Journal of Environmental Management 180 (2016) 111–122

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

The influence of fluvial dynamics and North Atlantic swells on the beach habitat of leatherback turtles at Grande Riviere Trinidad

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ARTICLE INFO

Article history:
Received 2 December 2015
Received in revised form
12 April 2016
Accepted 6 May 2016

Keywords:
Beach erosion
Episodic river flooding
River shifting
Coastal geomorphology
Endangered species

ABSTRACT

Grande Riviere beach, located on the north coast of Trinidad, West Indies, is internationally recognised as a critical habitat/nesting ground for the endangered leatherback turtles (*Dermochelys coriacea*). Episodic extreme flooding of the Grande Riviere River led to the shifting of the river mouth and resulted in backshore beach erosion, with the most recent recorded event occurring in 2012. Following this event, the construction of a sand dam to arrest further erosion which threatened coastal infrastructure, precipitated a host of new problems ranging from beach instability to public health threats. In January 2013, high energy swell waves naturally in-filled the erosion channel, and the beach recovery continued over the successive months, thereby rendering the intervention in the previous year questionable. This paper presents a geomorphological analysis of beach dynamics for Grande Riviere, within the context of this erosion event. Data on beach profiles, sediment and coastal processes were collected using standard geomorphological techniques. Beach topographic analysis and water quality tests on impounded water in the erosion channel were conducted. Results indicate that the event created an erosion channel of 4843.42 m^3 over a contiguous area of 2794.25 m^2. While swell waves were able to naturally infill the channel, they also eroded 17,762 m^3 of sand overall across the beach. Water quality tests revealed that the impounded water was classified as a pollutant, and created challenges for remediation. Hydrologic and coastal geomorphologic interplay is responsible for the existence and sustainability of this coastal system. It is also evident that the beach system is able to recover naturally following extreme events. Our results demonstrate that effective and integrated management of such critical habitats remains dependent upon continuous monitoring data which should be used to inform policy and decision making.

1. Introduction

Coastal dunes, beaches and shorefaces are linked by sediment transport pathways and morphodynamic feedbacks. Collectively, they make up coastal barriers and are considered the basic depositional elements of wave-dominated coasts (Roy et al., 1994). Nearshore processes shape beach morphology (Hardisty, 1990), but there is evidence to support that morphology can influence the processes in the nearshore (Komar, 1997). Beaches and their adjacent nearshore zones act as buffers to wave energy. As a result, they are prone to change over varying timescales ranging from a few seconds to several years (Komar, 1997; Darsan, 2013a, 2013b).

Previous research on mid-latitude beaches (e.g. Norcross et al., 2002; Aleman et al., 2015), demonstrates that the beach and near-shore exchange sediment within a winter-summer cycle. During the summer, low, flat swell waves build up the berm, causing the beach face to prograde seawards and form a steep profile; conversely, in winter, high and steep storm waves erode the beach face and transport the sediment seawards where it is deposited to form a long-shore bar. The work of Cambers (1998) on Caribbean beaches has also indicated the existence of this winter-summer cycle phenomenon for low latitudes. However, Short (1979), Nordstrom (1980) and Darsan (2005, 2013a) indicate that there may not be a defined seasonal pattern to beach change, but that the beach will go through cycles of erosion or accretion. A proper understanding of coastal processes and beach dynamics are

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http://dx.doi.org/10.1016/j.jenvman.2016.05.014
0301-4797/

therefore critical to management in terms of habitat provisioning.

Beaches provide a range of ecosystem services (Dugan et al., 2010; Schlacher et al., 2014a; Singh, 2016), with different expectations by the public in terms of their uses (McLachlan et al., 2013). The inherent dichotomous issues stem from recreational and developmental use of the beach, while protecting the beach habitat upon which the ecosystem depends (McLachlan et al., 2013). Species found on beaches are functionally dependent on these habitats (Maslo et al., 2011; Schlacher et al., 2012; 2014a; Schoeman et al., 2014), particularly marine turtles (Wallace et al., 2011). The most severe threat facing sandy beaches is coastal erosion, coastal squeeze (Schlacher et al., 2006, 2007, 2008; Schleupner, 2008; Defeo et al., 2009) and climate variability (Ortega et al., 2012, 2013).

Most management approaches to these issues involve beach nourishment (Nordstrom, 2000; Nordstrom and Mauriello, 2001; Schlacher et al., 2006), with beach habitat conservation as a minor component (Peterson and Bishop, 2005). Micallef and Williams (2002) argue that beach management decisions should be based on the analysis of empirical data. Others have identified metrics of beach size, geometry, orientation/configuration and sediment characteristics to be important (Barnard et al., 2012; Bathrellos et al., 2012; Harris et al., 2011a; Ortega et al., 2013; Schlacher et al., 2012; Schlacher and Thompson, 2012), while Schlacher et al. (2014b) has outlined a selection criteria of metrics that can be applied to beach management scenarios. Others have investigated the issues related to land-use planning, zoning and enforcement (Hossain and Kwei Lin, 2001), and set-back regulations within the context of climate change and sea level rise (Micallef and Williams, 2002; Caldwell and Segall, 2007; Fish et al., 2008).

