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Temporal shift of sea turtle nest sites in an eroding barrier island beach

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ABSTRACT

Shoreline changes affect functionality of a sandy beach as a wildlife habitat and coastal erosion is among the primary causes of the changes. We examined temporal shifts in locations where loggerheads placed nests in relation to coastal erosion along a barrier island beach in the northern Gulf of Mexico. We first confirmed consistency in long-term (1855–2001), short-term (1976–2001), and more recent (2002–2012) shoreline change rates in two adjacent beach sections, one historically eroding (west beach) and the other accreting (east beach). The mean annual shoreline change rate in the two sections was significantly different in all time periods. The recent (1998–2012) mean change rate was −10.9 ± 9.9 m/year in the west beach and −2.8 ± 4.9 m/year in the east beach, which resulted in the loss of about 70% and 30% of area in the west and east beaches, respectively. Loggerheads nested significantly closer to the vegetation line in 2012 than in 2002 in the west beach but the difference between the two time periods was not significant in the east beach. However, the distance from nests to the vegetation line from 2002 to 2014 was significantly reduced annually in both beaches; on average, loggerheads nested closer to the vegetation line by 9 m/year in the west beach and 5.8 m/year in the east beach. The observed shoreline change rate and corresponding shift of nest placement sites, combined with the forecasted future beach loss, highlighted the importance of addressing the issue of beach erosion to conserve sandy beach habitats.

1. Introduction

Sandy beaches provide critical habitat for a variety of wildlife species, thereby maintain high biodiversity. Conservation of sandy beach habitat is important but challenging because of the various natural and anthropogenic forces that alter the morphology and functionality of sandy beaches (Schlacher et al., 2006; Schooler et al., 2017). Coastal erosion is among the primary factors that influence shoreline and beach morphology. Severe beach erosion may reduce the area and change the condition of available habitat for coastal species and alter the abundance of infaunal organisms (Brown and McLachlan, 2002; Claudino-Sales et al., 2010; Zhang et al., 2005).

Sea turtles are circumglobally distributed species whose distribution and abundance is greatly influenced by availability and condition of sandy beaches. With their strong linkage to environmental conditions and degraded population status – of seven sea turtle species, six species are listed as vulnerable, endangered, or critically endangered on the IUCN Red list – there have been active research and conservation efforts to sustain the population of sea turtles (Hamann et al., 2010). Sea turtles spend most of their lives in the water, but they rely on sandy beaches for reproduction. Loss or narrowing of sandy beaches, also called “coastal squeeze” (Mazaris et al., 2008), could adversely affect sea turtle reproduction in several ways. First, the loss of nesting areas may increase density of nests in available beach areas, which may exceed the carrying capacity of the nesting beach (Mazaris et al., 2008). Loss of habitat may also result in fewer nests deposited. Second, erosion may create steeper slopes, making a given site less suitable for nesting in some beaches (Wood and Bjorndal, 2000; Maison et al., 2010). Third, the increased risk of saltwater inundation due to narrowed beach width could increase the risk of egg mortality and cause lower hatching success (Foley et al., 2006; Özdemir et al., 2008). Loss of sandy beaches caused by erosion has been evidenced in a number of sea turtle nesting beaches (Schlacher et al., 2006; Hawkes et al., 2009). An average annual decrease of 0.16 m beach width was observed in a high density loggerhead sea turtle (*Caretta caretta*) nesting beach along the Atlantic coast in the U.S. (Reece et al., 2013). In the Caribbean, 20% of historic nesting sites have been lost (McCleachan et al., 2006). Varied levels of erosion and partial shoreline reduction have been reported in a multiple sea turtle nesting beaches in Turkey (Kuleli et al., 2011).

Under the forecasted climate change, turtle nesting beaches may be

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negatively impacted by sea level rise and accelerated erosion caused by increased storm intensity which could lead to loss of beaches areas (Poloczanska et al., 2009; Hawkes et al., 2009). Furthermore, climate changes may affect ecological niches of species and thus their distributions (Mazaris et al., 2015). Increasing our knowledge on behavioral features in habitat selection and suitability for a species could greatly increase our conservation capacity.

Given that reduction of sandy beaches is predicted to further intensify in the coming decades (Brown and McLachlan, 2002), implementing beach management activities to protect biodiversity and maintain ecological processes is important (Ariza et al., 2008; James, 2000). Understanding how and to what extent shoreline change has been influencing sea turtle populations is essential in planning such management activities. In this study, we examine temporal changes in (1) the shoreline extent and (2) the spatial arrangements of loggerhead sea turtle nests in a historically eroding sea turtle nesting beach in a dynamic barrier island in northern Gulf of Mexico.

2. Methods

2.1. Study site

This study was conducted on 5.7 km (as of June 2013) of beach on Eglin Air Force Base property on Cape San Blas in Gulf County, Florida, USA (Fig. 1). The area represents the southern tip of the St. Joseph Peninsula, and is a part of the 2500 km coastline along the Gulf of Mexico that is made up of sandy beaches and barrier islands. Beaches in the northern Gulf of Mexico—the approximate southern limit of the temperate zone in the terrestrial domain of North America—historically serve as key habitats for a variety of wildlife species, including sea turtles (Godowin and Peterson, 2000). Our study beach supports one of the highest nesting densities of loggerhead sea turtles in the northern Gulf of Mexico. On average 43.4 loggerhead nests (8.7 nests/km) were placed annually in this beach, however a decline in nests has been observed between 1994 and 2010 (Lamont and Carthy, 2007; Lamont et al., 2012). The study beach is adjacent to the area predominated by mesic flatwoods and coastal scrub. There was neither major development nor landscape change along this beach during the study period.

