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Conceptual Model Development for Sea Turtle Nesting Habitat: Support for USACE Navigation Projects

by Lauren M. Dunkin, Molly K. Reif, Todd M. Swannack, and Jennifer M. Gerhardt-Smith

PURPOSE: This Dredging Operations and Environmental Research Technical Note (DOER-TN) describes the development of a conceptual model of key, spatial parameters and value range schemes to include in a spatially explicit ecological model for sea turtle nesting habitat.

INTRODUCTION: Much of the Atlantic and Gulf of Mexico coastlines are designated as critical habitat for loggerhead sea turtle (*Caretta caretta*) conservation. The terrestrial critical habitat areas include 88 nesting beaches in coastal counties located in North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi. Some of these beaches also overlap or are adjacent to areas that have U.S. Army Corps of Engineers (USACE) Navigation projects or Coastal Storm Damage Risk Reduction projects.

The USACE maintains navigation projects through dredging and strategic infrastructure that occur adjacent to many coastlines and through dredged material management activities. In addition, the USACE also utilizes beach nourishment and structures to accomplish some of its Coastal Storm Damage Risk Reduction projects in coastal areas. These projects are mission critical to maintaining safe navigation as well as reducing risk to coastal infrastructure from coastal storms. In addition, dredging of navigation channels provides sediment that can be used beneficially to create or improve the area. Key spatial parameters will be extracted from remote sensing data to be used as input in a spatially explicit ecological model in order to provide a relative suitability of habitat in areas with overlapping critical habitat designation and USACE projects. The model results can provide information needed to identify regional sediment management opportunities, evaluate project alternatives, and assess impacts to support critical USACE mission objectives. Working with the conservation priorities may lend itself to providing unique opportunities for beneficially using sediment obtained through dredging activities for improving habitat during a Coastal Storm Damage Risk Reduction project.

REMOTELY SENSED DATA: Currently, a majority of studies use nesting density as the sole indicator of suitability, and when other parameters are included, they are identified via in situ techniques for site-specific detail. The use of remote sensing data provides the unique opportunity to leverage the increasing availability of high-resolution and temporally frequent data to evaluate parameters on both a local and regional scale. The use of lidar data to quantify topographic features in relation to sea turtle nesting characteristics has been documented in recent literature (Long et al. 2011; Yamamoto et al. 2012), but the use of lidar-derived topography, bathymetry, and high spatial and spectral resolution imagery has not been fully explored to extract morphological and environmental parameters. For example, Yamamoto et al. (2012) illustrate that slope and elevation can be used to examine habitat criteria; however, they

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14. ABSTRACT

This Dredging Operations and Environmental Research Technical Note (DOER-TN) describes the development of a conceptual model of key, spatial parameters and value range schemes to include in a spatially explicit ecological model for sea turtle nesting habitat.

15. SUBJECT TERMS

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also acknowledge that the breadth of lidar-derived morphological features have not been examined for more detailed habitat mapping, and morphological features in combination with imagery-derived environmental parameters (i.e., dune vegetation) have not been attempted, primarily due to insufficient spatial resolution and extent as well as the need for current spatial data. With advances in remote sensing addressing these limitations, existing remotely sensed data (lidar-derived topography and bathymetry as well as high spatial and spectral resolution imagery) will be used to extract parameters on both a local and regional scale.

SUBJECT MATTER EXPERTS: An interagency team of subject matter experts was chosen to provide knowledge of loggerhead turtle nesting habitat and coastal processes as well as to make recommendations for model use and benefits to the USACE. The team included experts from the ERDC Environmental Laboratory (Dena Dickerson), Jacksonville District (Terri Jordan-Sellers, Paul DeMarco, and James Lagrone), and the National Oceanic and Atmospheric Administration National Marine Fisheries Service, Southeast Fisheries Science Center (Christopher Sasso). The experts participated in a webinar to review model objectives and provide information about critical parameters and specific value range criteria for the model. The members of the expert panel reviewed parameter summary documents prior to the webinar and provided feedback on the relative importance of each of the morphological, environmental, anthropogenic, and habitat parameters that can be extracted from remotely sensed data. In addition, the expert panel provided recommendations for site-selection criteria that were used to identify a few suitable study areas in which to evaluate the model.

