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Shoreline dynamics of the Lakshadweep islands

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Lakshadweep group of islands are mainly coral atolls. Fringing reefs protect these small islands from the attack of waves. This paper describes the waves and currents acting on Kalpeni, Kavaratti, Minicoy, Agatti, Kadamat and Androth islands. The main reason for erosion at these islands seems to be the removal of coral reef for construction and other purposes, and to some extent the dredging of navigational channel in the lagoons. While the wave induced currents govern the sediment processes along the open coast, the tidal and wave generated currents influence the lagoon beaches.

Waves, tides and associated currents are the main interacting dynamic factors influencing the geomorphological characteristics and growth of the Lakshadweep islands, including formation of beaches and lagoons. This paper presents wave climate and tides including associated currents in the lagoon contributing to the coastal processes. An attempt has been made to identify the factors responsible for beach erosion prevailing at some of the islands based on, on-the-spot measurements.

Materials and Methods

Lakshadweep group is an archipelago of coral islands in the Arabian Sea, situated between the lat. 8°-12°N and long. 71°-74°E (Fig. 1). It consists of 36 islands, 12 atolls, 3 reefs and 5 submerged coral banks. All islands except Androth are geometrically similar in shape with the orientation of the longer axis being in the north to south direction, relatively wider at north and narrowing down towards south. Reef formations in the Lakshadweep are of the atoll type, generally elliptical in shape, not exceeding 10 km in the longest axis, with one, and often several islands on the atoll[1]. Androth, a platform reef, is an exception. These islands are small in size ranging from 0.1 to 4.4 km² in area, and are encircled by fringing reefs with the formation of lagoon on the western side.

The wave data pertaining to the Lakshadweep group of islands (lat. 10°-15°N and long. 70°-75°E) was compiled based on ship reported visual wave data for the years 1968 to 1986, published in the Indian Daily Weather Reports. Longshore currents along the Kadamat island coastline were measured on 14 February 1992, by releasing fluorescent tracers in surfzone and noting the distance travelled in 2 min. Beach sediment samples were collected (Feb. 1992) at each island in open beach exposed to direct waves. The nearshore bathymetry of the islands was obtained from the Naval Hydrographic Charts (Nos.

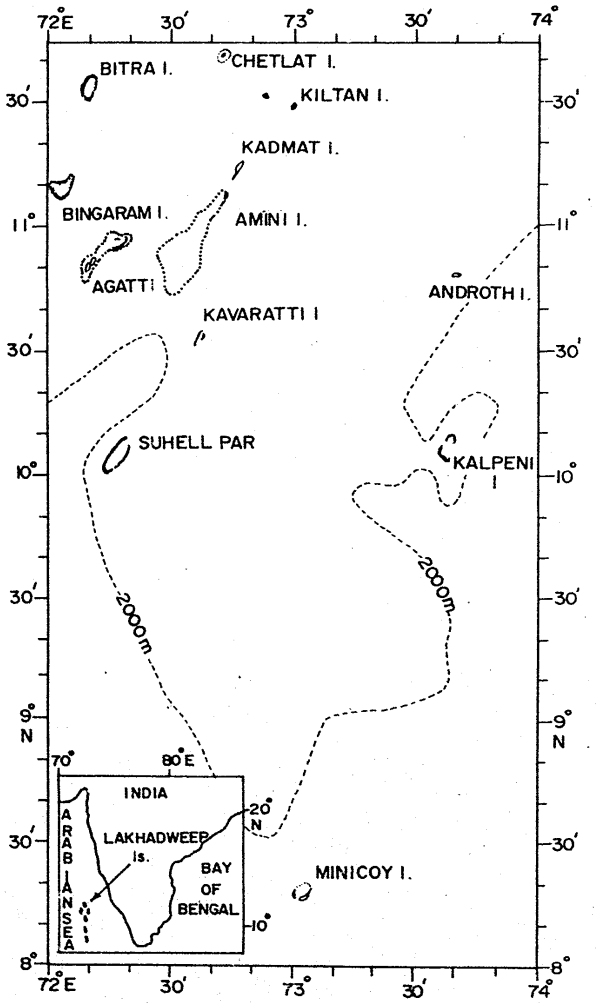

Fig. 1—Group of Lakshadweep islands

2006, 2007, 2023, 2035 and 2047). Sieve analyses for the beach sediments were carried out for the mesh openings between 0.063 and 2 mm. Inter Ocean S4 self recording current meter/tide gauge was used to measure the currents and tides in the lagoon, for 24 h at every island.

