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Consequence of cyclonic storm *Phailin* on coastal morphology of Rushikulya estuary: an arribada site of vulnerable Olive Ridley sea turtles along the east coast of India

A very severe cyclonic storm *Phailin*, a category-5 hurricane, was developed over the north of Andaman and Nicobar Islands on 9 October 2013. Subsequently, it propagated towards north–northwest and made landfall at the Gopalpur coast, Odisha on 12 October[1]. The present study area, Rushikulya estuary is in close proximity (15 km north) to the landfall point. Significant changes occurred in the geomorphologic structure of the estuary due to effect of *Phailin* (Figure 1). The study area receives international recognition due to episodic mass nesting event (arribada) of endangered Olive Ridley (*Lepidochelys olivacea*) sea turtles. A long sand spit which was running parallel to the coast, as a result separating the estuary from the sea, was eroded significantly due to the strong surge exerted by cyclone *Phailin*. Large areas of the coastal region were inundated due to storm surge (recorded 2.5 m) during the storm[2]. The spit development in the estuary mouth regions is correlated with the longshore transportation of sediments and the dominant influence of the southwest monsoon. The sand spits develop due to accumulation of sand derived from the adjacent sea bed or sand from the land through the river on the southern part[3]. In the present study, we have attempted to assess the spatio-temporal changes that occurred in the sand spit and shoreline using sequential satellite data pertaining to the period 2003–2014. Satellite remote sensing and Geographic Information System (GIS) have proved as meaningful tools to

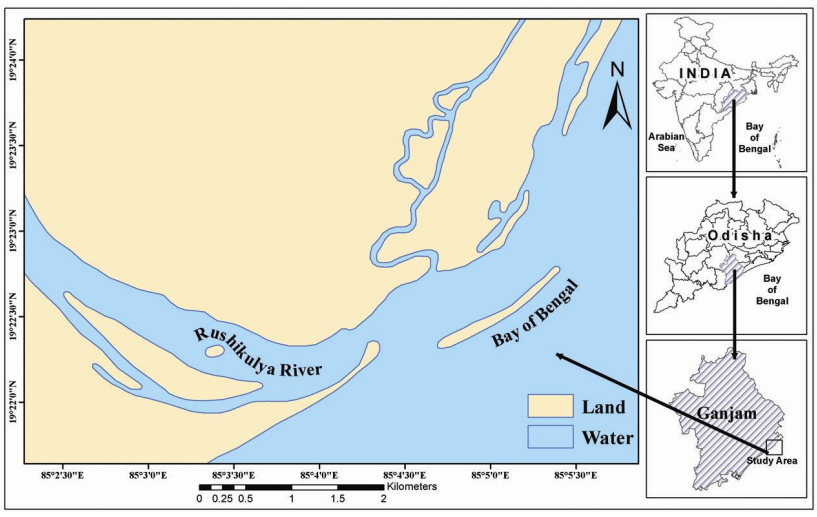

Figure 1. Geographic position of Rushikulya estuary.