MODEL PARAMETERS: An extensive literature review was conducted to identify all of the morphological, environmental, anthropogenic, and habitat parameters associated with loggerhead sea turtle nesting habitat. In addition, other spatial parameters were discussed with the subject matter experts to determine their value to nesting of loggerhead turtles and/or if the parameter could be used as a proxy. All of the reviewed remote sensing spatial parameters are shown in Figure 1.

<u>Parameter List and Descriptions</u>

- *Beach Slope*: The slope range is dependent on other factors that primarily include grain size and wave characteristics (height and energy). Loggerhead sea turtles have been found to nest more frequently on steeper sloped beaches (Dickerson et al. 2007; Provancha and Ehrhart 1987). Percent of slope will be used in the model based on relative regional values.
- *Beach Width*: The width of the beach (m) defines the region from the shoreline to the dune toe. Loggerhead turtles tend to prefer narrower beaches, but the designation for narrow vs. wide will be relative to regional values. Beach slope and beach width are considered to be the primary drivers of the model parameters.
- *Beach Elevation*: Beach elevation (m) is measured from the shoreline to the dune toe. Elevation influences nesting location as most nests are located above the mean high water (MHW) (Yamamoto et al. 2012; Wood and Bjorndal 2000). Data will be regionalized so that there is more than one value range.

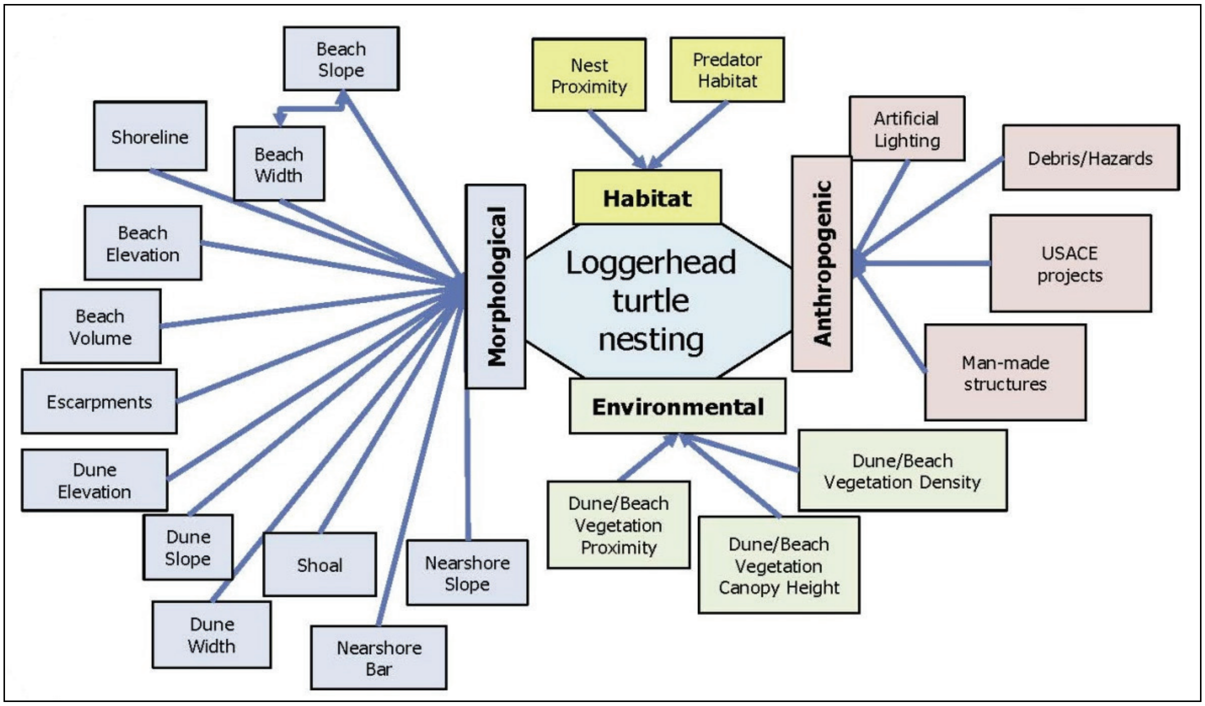

Figure 1. Conceptual model of reviewed remotely sensed spatial parameters.