The case presented in this paper, highlights backshore beach erosion by a river flood at an internationally important nesting ground for endangered leatherback turtles. The erosion event prompted reactionary sand dam construction (to arrest further damage to infrastructure) and created several new problems at the beach. Subsequent beach repair by swell waves pre-empted the public pressure to apply engineering solutions to in-fill the erosion channel in lieu of the upcoming nesting season of the leatherback turtles. In view of this, the primary aim of this study was to apply a multidisciplinary approach to analyse the impacts of the extreme event and advise on management of such occurrences by (a) analysing the coastal processes which occurred, (b) assessing the beach's topographic changes in response to hydrological, coastal and ecological forcing, (c) investigating the quality of the impounded water in the erosion channel and, (d) highlighting the management issues and challenges that arose. Further, a number of recommendations are provided for consideration to manage such future occurrences.

1.1. Study setting

Trinidad and Tobago is situated in the southernmost end of the Caribbean island chain (Fig. 1) and experiences a tropical marine climate with two distinct seasons. The tidal regime is that of a mixed semi-diurnal type, influenced by tide waves from the Caribbean Sea and the Atlantic Ocean (Darsan et al., 2013). Some waves occur as a result of the action of trade winds on the water's surface, storms and squalls throughout the hurricane months and swell waves originating from the North Atlantic (Deane, 1973). At high spring tides the maximum range is 1.2 m with some slight variation from north to south. At other times, the tidal range is less than 1 m, averaging 50–60 cm between high and low tides (Kenny, 2008). Swell waves are most often experienced in the Caribbean between the months of October to April, and is usually caused by intense mid-latitude storms in the North Atlantic Ocean (Cambers, 1998).

Grande Riviere bay, located on the north coast of Trinidad is exposed to the Caribbean Sea (Fig. 1), approximately 970 m long and arcuate in shape, making it a typical semi-enclosed pocket beach. Grande Riviere had an agro-economy based on cocoa in the early 1900's (Sookram and Sutherland, 2011). However, by 2000, with declining cocoa prices, ecotourism had taken over (Harrison, 2007), driven largely by the recognition of the importance of conservation efforts and recognition of the area as a prime nesting ground for the endangered leatherback turtles (*Dermochelys coriacea*) and the blue-throated piping-guan (*Pipile cumanensis*).

1.2. 2012 Grande Riviere erosion event

The Grande Riviere River usually exits through the berm flowing northerly with only marginal deviations to mouth width and location. Annually, during the beach's accretionary cycle, the river mouth may become blocked. However, members of the village routinely clear the mouth to allow for boat access to berth their fishing boats up river. In April 2012, the course of the Grande Riviere River had begun shifting westward, deviating from its normal path (Fig. 2).

Progression of this shift continued and by June 2012, the river had eroded a channel in the backshore, flowing westerly and parallel to the shoreline for approximately 150 m before entering the bay (Fig. 2). In July 2012, the Drainage Division (Ministry of Works and Infrastructure, Government of the Republic of Trinidad and Tobago) intervened and constructed a sand barrier to arrest the westward flow of the Grande Riviere River, which was threatening coastal infrastructure. Sand for the dam construction was mined from eastern section of the bay using heavy machinery. The narrower Ferdinand River in the bay's central region also shifted its path in a westerly direction along the backshore of the beach, though with less deleterious effects, given its much lower discharge. The Drainage Division also altered the Ferdinand River's course by straightening its mouth to flow directly into the sea in a northerly direction, arresting any further backshore erosion. The river was also dredged and widened to accommodate heavy flows in the upcoming rainy season and levees constructed from the spoil in an attempt to prevent any future shifting. These engineering interventions resulted in destruction of turtle nests and reduction in the beach habitat from sand excavation, pooling of stagnant water in the backshore erosion channel from dam construction, restricted beach access and reduced eco-tourists to the area.

2. Methodology

Analysis of the major threats to the physical, ecological and socio-economic facets of Grande Riviere required a multidisciplinary and holistic approach in dealing with the negative impacts of river shifting. In this study, several types of data were collected, including coastal geomorphological data on coastal processes, beach sediment and beach profiles (2003–2013), topographic data (October 2012, January 2013), and water quality data (October 2012, January 2013). Analysis of these data components was then made in order to inform on the best course of action to remedy the negative issues.

2.1. Coastal geomorphology

Beach profile, beach sediment and coastal processes data were collected at four monitoring stations (Fig. 1) using standard surveying methods as outlined by Goudie et al. (1990). Beach profiles were conducted at low tide, using the “break-in-slope” method where uneven horizontal distances were used to reflect