Sea turtle responses to barriers on their nesting beach

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1 Accepted 19 March 2011
2 Received 26 March 2010
3 Received in revised form 18 March 2011

A R T I C L E I N F O
Article history:
Received 26 March 2010
Received in revised form 18 March 2011
Accepted 19 March 2011

Keywords:
Beach erosion
Behavior
Caretta
Coastal armoring
Egg survivorship
Loggerhead
Seawalls

A B S T R A C T
We experimentally studied the nesting behavior and nest-site choice of loggerhead sea turtles (Caretta caretta) that emerged to nest at night on a beach in southern Brevard County, Florida USA. Emerging turtles were divided between two paired treatments: wall and control. Intercepted turtles in the wall treatment were presented a portable wall that blocked their ascent of the beach. The position of the portable wall was shore-parallel and midway between the recent wrack line and the dune toe. Intercepted turtles in the control treatment ascended the beach and did not encounter a wall. We observed individual turtles in both wall and control treatments so that their nesting behavior could be measured. We observed 44 female loggerheads (22 paired samples). In the control treatment, 15 of 22 turtles completed a nest, and in the wall treatment, 14 of 22 turtles completed a nest. There was no significant difference in nesting success (nests/attempts) between treatments (Chi-square = 0.10, p = 0.75). However, effects from the wall resulted in wall-treatment nests being 3.5 m closer to the surf than control nests, on average. Although it was possible for turtles to nest within 0.5 m of the wall, mean distance of nests from the wall was 3.2 m (SD ± 2.0 m). Although the wall affected the location where nesting occurred, there was no observable effect on the effort turtles made to prepare the nest site, dig an egg chamber, fill it with eggs, cover the eggs, or camouflage the nest site. Egg survivorship did not differ significantly between treatments; however, the sample size was not large enough to detect biologically significant differences in hatching success amidst the high variation in the data. An additional factor that made our test of hatching success less rigorous was the absence of significant beach erosion during the study period. Erosion has been shown to be the principal cause of mortality for nests low on the beach and can cause 100% mortality in the region of beach where the wall-treatment nests were located.

Published by Elsevier B.V.

1. Introduction

Sea turtles (Cheloniidae and Dermochelyidae) are marine reptiles that have declined from their historical abundance due to a variety of anthropogenic effects (National research council, committee on sea turtle conservation, 1990). Few sea turtle populations have shown recovery and 6 of 7 species are listed within the US Endangered Species Act of 1973 as being Threatened or Endangered.

Nesting of sea turtles occurs on sand beaches that are exposed to wave energy from warm water seas. Nest sites selected by sea turtles are most often on the backshore between mean high water and the line where either the wave-cut escarpment or permanent vegetation begins (Witherington, 1986; Hays et al., 1995). Nesting occurs between late spring and late summer on most temperate beaches and commonly during the rainy season on tropical beaches (Dodd, 1988; Hirth, 1997; Miller, 1997; Miller et al., 2003). Most nesting is nocturnal.

Nesting behavior comprises a series of action patterns that are similar for all sea turtle species (Miller, 1997). Action patterns include 1) emerging from the sea, 2) preparing the nest site by digging a body pit (sometimes at multiple trial locations), 3) digging an egg chamber within the body pit, 4) depositing eggs within this chamber, 5) covering the eggs using rear flippers, 6) camouflaging the site by casting sand with all flippers, and 7) returning to the sea (simplified from Hallman and Bowson, 1992). These action patterns determine the elevation of the nest, suitability of nest substrate and surroundings, depth of the eggs, and attractiveness to predators. The highly conserved nature of nesting behaviors among sea turtle species suggests that these patterns play an important role in egg survivorship. One of the most important sources of egg mortality is exposure and drowning of eggs that have been eroded from the beach (Witherington, 1986; McGeehee, 1990; Foley et al., 2006).

