary structures (lower flow regime).
Internal sedimentary structures	Seaward dipping cross-beds in alternation with parallel beds reflecting deposits of low and high tide respectively

3. NATURAL FORCINGS: THEIR EFFECTS ON BEACH DEVASTATION

3.1 TIDES, WAVES, RIP CURRENTS AND LONGSHORE CURRENTS

The coastal stretch belongs to a mesotidal (tidal amplitude 2-4 m) regime with semi-diurnal tides with slight diurnal inequality. The impact of macrotidal (tidal amplitude >4m) Hugli estuary is more pronounced towards the eastern part of the study area. The moderate to high tidal amplitude creates tidal currents which act as an effective means for reworking the tidal and estuarine sediments. Wave climate is moderate excepting periods of cyclonic storms when the wave height may reach up to 7m. These waves when attack the base of the dunes cause oversteepening of the seaward dune face. This leads to avalanching of sand from dune tops. The sands so avalanched are heaped up as fan deposits at the base of the dunes and later mixes with foreshore beach materials. Dune erosion leads to landward retreat of the beach, lowering of beach profile and loss of dune vegetation. Many of the planted large casurina trees are uprooted by gradual progress of erosion. Internal structures of the dunes, along with various cross-bedded units, exhibit on exposed face intercalated mud layers (5-15cm thick) for significant distances indicating episodes of inundation of the dunes at times of catastrophic floods.

Rip currents and alongshore currents transport sand at mutually right angle directions. There are seasonal reversals of NE winter to SW summer winds which play a significant role for transporting the dry sand of the subaerial beach causing mobilization and remobilizing of dunes and in spilling sand from the dunes to the intertidal zone (Bhattacharya and Sarkar, 1996).

3.2 CYCLONIC STORMS

The Bay of Bengal coast of northeast India is prone to periodic cyclonic storms which may recur 2 to 3 times in a year. The severity of the storms with spectacular wave heights occur particularly when a tropical cyclone accompanies the autumn equinoxial tide. This combination often brings devastation in this coast with wave heights as high as 7m or more. This wave height topples all coastal physiographic barriers including the seawalls and embankments and floods the inland areas behind the backshore. There were incidents of such severe storms in the recent past during the years 1987, 1997 and 2002 when the seawall was heavily destroyed along with extreme damage of the beach side road. The November 12, 1997 cyclone caused a havoc devastation of the coast bringing about massive damage. There were incidents when hundreds of fishing trawlers were capsized causing deaths of hundreds of fishermen. Dunes and embankments were damaged and breached at places. Dwelling and agricultural lands of many coastal families were totally eaten up by the sea. There were ecological damages when hundreds of sea birds died helplessly. Many of these birds together with other sea animals (dolphins) came floating on the beach at a much later time and caused coastal pollution.

3.3 BIOGENETIC ACTIVITY

Biogenic activities in the soft-bottom sediments in the form of bioturbation structures (Richter, 1952) by the macrozoobenthic groups are quite conspicuous in the beach. They move both surficial and internal sediments up to a depth of 1m by burrowing, crawling, grazing and tunneling in the sediments (Frey, 1975; Cadée, 2001; Bhattacharya, 2002).

4. DAMAGE CAUSED BY MAN-MADE ACTIVITIES

4.1 CONSTRUCTION OF SEA WALL AND EMBANKMENTS

A 4 km long bouldery embankment and concrete seawall had been constructed by the State Government to protect the sea resort of Digha at a total cost of Rs. 50.5 million rupees (1US $ = Rs. 47.00 approx.) during the last one-decade. But this measure did not prove to be yielding any effective benefit against erosion of the coast. Hundreds of coastal families and the hotel owner are suffering from panic of massive coastal erosion within a couple of years as the trend of erosion continues unchecked particularly in the areas immediately adjacent to the constructions. In many portions, construction of bouldery embankments and revetments in front of the seawall was proved to be of no use even within a span of one or two years time chiefly during the cyclonic storm events.

In addition to the Government endeavour, Digha Fishermen and Fish Traders Association also spend every year some hundred thousands rupees for protecting the Digha Mohona (mouth of Digha river) area by building parallel- to -shore dykes made of sand-filled bags. All these constructions have strong detrimental effects on the coast as these accelerate the erosive power of the waves. Each time, the seawaves dash against the protective devises which also hit equally hard against the beach eroding the embankments much faster and lowering the beach profile. Large waves when topple the embankments loosen the bondage of the embankment materials. The backwash returns with more power to endanger the stability of the dykes. Furthermore, embankments constructed under the endeavour of the State Government at Digha Mohana for prawn culture also came out to be damaging for the Mohana area. These embankments hinder dissipation of wave energy for a longer stretch from Digha Mohana to Sankarpur that was initially the spreading zone of the waves before the construction. Consequently, huge volume of water directly hits this zone and enhances erosion. Survival of hundreds of poor fishermen families inhabiting in this belt is presently at stake.