Some portions of the St. Joseph Peninsula have historically experienced high rates of shoreline change (Orhan, 1992) and sediment transport (Stone and Stapor, 1996). In our study site, the cape spit, which is located approximately in the center of the study site, experiences one of the greatest rates of natural erosion in Florida (Lamont and Carthy, 2007, Fig. 1 B & C). This sand shoal extends approximately 15-km southward into the Gulf of Mexico and is in a near constant state of flux. During a three week period in the summer of 1994, the spit lost approximately 23 m of sand (Lamont and Carthy, 2007). The cape spit divides the study site into two distinct sections of beach, the western and eastern beaches that differ in bathymetry and current dynamics. The western portion (west beach) extends about 3 km to the northwest from the cape spit and is narrower and eroding, whereas the eastern portion (east beach), extends about 2.7 km from the cape spit and is wider and accreting (Lamont and Carthy, 2007). A previous study showed steeper slope on the eastern beach (−0.135) than in the west beach (−0.060; Lamont and Carthy, 2007).

2.2. Sea turtle nest survey

We used sea turtle nest survey data, including latitude/longitude of nest locations and identified species, from this study area gathered between 2002 and 2014 by the U.S. Geological Survey and University of Florida. Surveys were conducted each morning from May 1 to September 1 during the nesting season which continues until October 31. Surveyors walked along the beach, recorded GPS coordinates of nests (< 4.5 m accuracy) and identified the associated species by assessing features of track and nest, such as track width, track configuration, and body pit size, following the methods outlined by Pritchard et al. (1983). In this study, we focus on loggerhead, the primary nesting sea turtle species in this study beach, because nesting of other species, including green turtle (*Chelonia mydas*) and Kemp's ridley (*Lepidochelys kempii*), is rare.

2.3. Shoreline data and estimating erosion rates

Florida shoreline shapefile for 1998–2001, which was created based on the aerial images during this period, was obtained from the U.S. Geological Survey's National Assessment of Shoreline Change Web Mapping Application (http://coastal.er.usgs.gov/shoreline-change; accessed on March 3, 2016). More recent measures of the shoreline and the vegetation line bordering the beach were taken by a walking survey recording a series of GPS coordinates (< 15 m accuracy) at approximately every 10 s along the water line and vegetation in June 2012. The recorded coordinates were overlaid with the high-resolution orthorectified image (3 m) in 2013 (U.S. Geological Survey, Earth Resources

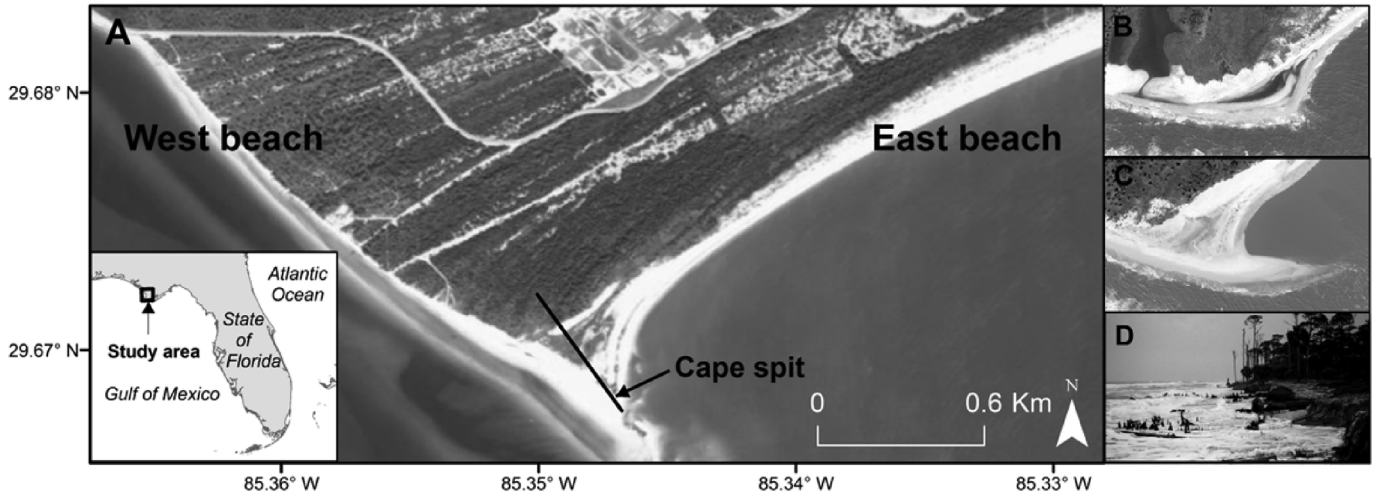

Fig. 1. (A) An aerial photo of Cape San Blas, which represents the southern tip of the St. Joseph Peninsula, Florida, in which the boundary (cape spit) of the east and west beaches in the study area is shown. The inset box shows the location of the study area within the state of Florida, USA. (B) Aerial images of cape spit in 2003 (Florida Department of Transportation, Aerial Photo Look-Up System, https://fdotewp1.dot.state.fl.us/aerialphotolookupsystem, accessed 31 May 2016) and 2013 (U.S. Geological Survey, Earth Resources Observation and Science Center, http://eros.usgs.gov/usa, accessed 31 May 2016). These images show server erosion and apparent shoreline change in the study beach. (D) An eroding portion of the west beach, located approximately 0.5 km west of the Cape spit, during a winter storm in January 2002.