Beaches are the sea turtle habitat that overlaps most with human populations and are greatly affected by human activities. Because most nesting occurs at night, direct contact between sea turtles and humans is minimized; however, anthropogenic structures affixed on the beach have the potential for persistent effects on sea turtles and nests.
their nests. Structures with the greatest effects are likely to be those with the potential to act as barriers. Some of the structures that fit into this category include beach access structures (dune crossovers), sand fences, recreational equipment, temporary buildings, and a wide array of coastal armoring, which includes seawalls, rock revetments, and sandbags designed to protect upland property from erosion. Coastal armoring and other sand-retaining structures have a great potential to act as nesting barriers because of their solid, lengthy configuration and shore-parallel construction. Witherington et al. (in press) found that seawalls were the most common potential barrier to sea turtle nesting on the beaches of Florida (USA).

Sea turtles attempting to nest on armored beaches have been shown to abandon their attempts at a higher rate than turtles emerging onto adjacent stretches without armoring (Mosier, 1998). However, there has been little understanding of the biological consequences of armoring on nesting beaches—such as changes in egg mortality and fitness of nesting females. Nor has there been a clear demonstration of the direct effects of armoring—effects that are independent of effects from the beach on which the structure sits. Armoring present at a nesting beach is likely to have been constructed because of severe beach erosion and may have contributed to additional erosion at the site (Pilkey and Wright, 1988). Thus, it is difficult to attribute nesting pattern changes to individual effects from the armoring barrier, from the eroded beach, or from other confounding factors associated with armoring and coastal development.

Barriers to sea turtle nesting prevent nesting landward of the structure. As a result, we hypothesize that barriers would alter the vertical distribution of nests made by turtles not deterred from nesting. Even a subtle change in nest elevation could have important consequences, and these consequences would be more severe with the progression of climate change. For example, sea level rise and an increase in storminess would be expected to inundate lower beach areas and destroy nests of turtles prevented from upper-beach access (Hawkes et al., 2009; Poloczanska et al., 2009).

The purpose of this study was to experimentally measure how artificial barriers encountered by nesting sea turtles affect nest-site choice and the nesting behaviors that influence egg survivorship. To measure effects from barriers, we presented a portable wall to turtles as they emerge to nest, recorded their behavior, monitored their nests, and compared these measurements to turtle behaviors and nests at the same beach without the wall present. We chose a relatively stable (during the study period) undeveloped stretch of beach that had a high level of nesting by loggerhead sea turtles (Caretta caretta).

2. Materials and methods

The study area where we conducted field experiments was the beach at the Archie Carr National Wildlife Refuge near Melbourne Beach in southern Brevard County, Florida USA (27.9° N, 80.5° W). The Atlantic beaches in this region of Florida receive high wave energy, have a steep slope, coarse-grained sediments, and have never been artificially nourished. During the period of study, June–August 2003, the shoreline did not reveal any evidence of significant net erosion. This beach has one of the highest densities of nesting loggerhead sea turtles in the Western Hemisphere (Witherington et al., 2009).

Nesting density within the region of beach studied ranged approximately 300–1000 nests/km/season during the period 1998–2010 (Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Index Nesting Beach Database, unpublished data). We studied the nesting behavior and nest-site choice of loggerhead sea turtles that emerged to nest on the southern Brevard County study beach. Emerging turtles sampled in this study were divided between two paired treatments: wall and control. Samples were paired such that a wall-treatment turtle and a control turtle were sampled on the same or subsequent nights. We randomized the sampling order of wall-treatment and control turtles. We did not know the history of each turtle used in the experiment; some may have attempted to nest previously. However, we were careful not to bias our selection of subject turtles based on whether they had nested. Thus, to the extent that nesting history affected each turtle’s propensity to nest, this shortcoming simply added variation to our measurements and not bias. On Florida beaches, loggerhead females nest on approximately 50% of their nesting attempts that proceed above the swash zone (Witherington et al., 2009).