Partial construction of seawall in the Digha sea resort area imparts a negative impact on the adjoining coastal areas. It is observed for the last few years that dunes of the Digha sea beach are fast retreating landward where the seawall has terminated against the unprotected dunes. Measurements show that after the construction of seawall, the rate of retreat of the dunes is as high as 16 to 18m per year that was only 11m per year in 1980s before the construction.

The bulk of embankment boulders are laterites together with a smaller proportion of charnockites and amphibolites. Although the porous lateritic boulders have high power of wave energy dissipation, their sizes are small compared to the impacted wave energy. As a result, the boulders are easily displaced and broken down to small fragments and finally affect the beach sand budget. These boulders also act as hard substrates for profuse settlement of barnacles and oysters and endanger recreational activities on the beach (Fig. 2).

Fig. 2 Revetments boulders used for beach protection thrown away from their original positions and strewn haphazardly on the beach. Many boulders act as hard substratum for the settlement of barnacles and oysters

Fig. 3 Bamboo and wire fencing in the neodune area to protect the plantation on bare supratidal beach

4.2 BREACHING, LEVELING AND DESTRUCTION OF COASTAL DUNES

Although some attempts have been made by the State Government to conserve the neodune fields by plantation and with bamboo and wire fencing (Fig. 3), human interference in these areas often destroy the whole arrangement. Sand dunes are ideal places for building hotels simply because they offer an open sea view in addition to their better basement stability in the high land areas. So the tops of dunes are generally flattened for building hotels in series without considering much about the Coastal Zone Regulation Act (1986). Even the State Government had built a hotel at Digha barely 250 m from the beach front in utter violation of the Act. All these constructions are against the principle of dune-sea dynamics and may imperil the Digha sea resort. In other cases, dunes are often breached for easy access to the beach for bathing and recreation. There are cases of such breaching of dunes at Digha, Digha Mohona, Sankarpur and Dadanpatrabar beaches (Fig 1). Cases of breaching and leveling of dunes for unobstructed sea vistas are also quite common at the sea resort and Mohona areas. All these avenues are further widened by erosion during hostile periods of high wave attacks.

4.3 MINING AND TRANSPORTATION OF BEACH SAND

Mining and transportation of beach sand particularly, from the supratidal and intertidal areas is a common practice in many areas of the coast. This is done mainly for construction purposes as well as for making dykes in the inland areas. This operation of beach sand transportation endangers the intertidal-supratidal sediment budget of the beach and often provokes erosion in and around the mining places that had been in stable equilibrium for a long time in the past.

4.4 IMPACT OF DISCHARGE OF HOTEL SEWAGE ON THE EMBANKMENT

Most large hotels constructed on the dunes and a large number of makeshift hotels and shops in the low-lying areas do not have any sewage system. The sewage water runs over the beach sand and ultimately seeps beneath the embankments. This loosens the base material of the constructions leading to their failures at places.

4.5 POLLUTION OF COASTAL WATERS

The coastal waters near Digha sea resort and fishing harbour of Sankarpur are receiving a lot of pollutants from the hotel sewage and harbour wastewaters. This sewage sludge and wastewaters are directly discharged into the sea without using the devise of multiport diffuses at the end of the outfall pipes or drainage openings (Nathanson, 2002). As a result, the circulation and mixing capacities of the sludge and wastewaters are restricted within the shallow nearshore zone. This polluted water brings mortality to coastal organisms and skin diseases to the poor fishermen using dragnets for fishing.

5. CONCLUDING REMARKS

As revealed from the study, the coastal zone under consideration is under severe environmental threat. The State Government has a master plan to develop the Digha sea resort and adjoining areas in near future. There is a pressure of developing the area with a view to make it more attractive for recreation, fishing and tourism purposes. All these will simply trigger urban development-conservation dilemma to this region, so typical of coastal zone irrespective of developing and developed countries (van der Merwe and Lohrentz, 2001).

The authors have certain recommendations in favour of protection and conservation strategies:

1. Natural dunes should be given protection by creating obstruction across the path of wind. Artificial simulation of dune growth includes creation of sand fences, brush barriers and plantation of dune vegetation. This would help stimulation of dune growth.
2. A constant vigil is to be established to prevent grazing and fodder collection from dune fields.
3. Artificial dunes may be created where there is no natural dune or where long stretches of dunes are breached. But the imported dune materials must corroborate to the texture and composition of the adjoining beach material.
4. Beach mining and transportation of beach sand are to be stopped by legislation. Such activities not only modify the local beach profile but also disturb the equilibrium of beach sand budget.