Results and Discussion

Monthly wave roses based on ship reported wave data for the Lakshadweep island group are presented in Fig. 2. Histograms showing the percentage distribution of significant wave heights and zero crossing wave periods during southwest monsoon (June to September), northeast monsoon (October to January) and the fair weather period (February to May) are shown in Fig. 3. Wave heights predominantly varied between 0.5-1.5 m from October to February, and 1-3 m from June to September. Zero crossing wave periods predominantly varied between 5-6 sec from October to February, and 5-8 sec from June to September. The predominant wave direction with respect to north was from the sectors 315°-345° (January to March), 315°-360° (April), 225 °-315° (May to September), 180°-360° (October), 315°-135°

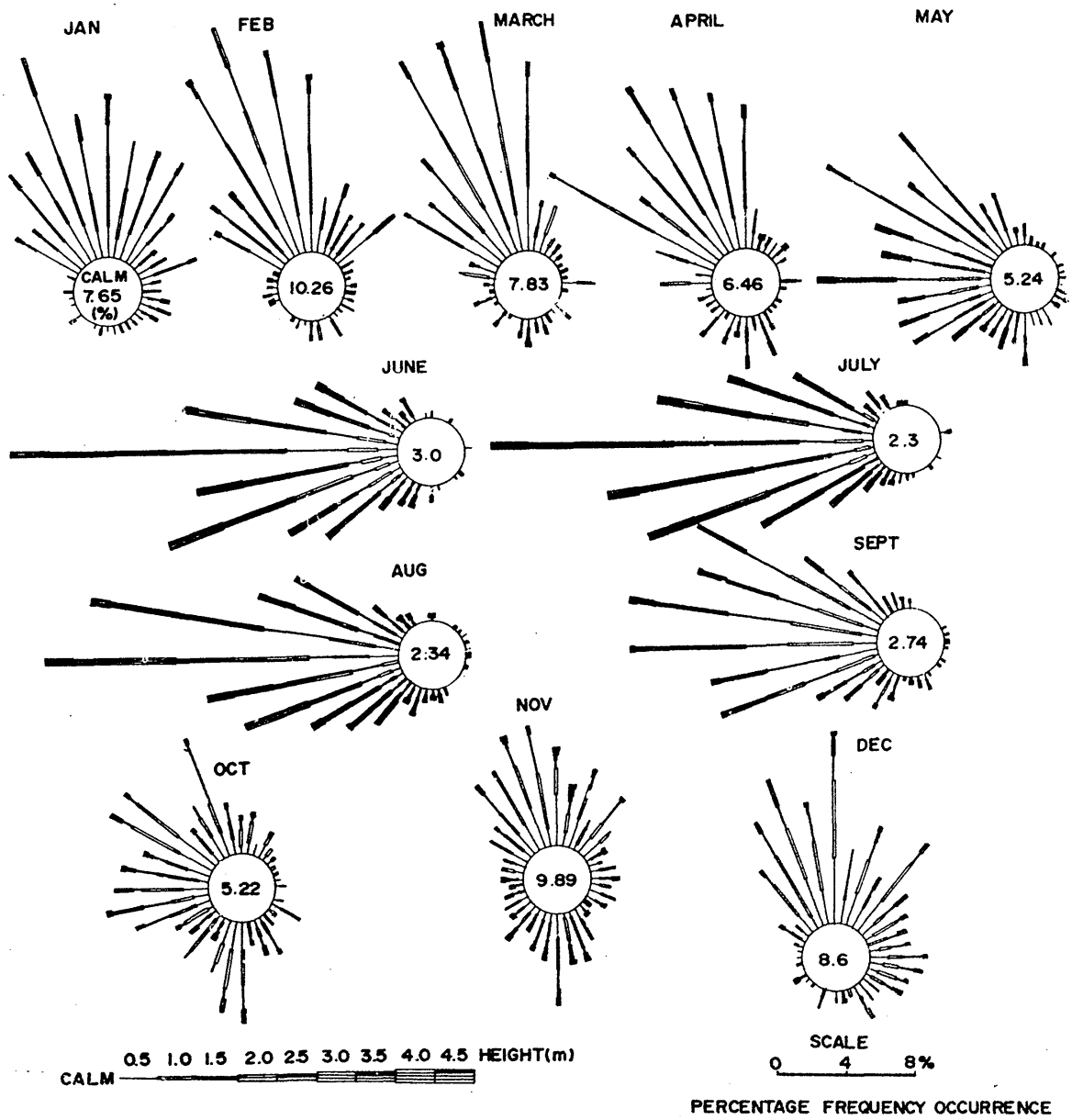

Fig. 2—Monthly wave rose diagrams

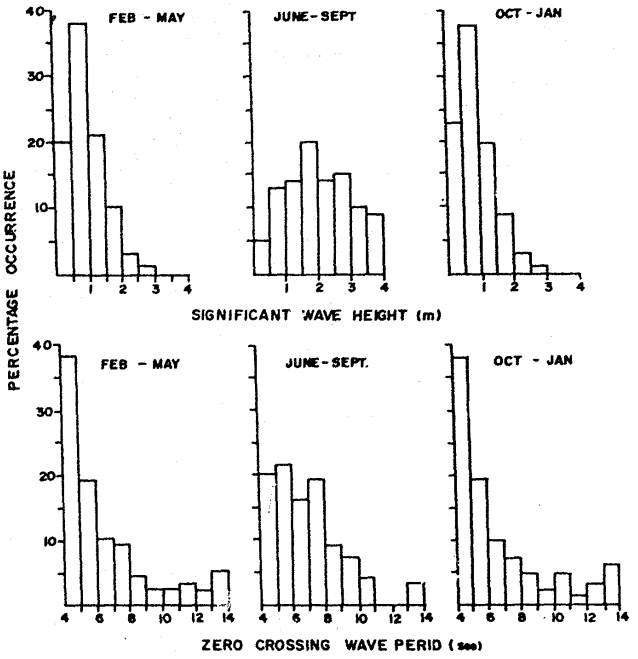

Fig. 3—Percentage distribution of significant wave heights and wave periods

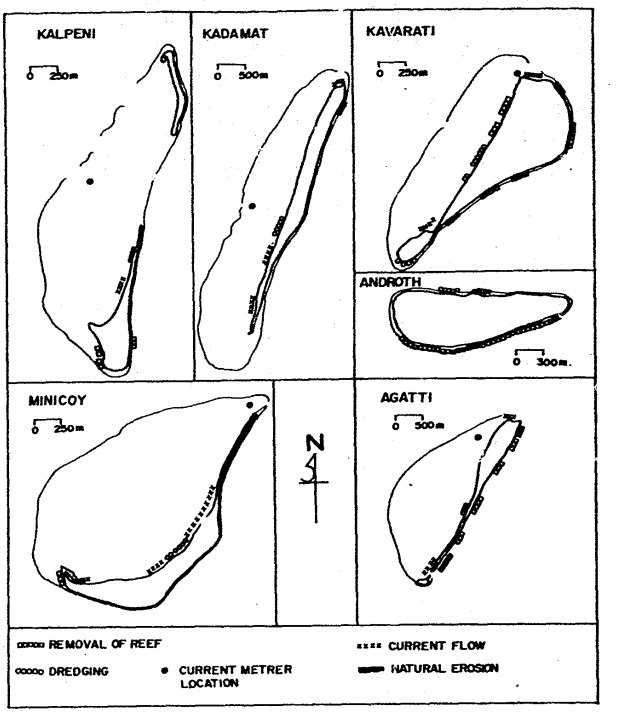

Fig. 4—Coastline under various kinds of erosion

(December) and it was variable in November. Earlier studies, as reported for this region gave the monthly mean significant wave height values as 1.5 to 2.7 m for the southwest monsoon period and 1 m for the rest of the year[2,3].