We intercepted individual turtles assigned to each treatment as they emerged from the surf and before they had neared the recent high tide line. To reach turtles at this specific point in their nesting sequence, the duration of which is approximately 5 min, we patrolled the beach at night with a small 4-wheeled balloon-tired motorcycle. At each intercepted turtle, we were able to recognize the silhouette of the turtle, stop the motorcycle at a distance of >20 m, approach the turtle from behind at the surf line, and conduct our observations and measurements without the turtle responding to our presence. In order to remain inconspicuous we made all of our detailed observations from a vantage point behind the turtle where its carapace concealed us from view. On moonless nights, we used a dim red light to aid our vision. Two turtles that immediately turned away and crawled back to the water when we began to observe them were not used in the study. We also excluded one turtle with flipper injuries (rear flipper largely missing) that would have affected its ability to dig an egg chamber. The missing flipper was evident from a preliminary inspection of the turtles’ track up the beach.

Intercepted turtles that were assigned to the wall treatment were presented a portable wall that blocked their ascent of the beach. The wall was a 2-m-wide and 1-m-high solid sheet of PVC plastic held rigid by a tubular PVC frame. We positioned the wall in front of the emerging turtle by dragging it into place down the beach at the base of the dune silhouette (to conceal this movement from the turtle), by erecting the wall at the dune base, and by slowing moving the wall toward the turtle. An experimenter concealed behind the wall positioned it with the help of a second concealed experimenter who had quickly measured the appropriate position for the wall by counting standard paces. This concealment in the dune, slow steady movement of the wall, and hidden observers proved successful in positioning the wall without eliciting a flight response from the turtle in 22 of 23 attempts (one sample attempt was discarded).

The final position of the portable wall was shore-parallel and midway between the recent wrack line and the dune toe (all locations had a prominent dune and a clearly identifiable escarpment base). This location for the wall was chosen for three reasons: 1) the wall in this location would divide the beach near the center of the spatial distribution of loggerhead nests (Witherington, 1986) such that approximately half of the nested beach would be blocked, 2) this location could be found easily using landmarks identified at night, and 3) the location represented a plausible location for a seawall, revetment, or similar structure.

All wall-treatment turtles in this study continued to crawl up the beach after the wall was put into position. If turtles attempted to crawl around the wall, the wall was slowly moved in a shore-parallel direction so that it continued to block the turtle’s access to the beach landward of the wall. Shore-parallel repositioning of the wall took place simultaneous with the turtles’ crawling movements so that the possibility of a flight response was minimized. No turtles abandoned their nesting attempt during movement of the wall.

Intercepted turtles that were previously assigned to the control group ascended the beach and did not encounter a wall. We observed individual turtles in both wall and control treatments so that the fixed action patterns of their nesting behavior could be measured. The action patterns measured followed the ethogram prepared by (Hallman and Elowson, 1992). Table 1 describes how each action pattern in the nesting behavior sequence was timed.

The locations of tracks, nesting attempts, and nests were determined by recording positions with a differentially corrected global positioning system (DGPS) and by direct measurements with a fiberglass tape. For
ABANDONED ATTEMPTS

accurate counting of total clutch size from hatched and unhatched eggs, and numbers of hatchlings that did not emerge or after 70 days. Nest inventories recorded numbers of marked clutches, using DGPS and a FX-3 magnetic locator. We relocated iron bars, to dig egg chamber and to end of final flipper stroke. First egg to first flipper stroke to first egg chamber to first front flipper stroke covering the body pit to first crawling. First egg to first flipper stroke filling and packing the egg chamber.

return First crawling to the turtle’s head reaching the recent high tide mark.

Locations of beach landmarks used in positioning the portable wall presented to turtles in the wall treatment and in measuring positions of tracks and nests from turtles in either wall or control treatments. Landmarks are: A, dune toe; B, the line where the portable wall was or would have been positioned (approximately midway between A and C); C, spring-tide wrack line; and D, recent high-tide line. For all sampled turtles, mean distances (±SD) between landmarks were: A-B = 5.2 ± 1.2 m; B-C = 4.5 ± 1.1 m; and C-D = 3.6 ± 0.7 m.