- *Dune Elevation*: Dune crest (m) is measured as the peak on the foredune. Dunes provide a buffer from upland light sources and provide silhouetted areas that contrast with the lighter seaward horizon (Landry and Hughes 2008). Dune elevation may be a function of regional criteria in addition to the proximity of upland infrastructure since the dune peak will be the primary feature to shield the beach from artificial lighting, a potential deterrence to nesting.
- *Nearshore Slope*: Provancha and Ehrhart (1987) state that nearshore features may influence nest site selection of loggerhead sea turtles prior to emergence from the water. Loggerhead sea turtles have higher nesting densities in areas with a shallow nearshore. Nearshore slope may be a relative function based on regional data.
- *Nearshore Bar*: The nearshore bar may be indicated by presence/absence or as a function of distance to shore.
- *Shoal*: Shoals are nearshore features of sediment offshore of an inlet, a coastline prominence or cape associated shoal, or relic shoals. Lower nesting densities for loggerhead sea turtles have been found near shoal features (Provancha and Ehrhart 1987). In areas with a shoal, the area of the shoal may be used as an indicator for the influence it will have on nearshore currents or waves. The presence/absence of the shoal should be noted. The extent of the shoal may vary, but the feature is primarily concentrated around inlets. As with the other bathymetric features, availability of data is dependent on water clarity.
- *Dune/Beach Vegetation Proximity*: Proximity to vegetation has been found to influence loggerhead nest site selection (Garmestani et al. 2000; Hays et al. 1995). For example, studies have shown that nests tend to be clumped near the border between open sand and supralittoral or littoral vegetation (or vegetation that backs the beach). Distance to vegetation may be relative depending on location. Vegetation proximity is not a key factor, so the weighting for the parameter will likely be lower than other parameters.

- *Dune/Beach Vegetation Density*: Vegetation density (percent of coverage) is considered a secondary parameter as vegetation reduces beach erosion, increasing stability and attractiveness to nesting suitability (Landry and Hughes 2008; Varela-Acevedo et al. 2009).
- *Artificial Lighting*: Light pollution from beach front development has been found to disorient and disrupt both nesting females as well as hatchlings, increasing mortality rates (Dickerson et al. 2007; Santos et al. 2006; Landry and Hughes 2008; Varela-Acevedo et al. 2009; Salmon 2003). Artificial lightning may be included in the model as either percent of impervious surface as a proxy or defined as line of sight. This parameter may be difficult to quantify only using remote sensing data.
- *USACE Projects*: Nourishing beaches through Coastal Storm Damage Reduction Projects are commonly utilized to widen erosive beaches. The presence or absence of a nourished project may be included as a binary variable or may be used outside the model as an overlay with model results to identify areas where habitat quality could be improved.

The expert panel decided to exclude the following parameters that were identified as having limited influence on nesting habitat:

- *Shoreline*: This parameter will be used as a boundary for other parameters.
- *Beach Volume*: Beach elevation and beach width provide more valuable information regarding the beach area. Assuming there is available sand on the beach, beach volume does not directly influence nesting habitat.
- *Dune Slope/Width*: Dune elevation is the primary dune parameter to determine blocking artificial lighting potential. Dune slope and width are secondary factors to dune elevation for blocking light.
- *Dune/Beach Vegetation Canopy Height*: Loggerheads do not typically nest in vegetation, and vegetation is more a factor of blocking light.
- *Nest Proximity*: This parameter will be used to validate results from the model.
- *Predator Habitat*: Majority of predators of nests in the United States are opportunistic and do not have specific habitats (for example, fire ants, fox).
- *Man-Made Structures*: There is too much variability in the structures and appears to be a site-specific influence on nesting habitat.

Additional parameters were removed due to spatial or temporal constraints:

- *Escarpments*: This typically occurs on nourished beaches, but the spatial scale and dynamic nature may prevent reliable inclusion as a parameter.
- *Debris/Hazards*: Spatial scale, episodic periodicity, and the dynamic nature prevent inclusion of this parameter.

Upon excluding those parameters, the conceptual model was revised to include only parameters that are important for loggerhead turtle nesting habitat and correlate with the spatial and temporal resolution of the datasets. Parameters that did not meet the nesting habitat and spatial/temporal resolution criteria are dimmed in Figure 2.