During the low tide, the major portion of the approaching waves dissipate their energy over the barrier reefs surrounding the lagoon. During high tide, part of the waves passing over the barrier reef into the lagoon, breaks on the beach. The open coast of the islands, has a wide fringing reef bed, which dissipates considerable wave energy, and so the smaller waves reach the shore and break.

The variation of tide over the Lakshadweep islands region is of semi-diurnal type, with the spring tidal range of about 1.2 m and the neap tidal range of about 0.3 m. Water level fluctuations due to tides and currents were measured in Kalpeni, Kavaratti, Minicoy, Agatti and Kadamat lagoons (Fig. 4). Variations of current velocity and direction are presented in Fig. 5. At Kalpeni, tidal variation was around 0.3 m on 5-6 February 1993. The current speed varied between 5-15 cm.sec^{-1}, showing flood current as relatively stronger than ebb current. At Kavaratti, tidal current varied between 5-20 cm.sec^{-1} with more fluctuation over the tidal variation. At Minicoy and Agatti, the current speed varied between 2-15 cm.sec^{-1}. In general, the currents in the entrance channel are weak, the maximum velocity being about 15 cm.sec^{-1} at all the

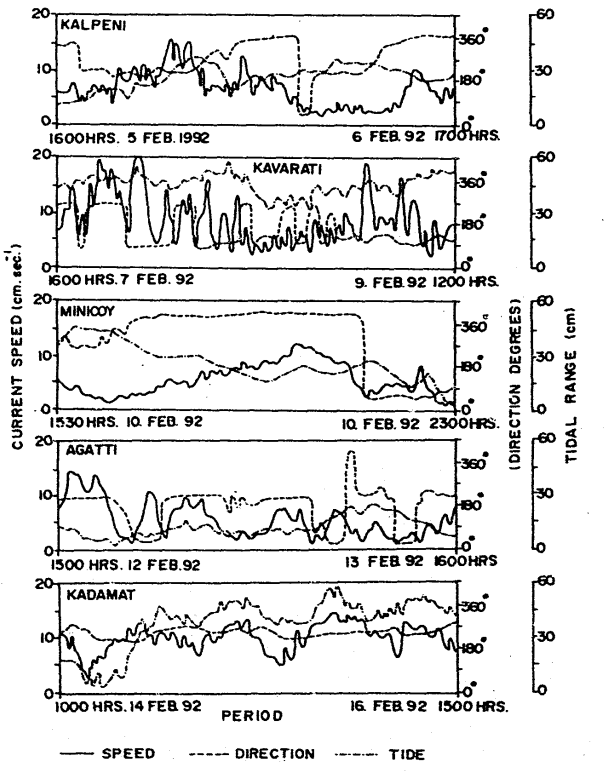

Fig. 5—Variation of current velocity and direction at Kalpeni, Kavaratti, Minicoy, Agatti and Kadamat

islands. The flow through the channel was into the lagoon during flood tide with a reversal in the direction during the ebb tide at Kalpeni, Kavaratti, Minicoy and Agatti. At Kadamat island, however, the flow in the channel was always from the lagoon to the sea, with the current speed varying with the tide. Even at low tide, major portion of the barrier reef adjoining the elongated narrow lagoon of the Kadamat island is found to be submerged, thereby causing flow of water into the lagoon from the sea over the reef due to waves and tides. As a result of this, the flow through the entrance channel is unidirectional throughout the tidal cycle from the lagoon to the sea.

Owing to the presence of wide reef on the open sea side, wave induced longshore currents along the open beaches were relatively weak, within 0.1 m.sec^{-1} at all the islands. But in Androth island, because of the east-west orientation, longshore currents along the southern coast were relatively higher and were between 0.1-0.2 m.sec^{-1} in February.

Distribution of the sediment along the lagoon beach during monsoon and fair weather seasons, is predominantly controlled by wave activity and current circulation pattern in the lagoon. During high tide, the current induced by part of wave energy passing over the barrier reef and the tidal inflow stir up the sediment and carry parallel to the shore. As the wave activity is intense during the southwest monsoon, considerable quantity of water would flow over the reef due to waves and tides, and hence the changes in the lagoon beach are significant.