Fig. 1. Locations of beach landmarks used in positioning the portable wall presented to turtles in the wall treatment and in measuring positions of tracks and nests from turtles in either wall or control treatments. Landmarks are: A, dune toe; B, the line where the portable wall was or would have been positioned (approximately midway between A and C); C, spring-tide wrack line; and D, recent high-tide line. For all sampled turtles, mean distances (±SD) between landmarks were: A-B = 5.2 ± 1.2 m; B-C = 4.5 ± 1.1 m; and C-D = 3.6 ± 0.7 m.

Fig. 2. Relative position on the beach of crawls (nests and abandoned nesting attempts) made by loggerhead sea turtles presented a portable wall (wall treatment) or no wall (control treatment). Relative distance from dune toe was measured as the percent of total beach from dune toe to recent high-tide line at each crawl. Positions of nests were represented by clutch location. Positions of abandoned attempts were represented by the center of the track at the point where the turtle turned toward the surf, which was always the most landward point in this study. Mean relative distance (±SD) of the wall location in both wall and control treatments was 39% ± 4%.

3. Results

We observed 44 female loggerheads during their nocturnal nesting attempts. Measurements from turtles were made as 22 paired samples (wall and control treatments). However, each turtle in a pair did not always either complete a nest or abandon their attempt, and as such, we could not assign comparable data pairs to paired statistical tests. Tests on independent samples were used.

In the control treatment, 15 of 22 turtles completed a nest, and in the wall treatment, 14 of 22 turtles completed a nest. A Chi-square test revealed no significant difference in nesting success (nests/attempts) between treatments (Chi-square = 0.10, p = 0.75). A normal approximation interval of 95% (a binomial confidence interval) was 0.68 ± 0.19 for nesting success in the control treatment and 0.64 ± 0.20 in the wall treatment.

Female loggerheads in the control treatment made nests or turned to abandon their nesting attempts at points spread over the entire beach between the dune and the recent high tide line (Fig. 2). Two control turtles nested landward of the dune toe. Turtles in the wall treatment could only attempt to nest seaward of the portable wall, but their nesting attempts did not cluster at the base of the wall (Fig. 2). The mean distance (±SD) between control nests (n = 15) and high

Table 1

<table>
<thead>
<tr>
<th>Action pattern, this study</th>
<th>Timing definitions using terms from Hailman and Elowski (1992)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence</td>
<td>Ascent of the beach timed from turtle’s head at recent high tide mark to first flipper stroke to make body pit</td>
</tr>
<tr>
<td>Body pitting</td>
<td>First flipper stroke to make body pit to first rear-flipper stroke to dig egg chamber</td>
</tr>
<tr>
<td>Digging</td>
<td>First rear-flipper stroke to dig egg chamber to end of final flipper stroke</td>
</tr>
<tr>
<td>Egg latency</td>
<td>End of final flipper stroke to dig egg chamber to first egg</td>
</tr>
<tr>
<td>Egg laying</td>
<td>First egg to first rear-flipper stroke filling and packing the egg chamber</td>
</tr>
<tr>
<td>Covering</td>
<td>First rear-flipper stroke filling and packing the egg chamber to first front flipper stroke covering the body pit</td>
</tr>
<tr>
<td>Camouflaging</td>
<td>First front-flipper stroke covering the body pit to first crawling</td>
</tr>
<tr>
<td>Return</td>
<td>First crawling to the turtle’s head reaching the recent high tide mark</td>
</tr>
</tbody>
</table>

Each site where turtles were sampled, we also measured distances of three beach landmarks from the dune toe: recent tide line, spring-tide wrack line, and the line where the portable wall was or would have been positioned (Fig. 1). In control turtles, the line between the wrack and the dune was measured in the same way (by pacing) as the cursory measurements made for the placement of the wall for the wall treatment.

