

Quantifying Nesting Responses to Hurricane Erosion: A Unique Application of LiDAR Remote Sensing

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Abstract

The Archie Carr National Wildlife Refuge located on the Atlantic coast of Florida represents one of the most important nesting beaches for green turtles (*Chelonia mydas*) in the United States and for loggerhead turtles (*Caretta caretta*) in the Western Hemisphere. This coastline is one of many throughout the southeastern U.S. that becomes vulnerable during the annual hurricane season (June–November), which closely overlaps the sea turtle nesting season (May–September). Although a few studies have quantified direct effects of hurricanes on turtle nesting, broad-scale (landscape level) effects have not been quantified. Using LiDAR (Light Detection and Ranging) remote sensing, we assessed dynamics of dune morphology throughout the refuge caused by an unusually active 2004 hurricane season. It was concluded that the hurricanes led to significant erosion along most of the shoreline. Nesting in pre- and post-hurricane years was analyzed alongside the LiDAR data to determine the overall impact of erosion on sea turtle nesting behavior. The use of LiDAR technology has the potential to be a practical tool in evaluating turtle nesting habitat as it allows for broad surveys of the shoreline.

Introduction

Light Detection and Ranging (LiDAR) remote sensing is a system that uses pulsed light to measure distance. Traditionally this technology has been used for inland areas, especially in forests, however when attached to a small aircraft with GPS and internal navigation, it can be flown over coastal areas to map terrain (Fig. 1). Recently, airborne LiDAR has been shown to be an effective tool for mapping coastal topography due to its accuracy and efficiency in conducting broad surveys (Woolard and Colby 2002).

Though previous studies have quantified the direct effects of hurricanes on sea turtle nesting (e.g. Milton et al. 1994, Pike and Stiner 2007), landscape level and long-term impacts due to topographic alterations have not been studied. Conversely, the effects of beach restoration projects (commonly referred to as beach nourishment), which may be necessary following a hurricane, have been studied on several occasions. Brock et al. (in press) found that nesting in nourished areas of the Archie Carr National Wildlife Refuge (ACNWR) decreased one year post-nourishment but returned to normal after two years when the characteristics of both areas became more similar. While Brock et al. (2007) conducted their study prior to the 2004 hurricane season, the intensity and frequency of storms during that season necessitated a large-scale nourishment throughout the ACNWR. For this study, LiDAR surveys of the shoreline conducted prior to and immediately following the 2004 hurricane season were used to assess changes in dune morphology. Here we present our preliminary findings in an ongoing study to determine the impacts that beach erosion due to intense hurricane activity and subsequent beach restoration projects have had on *Caretta caretta* and *Chelonia mydas* nesting patterns.

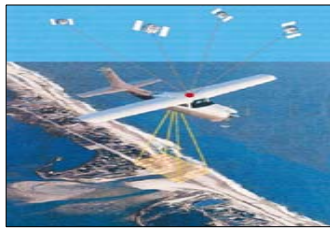


Fig. 1. LiDAR is a remote sensing system that uses swaths of pulsed light to measure distances. By attaching this system to a small aircraft, with GPS and a precise internal navigation system, these distances can be used to map terrain to cm accuracy.

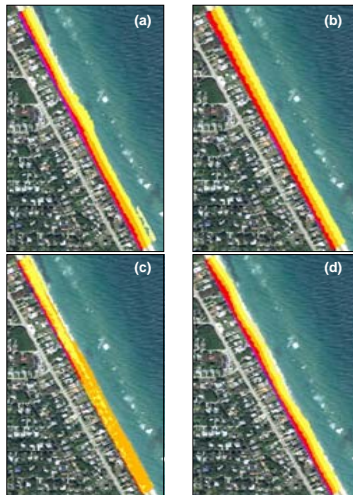
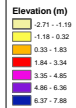


Fig. 2. LiDAR surveys of a 1-km segment of the Archie Carr National Wildlife Refuge indicates:

(a) beach topography prior to the 2004 hurricane season,
(b) after the 2004 season,
(c) the difference due to erosion caused by the hurricanes, and
(d) the topography in early 2006 after restoration.



Methods

Study Area and Nesting Data

- The ACNWR is a 21-km stretch of beach extending from Sebastian Inlet to Melbourne Beach that is divided into 0.5-km segments.
- Each nesting season, crawls in each segment were recorded during daily early-morning surveys. Species were identified by track and nest characteristics.
- Nesting success was calculated for each segment by dividing the number of successful nesting attempts by the total number of emergences.

LiDAR Data and Analysis

- LiDAR data were obtained through the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center website (<http://maps.csc.noaa.gov/TCM/>).
- Data collected included missions flown along the eastern coast in April 2004, November 2004, and February 2006.
- LiDAR data were analyzed using ArcGIS 9.1. ArcMap was used to overlay LiDAR surveys on aerial photos.
- ArcScene was used for visualization to create three-dimensional topographic images.
- Values for average profiles were obtained using LiDAR Analyst within ArcMap. Five evenly-spaced profiles were taken along half-kilometer segments of the beach at the north end, center, and south end of the ACNWR study area and averaged.
- Two-sample t-tests were performed to evaluate changes in nesting success in nourished versus non-nourished areas.