All lagoons are geometrically similar in shape and orientation, with relatively large opening at the north. Distribution of currents is similar in all the lagoons. Very weak currents are observed in the southern part of the lagoon. The sediments in suspension and bed load are transported southward during the flood tide causing deposition along the southern part of the island. This phenomenon is evidenced almost in all the islands.

It is observed that almost all the inhabited islands are subjected to erosion problem at various segments of the shoreline. The coastline undergoing erosion at present in Kalpeni, Kavaratti, Minicoy, Agatti, Kadamat and Androth are indicated in Fig. 4. Erosion can primarily be attributed to 4 causes, viz. removal of reef materials, dredging and associated construction of harbour structures, natural readjustment of the beach materials, and current circulation pattern in the lagoon.

Increase in the construction activity and lack of alternative source of construction materials are the major reasons for the removal of reef boulders, thereby destroying the natural barrier which protects the islands from the direct attack of the waves. In order to provide the inter island navigational facility, entrance channel is being dredged at all islands, through blasting the coral bed. The dredged materials are then disposed on the other side of the lagoon, which would destroy the coral reef in the vicinity of dumping site. Controlled blasting using the right charges and dumping of the dredged material at specially selected places could minimize the damages.

The western side of the islands are exposed to high waves during the southwest monsoon, and northern coasts during the northeast monsoon. As the nearshore bottom of all islands is composed of rocky coral bed, the sediment supply is very much lower than that available at the sandy beaches on the mainland. The northerly longshore current along the eastern coast during the southwest monsoon, and the weak wave induced northerly longshore current along the lagoon beaches on the western coast, cause the littoral sediment to move and deposit on the northern part of the island. During the ensuing northeast monsoon, however the southerly longshore current carries a part of the sediment deposited at the north and deposits back at the southern part of the island. As the wave activity during the southwest monsoon is relatively more severe, the net deposition of sediment on the northern part of the island is relatively higher than that taking place on the southern side. The seasonal re-adjustment of the beach sediments is a natural phenomenon, which may temporarily cause erosion at certain parts of the coast. As long as the process is not disturbed, the coast would readjust itself to attain a stable form.

Southward transport of sediments along lagoon beaches, results in the formation of a sand spit. This phenomenon is evidenced by the occurrence of large tidal flats at the southern side of almost all islands. The flood and ebb tidal flows as well as mass transport of water due to waves overtopping the barrier reefs set up characteristic circulation pattern in the lagoon which govern beach processes influencing the erosion and accretion pattern along lagoon beaches. Erosion of the beach in the lagoon is noticeable opposite the reef channels as more wave energy and flow take place in these channels affecting the beach in front of the channel.

The coastline of the islands can broadly be classified into 3 categories, viz. i) boulder and pebble beaches on the open coast on the east exposed to open sea, ii) sand and pebble beaches particularly on the northern side, and iii) sandy beaches in the lagoon side. All these three types of shoreline exist at Kalpeni, Kavaratti, Minicoy and Androth. Agatti

and Kadamat consist mostly of sandy beaches all around the islands. Sieve analysis of the beach sediments showed that the median size (d_{50}) was 0.28 mm in Kalpeni, 0.29 mm in Kavaratti, 0.22 mm in Minicoy, 0.33 mm in Kadamat, 0.48 mm in Agatti and 0.38 mm in Androth. Sea walls were constructed using 3 layers of tetrapods (0.5 tons wt) and the rear side covered by rows of hollow concerete blocks at erosional sites of every island. These sea walls are effective in protecting the shoreline, however, in most of the cases, terminal erosion problem at the end of sea walls is apparent.

Sediment processes at the nearshore of Lakshadweep islands are governed predominantly by waves on the eastern side open beaches, and by current on the western side lagoon beaches. Formation of wide fringing reef bed dissipates considerable wave energy approaching the shore. Large erosion is taking place almost at all islands due to various forms of human interaction with the nature. Effective planning, prevention of quarrying of the reef for construction purposes, adoption of controlled blasting, dredging and disposal of the dredged material at selected dumping places would be urgently needed to control the erosion problem.

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