5. Quick repairing work should be undertaken when a portion of the seawall or embankment is damaged. Tardy repairing not only enhances further erosion but also involves more cost of repairing at a later time.
6. In order to mitigate pollution of coastal waters, the authors recommend use of multiport diffusers at the end the discharge pipes that should be extended long from land-water interface.
7. A mass awareness programme with a slogan to save the coast is advocated as a measure of conservation strategy.

ACKNOWLEDGEMENT

The authors acknowledge the assistance obtained from Mr. Debajyoti Dey, a research scholar in the department of Marine Science, Calcutta University in preparing the manuscript.

REFERENCES

Bearman, G. 1989. Waves, Tides and Shallow-water Processes. Pergamon Press (in association with the Open University), Watton hall, England. pp. 187

Bhattacharya, A. 2002. The role of macrofauna in the bioturbation processes around the mangrove zones of the Sunderbans Biosphere Reserve and its impact on environmental management. In: Biosphere Reserves in India and Their Management. (Eds. J.K. Sharma, P.S. Easa, C. Mohanan, N. Sasidharan and R.K. Rai), Ministry of Environment and Forests, GOI, New Delhi (India). pp. 166-180.

Bhattacharya, A. 2001. Sedimentary structures in the transitional zone between intertidal and supratidal flats of the mesotidal tropical coast of eastern India. *Proc. Tidalites 2000* (Eds. Y.A. Park & R.A. Davis, Jr.), *The Korean Society of Oceanography*, pp. 47-54.

Bhattacharya, A. and Sarkar, S.K. 1996. Study on salt-marsh and associated meso-tidal beach facies variation from the coastal zone of eastern India. *Proc. of the International Conference on Ocean Engineering COE '96 IIT Madras, India. Dec.1996*, Allied Pub. Ltd., Chennai, pp. 475-479.

Cadée, G. C. 2001. Sediment dynamics by bioturbating organisms. In: Ecological comparisons of sedimentary shores. (Ed. K. Reise) Springer-Verlag. Heidelberg. pp. 127-148.

Chakrabarti, P. 1990. Process-response system analysis in the macrotidal estuarine and mesotidal coastal plain of eastern India. Mem. Geol. Surv. India, Vol. 22, pp. 165-187.

Friedman, G.M. and Sanders, J.E. 1978. Principles of sedimentology. John Wiley, New York. 792 p.

Frey, R.W. 1975. The realm of ichnology, its strengths and limitations, In: The Study of Trace fossils, (Ed. R.W. Frey) Springer -Verlag, New York, pp. 13-38.

King, C.A.M. 1961. Beaches and Coasts. Edward Arnold Ltd., London, 403p.

Kuehl S.A., Levy B.M., Moore W.S., and Allison M.A. 1997. Subaqueous delta of the Ganges-Brahmaputra river system. *Marine Geol.*, Elsevier, Vol. 144, pp. 81-96.

Komar, P.D. 1976. Beach Processes and sedimentation. Prentice-Hall, Englewood Cliffs, New Jersey, 429p.

Leeder, M.R. 1982. Sedimentary Process and product. George Allen and Unwin, London, 344 p.

Nathanson, J.A. 2002. Basic Environmental Technology (4th. ed.). Prentice-Hall India Pvt. Ltd., New Delhi, 532p.

Richter, R., 1952. Fluidal-Textur in Sediment-Gesteinen and über Sedifluktion überaupt. Notizblatt des Hessischen Landesamtes für Bodenforschung zu Wiesbaden, Vol. 3(6), pp. 67 – 81.

Short, A.D. 1983. Sediments and structures in beach-nearshore environments, southeast Australia. In: Sandy Beaches as Ecosystems. (Eds. A. Mctachlan and T. Erasmus) , Dr. W. Junk Publishers. The Hague, pp. 145-167.

Umitsu, M. 1987. Late Quaternary sedimentary environment and landform evolution in the Bengal lowland. *Geogr. Rev. Jpn.*, Vol.60, pp. 164-178.

Umitsu, M. 1993. Late Quaternary sedimentary environment and landform in the Ganges, Delta. *Sediment. Geol.*, Vol. 83, pp. 177-186.

van der Merwe, J.M. and Lohrentz, G. 2001. Demarcating coastal vegetation buffers With multicriteria evolution and GIS at Saldanha Bay, South Africa. *Ambio*, Vol. 39, No. 2, Royal Swedesh Academy of Science, pp. 89-95.

Wright, L.D. and Coleman, J.M. 1973. Variations in morphology of major deltas as function of ocean waves and River discharge regions. *Bull. AAPG57*, pp. 370-398
Wright, L.D. and Nittrouer, C.A. 1995. Dispersal of river sediments in coastal seas. Six contrasting cases. *Estuaries,* Vol. 18, pp. 498-508.