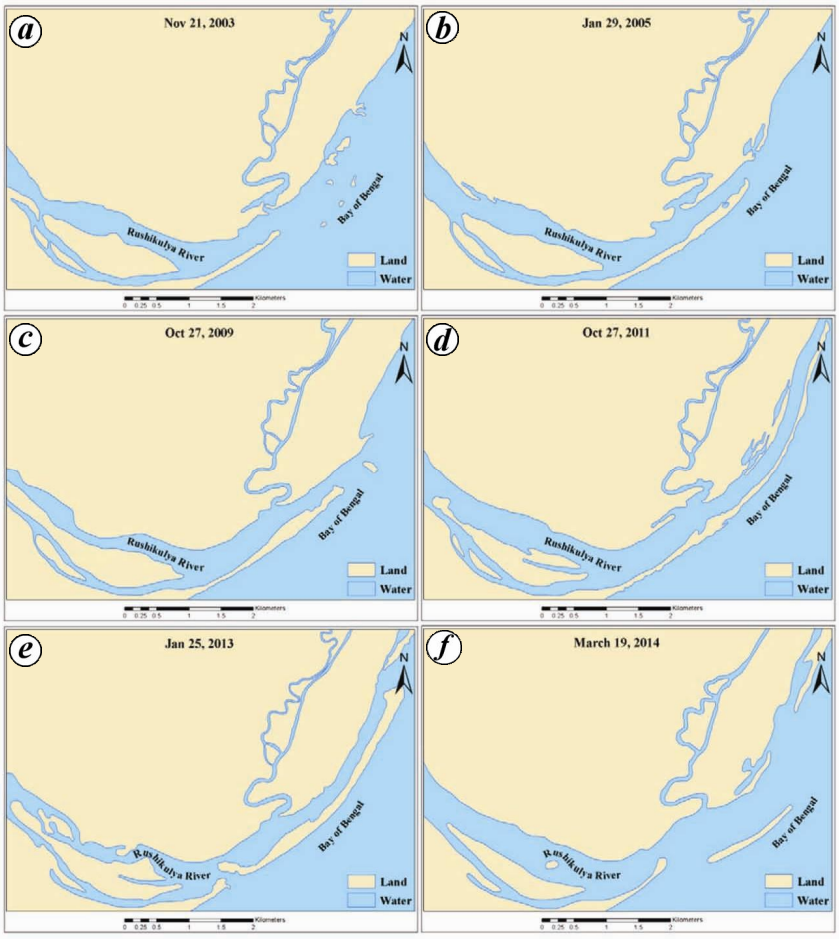

Figure 2. Spatio-temporal morphological changes in the mouth region of Rushikulya estuary.

monitor and evaluate the land-form changes[4,5]. For the present study, satellite datasets of Geoeye (Pass: 11-21-2003, 01-29-2005, 10-27-2009, 10-27-2011, 12-20-2012, 01-25-2013) and of Landsat-8 (Pass: 04-10-2013, 03-19-2014) were processed using GIS software package ERDAS Imagine (version 2014) and ArcGIS (version 10.2.1) to assess the coastal morphological changes.

Geomorphologic features, viz. position of sand spit, river mouth position and shoreline status of the study area during 2003, 2005, 2009, 2011, 2012, 2013 and 2014 are depicted in Figure 2. Special attention is given to the sand spit as it is the important geomorphologic feature which formed the long channel of Rushikulya estuary. From 2003 to 2005, it is apparent that the sand spit had been increased in length. This increase was prevalent till 2009 and 2011. Northward increase in length of the sand spit is commonly observed along Odisha coast, which is the effect of round-the-year longshore transport directed from north to south[6]. The sand spit was further elongated and increased its length parallel to the coast with a narrow channel. This led to local flooding at the river mouth during monsoon. In 2012, the sand spit was artificially engraved at the proximal end (base) by inhabitants to avoid waterlogging during floods[7]. However, the striking feature of the present study was the significant length reduction of the sand spit during October, 2013 due to the strong cyclonic surge by *Phailin* (Figure 2 *f*).

The length and area of the sand spit were 4.16 km and 0.56 sq. km respectively, during January 2013 (pre-*Phailin* period). Whereas length was reduced to 1.52 km and area was reduced to 0.13 sq. km in 2014 (post-*Phailin*). It was observed that the total reduction in the length and area of the sand spit was 4.13 km and 0.43 sq. km respectively. The river mouth morphology was reset to the conditions which were similar to the period 2003, except the small sand spit. The coastal sandy area in the current study is a recognized rookery of migratory reptilian guests, i.e. Olive Ridley sea turtles. It was observed that the number of Olive Ridley turtles declined significantly during 2014. In the previous year, mass nesting reached a record number of 3.0 lakhs. It was reported that the sand spit was providing an additional nesting ground, which favoured the increment in mass nesting[7]. During post-*Phailin* (2014), nesting drastically reduced to 25,000, and was sporadic in nature[8]. Severe morphological changes and reduction in the spatial extent of the sand spit due to *Phailin* cyclonic surge may have contributed to the adverse nesting preferences for the Olive Ridley turtles. Hence the cyclonic surge-induced coastal morphological changes could be one of the major reasons for decline in the number (failure of mass nesting) of these migratory endangered species[9].

It can be concluded that the remote sensing data with the aid of GIS tools demonstrate the usefulness in identification of the spatio-temporal changes in the preferable nesting sandy areas of Olive

Ridley turtles. Cyclone *Phailin*-induced breaching of the sand spit was one of the causative factors for the significant changes in estuarine geomorphology, resulting in a decline in the number of Olive Ridley turtles nesting in the subsequent year. The study can be further enhanced using high temporal and spatial resolution satellite data along with *in situ* observations. Though the technique used in the present study seems simple, it provides vital information for the prediction of decline in Olive Ridley mass nesting.

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