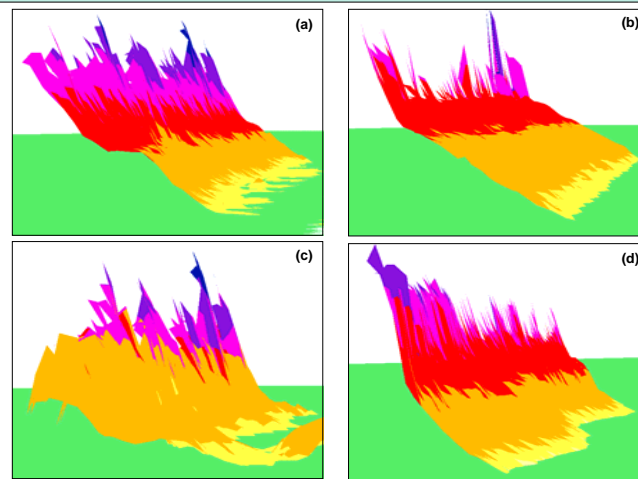


Fig. 3. Three-dimensional topographic maps of a 0.5-km segment of beach (a) before the 2004 hurricane season and (b) after the 2004 hurricane season, (c) a depiction of the change in elevation due to the storms, and (d) the segment in early 2006 after beach restoration. The green plane indicates sea level.

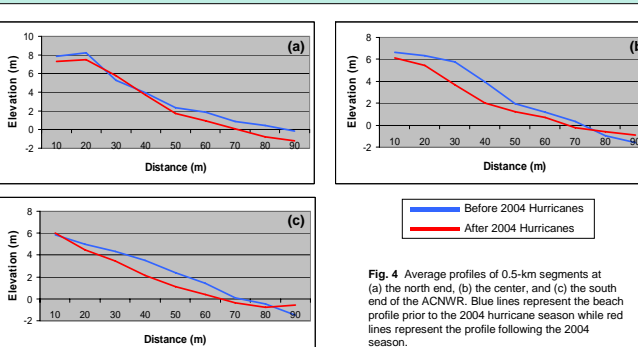


Fig. 4. Average profiles of 0.5-km segments at (a) the north end, (b) the center, and (c) the south end of the ACNWR. Blue lines represent the beach profile prior to the 2004 hurricane season while red lines represent the profile following the 2004 season.

Results and Discussion

- From inspection of the two-dimensional (Fig. 2) and three-dimensional (Fig. 3) LiDAR data, it can be seen that significant erosion occurred along most of the ACNWR.
- Average profiles (Fig. 4) show that erosion altered dune profiles.
- Nesting success declined for both loggerheads and green turtles in 2005 (Fig. 5), though further analysis is needed to determine the cause.
- Preliminary analysis shows that *C. caretta* nesting success in non-restored (i.e. eroded) beach segments was significantly less in 2005 than in 2004 ($P < 0.01$). *C. caretta* success in restored segments showed no difference from 2004 to 2005. Likewise, *C. mydas* showed no difference from 2004 to 2005 in either restored or non-restored segments, however further analysis will compare the study area to a completely natural (i.e. non-restored) beach.
- Future research will analyze beach restoration projects along the ACNWR and other areas along the east coast of Florida and assess nesting responses to these projects.

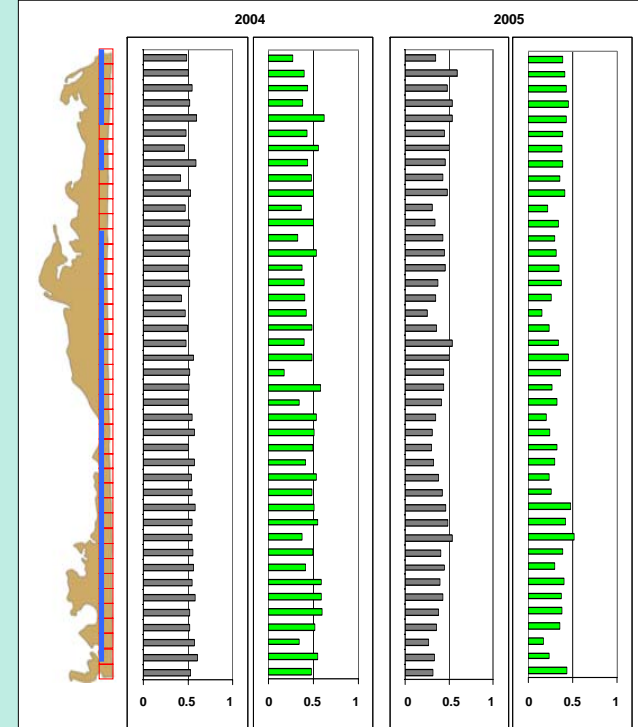


Fig. 5. Nesting success of loggerheads and green turtles by 0.5-km segment in 2004 and 2005. Areas crossed by the blue line represent segments that had at least 75% of their beach restored in early 2005. Grey bars indicate *C. caretta* success and green bars indicate *C. mydas* success.

References

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Acknowledgments

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