We marked all nests so that the exact location of the clutch could be found following the approximately 8-week incubation period. A DGPS recorded clutch position and an iron bar was buried deeper than the clutch at a standard bearing 0.5 m away. We relocated iron bars, and the marked clutches, using DGPS and a FX-3 magnetic locator. Marked nests were inventoried three days after evidence of hatching emergence or after 70 days. Nest inventories recorded numbers of hatched and unhatched eggs, and numbers of hatchlings that did not escape from the nest. The papery eggshells of sea turtles allow an accurate counting of total clutch size from hatched and unhatched eggs (Witherington, 1986). We assessed hatching success as the proportion of eggs resulting in a hatching that left the egg, and we assessed emerging success as the proportion of eggs resulting in hatchlings that emerge from the nest.
tide lines was 8.6 ± 2.9 m and the mean distance between wall-treatment nests (n = 14) and tide lines was 5.1 ± 2.8 m.

The duration of each measured action pattern in the nesting behavior sequence was statistically similar between control and wall-treatment turtles (Table 2). Total duration of nesting was also similar between treatments. One difference in nesting behavior that is not revealed through the duration of action patterns is the behavior of turtles that contacted the portable wall. Two of 22 wall-treatment turtles contacted the wall and attempted to crawl around it. One turtle moved along the wall for 4.0 m and completed a nest. The other turtle crawled along the wall for 9.9 m before abandoning the nesting attempt. These two turtles showed behavior consistent with an attempt to crawl over the wall similar to authors’ observations of turtles at mid-beach sand escarpments.

We were able to determine fates of 12 control nests and 13 wall-treatment nests. Three control nests and one wall-treatment nest could not be found because nest markers were removed. For control nests, mean hatching success (±SD) was 71 ± 29% and mean emerging success was 70 ± 28%. In wall-treatment nests, mean hatching success (±SD) was 55 ± 40% and mean emerging success was 47 ± 41%. We transformed the hatching and emerging success proportion values by arcsin square root and performed a t-test for independent samples. Neither hatching success (p = 0.12) nor emerging success (p = 0.06) differed significantly between control and wall treatments. In a t-distribution power analysis to determine sample size, we found that with our observed sample variances, and with alpha = 0.05 and beta = 0.20, detecting a 20% difference in mean hatching success between treatments would require approximately 20 nests and that a 10% difference would require approximately 80 nests.

4. Discussion

4.1. Barrier effects on nesting success (nests/attempts) and nest-site choice

Proportions of loggerheads that abandoned their nesting attempts were nearly identical between control and wall treatments. For undisturbed sea turtles attempting to nest on undeveloped beaches, approximately half of nesting attempts result in nests (Meylan et al., 1995; Witherington et al., 2009). Thus, we believe that the nesting success we observed (60–70%) was not significantly lowered by effects from observers.

In a study of the effects of existing seawalls on loggerhead nesting, Mosier (1998) found that turtles at 2 of 3 sites attempted to nest at a significantly lower frequency in front of seawalls compared to nesting attempts at adjacent non-walled beaches. Mosier also observed that nesting success was lower at walled beaches than at adjacent non-walled beaches. In the present study, turtles had no opportunity to respond to the portable wall until the turtle was already ascending the beach because this was the time at which we presented the wall. However, turtles in our study did have opportunities to abandon their nesting attempts on the beach after experiencing the portable wall.

Differences in nesting-success effects from the portable wall and from the existing walls in the Mosier study suggest that actual seawalls have effects in addition to being physical barriers to nesting turtles. One such effect may be from altered beach profiles that result from wave and current energy altered by the wall. These beach changes include lowering of beach elevation and the production of scour holes (Kraus and McDougal, 1996). In addition, beaches fronting seawalls might also be expected to have had a preexisting eroded profile that was the justification for the armor. Although Mosier measured beach profile and found little difference between walled and non-walled beaches, low-beach and nearshore profile were not measured. An additional difference between our portable wall and existing walls may come from the visual appearance of a high seawall with accompanying buildings on the dune. In our study, the wall height was 1 m. In the Mosier study, wall height was typically 2 m, with additional silhouette height contributed by buildings immediately landward of the seawalls.