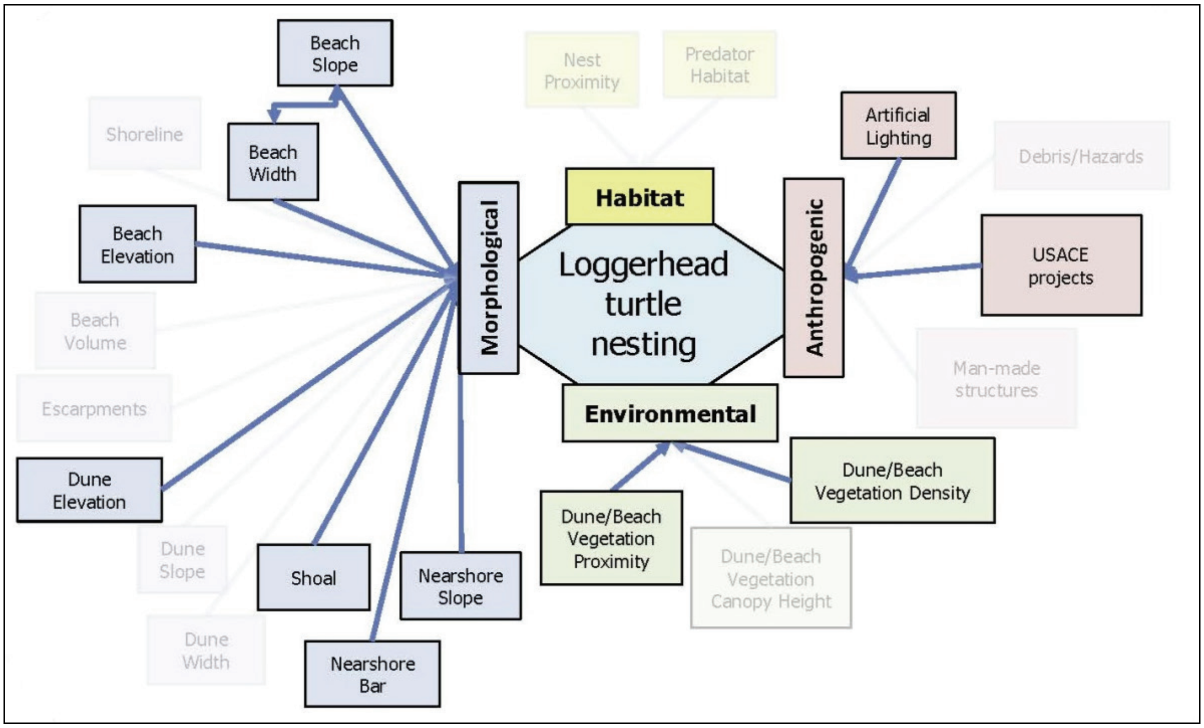

Figure 2. Conceptual model of refined parameters to include in the turtle nesting habitat model.

VALUE RANGES AND PARAMETER WEIGHTS: The subject matter experts recommended a relative function for the value ranges to be used in the model since preference by the loggerhead sea turtle for nesting habitat may vary regionally. In addition, regional values will allow for more widespread applicability of the model. Thus, the process and methods will be transferable to other sites where remotely sensed data can be used to define regional value ranges. The final parameters with the proposed value range schemes are shown in Figure 3. The asterisk at the end of the value range designation indicates that this will be a regional value range scheme.

The parameters will be assigned weights that will be used to further refine the model by determining the relative importance of each parameter. The model can be run with equal weighting and alternatively with varying weighting schemes to allow more emphasis to be placed on the primary driving parameters.

MODEL APPROACHES: Spatially explicit ecological models in a geographic information system (GIS) framework are widely used, recognized, and have been developed for the marine habitat of sea turtle life history but very rarely for the terrestrial habitats. The majority of the literature focuses on tracking turtle migration patterns compared to remotely sensed oceanographic data (Kobayashi et al. 2008; Hawkes et al. 2007). Limited literature exists describing the use of models to identify sea turtle habitat preference using measured and mapped habitat variables (Santos et al. 2006). The model will be formulated based on the key spatial parameters and regional value ranges to determine relative nesting habitat suitability in areas with overlapping critical habitat and USACE projects. The modeling approaches being considered are centered around state-of-the-art techniques in spatial analytics, including

- weighted modeling (assigning relative values to different parameters)
- suitability modeling
- indicator Kriging (spatial interpolation)
- probabilistic-based weighted simulation (e.g., Monte Carlo replicates).

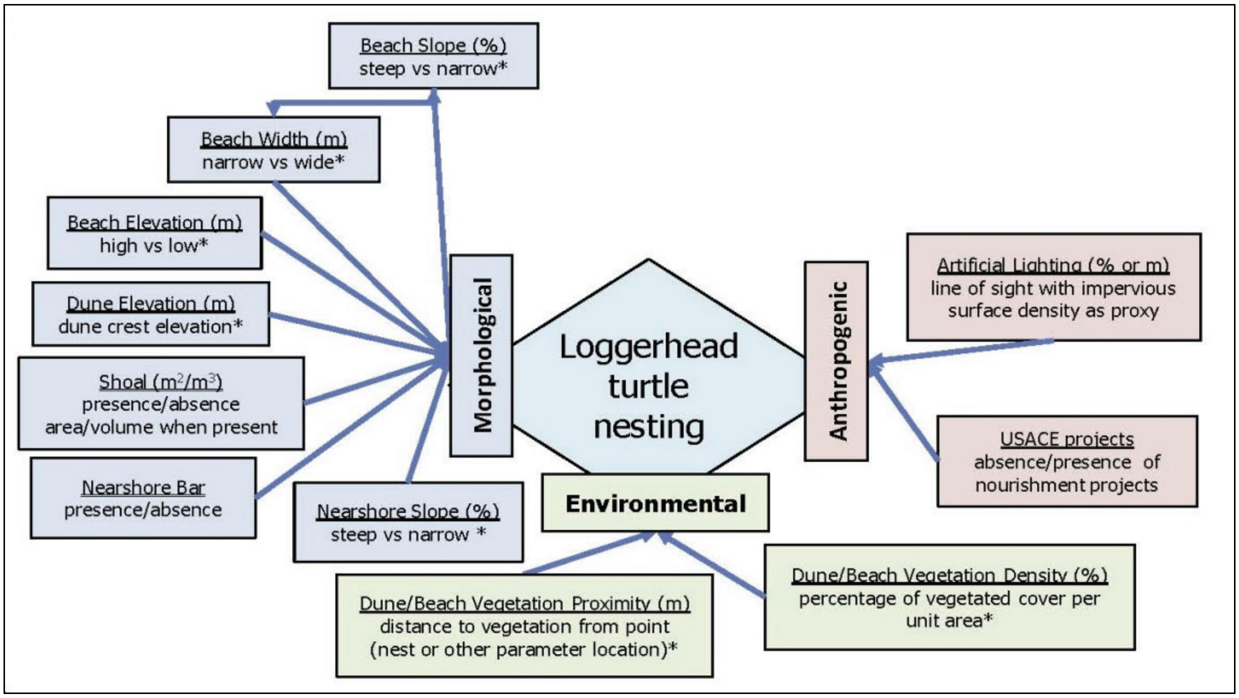

Figure 3. Conceptual model of final parameter list with value range scheme.

It is likely that a combination of the above approaches will be used. Spatial analyses are advantageous for this study since one of the goals seeks to determine the value of using remote sensing data for extracting morphological and environmental parameters to improve model capabilities supporting USACE planning and management objectives.

SUMMARY: The purpose of this DOER-TN is to provide an overview of the conceptual model and key spatial parameters identified for use within a spatially explicit ecological model for loggerhead turtle nesting habitat. The model framework was generated based on input from the subject matter experts and data found during the literature review. The conceptual model framework and supporting document includes information about the (1) list of extractable spatial parameters, (2) regional value range schemes, and (3) major geoprocessing steps required to process the spatial parameters.

This work lays the foundation for future model development and evaluation, and it will benefit the USACE by providing a higher-level approach to support operations and planning decisions. Furthermore, it will be used to inform and address integrated resource management concepts, such as those included in Environmental Operating Principles and Engineering with Nature, for use by the Navigation and Coastal Storm Damage Risk Management mission areas. The end result will provide an information tool for agency partners to better communicate management

priorities and efficiently evaluate management strategies assessing the relative suitability of the loggerhead critical nesting habitat areas highlighting habitat needs.

POINTS OF CONTACT: For additional information, contact Lauren Dunkin (Voice: 228-252-1142, e-mail: *Lauren.M.Dunkin@usace.army.mil*). This technical note should be cited as follows:

> Dunkin, L. M., M. K. Reif, T. M. Swannack, and J. M. Gerhardt-Smith. 2014. *Demonstration of sea turtle habitat modeling using remotely sensed data*. ERDC TN-DOER-R23. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://chl.erdc.usace.army.mil/chetn*

REFERENCES

Dickerson, D. D., J. Smith, M. Wolters, C. Theriot, K. J. Reine, and J. Dolan. 2007. A review of beach nourishment impacts on marine turtles. *Shore and Beach* 75(1):49–56.

Garmestani, A. S., F. Percival, K. M. Portier, and K. G. Rice. 2000. Nest-site selection by the loggerhead sea turtle in Florida’s ten thousand islands. *Journal of Herpetology* 34(4):504–510.

Hawkes, L. A., A. C. Broderick, M. S. Coyne, M. H. Godfrey, and B. J. Godley. 2007. Only some like it hot – quantifying the environmental niche of the loggerhead sea turtle. *Diversity and Distributions* 13:447–457.

Hays, G. C., A. Mackay, C. R. Adams, J. A. Mortimer, J. R. Speakman, and M. Boerema. 1995. Nest site selection by sea turtles. *Journal of Marine Biology* 75:667–674.

Kobayashi, D. R., J. J. Polovina, D. M. Parker, N. Kamezaki, I. Cheng, I. Uchida, P. H. Dutton, and G. H. Balazs. 2008. Pelagic habitat characterization of loggerhead sea turtles, Caretta caretta, in the North Pacific Ocean (1997–2006): Insights from satellite tag tracking and remotely sensed data. *Experimental Marine Biology and Ecology* 356:96–114.

Landry, A. M., and C. L. Hughes. 2008. *Guide to managing sea turtle nesting habitat on the upper Texas coast*. Prepared by the Sea Turtle & Fisheries Ecology Research Laboratory, Texas A&M University at Galveston. Texas General Land Office Coastal Management Program.

Long, T. M., J. Angelo, and J. F. Weishampel. 2011. LiDAR-derived measures of hurricane- and restoration-generated beach morphodynamics in relation to sea turtle nesting behavior. *International Journal of Remote Sensing* 32(1).

Provancha, J. A., and L. M. Ehrhart. 1987. Sea turtle nesting trends at John F. Kennedy Space Center and Cape Canaveral Air Force Station, Florida, and relationships with factors influencing nest site selection. In *Ecology of East Florida Sea Turtles: Proceedings of the Cape Canaveral, Florida Sea Turtle Workshop*. National Oceanographic and Atmospheric Administration Technical Report NMFS-53, 33–44. NOAA, National Marine Fisheries Service.

Salmon, M. 2003. Artificial night lighting and sea turtles. *Biologist* 50(4):163–168.

Santos, K. C., C. Tague, A. C. Alberts, and J. Franklin. 2006. Sea turtle nesting habitat on the U.S. Naval Station, Guantanamo Bay, Cuba: A comparison of habitat suitability index models. *Chelonian Conservation and Biology* 5(2):175–187.

Varela-Acevedo, E., K. L. Eckert, S. A. Eckert, G. Cambers, and J. A. Horrocks. 2009. Sea turtle nesting beach characterization manual. In: Examining the Effects of Changing Coastline Processes on Hawksbill Sea Turtle (Eretmochelys imbricate) Nesting Habitat, 46–97. Master’s Project. Nicholas School for the Environmental and Earth Sciences, Duke University, Beaufort, NC.

Wood, D. W., and K. A. Bjorndal. 2000. Relation of temperature, moisture, salinity, and slope to nest site selection in loggerhead sea turtles. *American Society of Ichtyologists and Herpetologists* COPEIA(1):119–128.

Yamamoto, K. H., R. L. Powell, S. Anderson, and P. C. Sutton. 2012. Using LiDAR to quantify topographic and bathymetric details for sea turtle nesting beaches in Florida. *Remote Sensing of Environment* 125(2012):125–133.