In a study of how exposed beach pilings affected loggerhead nesting, Bouchard et al. (1998) counted nesting attempts on beaches with and without artificial pilings positioned at mean high water, 5.2 m apart. They found that the number of nesting attempts was approximately 41% lower than the number of attempts on the adjacent beach without pilings. Bouchard et al. did not report data for nesting success. It is likely that the stimulus provided by the pilings was different from the stimuli from the existing seawalls in the Mosier (1998) study and also different from the stimulus of the portable wall in this study. Many of the turtles that physically encountered the pilings would have been in or near the swash zone where a number of cues (such as wet sand or wave wash) are available to indicate to a turtle that seaward of the encountered piling was not an appropriate nest site. However, given the spacing of the pilings, some turtles could ascend the beach without being deterred by pilings. Wall-treatment turtles in our study had no possibility of ascent beyond the wall but may have assessed that the dry sand on the lower beach was acceptable nesting habitat.

Our results do not conform with observations of reductions in sea turtle nesting success where there have been major artificial alterations of beach profile (i.e., beach nourishment, Brock et al., 2009), which occur on artificial beaches along with other confounding factors such as scarping and increased sand compaction (Crain et al., 1995; Rumbold et al., 2001). Further, the nesting turtles in our experiment did not abandon their nesting attempts as has been observed where turtles encounter impediments to digging such as compact sand, shell hash, and roots from dune plants (BEW, personal observation). In their observation of increased nest abandonment by loggerhead turtles near vegetation, Hays and Speakman (1993) noted lower sand temperature at these plant-shaded sites, which also could have had roots that hindered digging.

Although the portable wall did not have a significant effect on the turtles’ decisions to nest or abandon nesting, the wall did have an effect on nest-site choice. Because nesting females could not ascend the beach beyond the wall, they could only nest seaward of the barrier. One hypothesized outcome of this experiment predicted that nesting attempts and nests would cluster near the wall. Reasoning behind this hypothesis was that turtles with a propensity to nest higher on the beach than the wall would allow would ascend the beach as high as they could. This hypothesis was not supported by our measurement of nest and nesting-attempt positions (Fig. 2). Turtles that were presented the portable wall while emerging to nest either completed a nest or abandoned their attempt at points distributed throughout the dry beach available to them. Likewise, nesting attempts in the control treatment were also distributed throughout the available dry beach. Effects from the wall resulted in wall-treatment nests being 3.5 m closer to the surf.

Table 2
Duration of nesting behavior action patterns observed in 15 control loggerheads and 14 wall-treatment loggerheads that completed nesting. Control-treatment turtles experienced no barrier to their access of the beach and wall-treatment turtles encountered a portable wall positioned between the dune toe and the wrack line.

<table>
<thead>
<tr>
<th>Action pattern</th>
<th>Control treatment (±SD)</th>
<th>Wall treatment (±SD)</th>
<th>p t-test for independent samples, two-tailed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence</td>
<td>3.9 ± 1.6</td>
<td>2.9 ± 2.2</td>
<td>0.17</td>
</tr>
<tr>
<td>Body pitting</td>
<td>6.4 ± 3.1</td>
<td>6.5 ± 2.0</td>
<td>0.92</td>
</tr>
<tr>
<td>Digging</td>
<td>25.0 ± 9.0</td>
<td>22.0 ± 6.7</td>
<td>0.32</td>
</tr>
<tr>
<td>Egg latency</td>
<td>1.8 ± 0.8</td>
<td>2.2 ± 1.3</td>
<td>0.32</td>
</tr>
<tr>
<td>Egg laying</td>
<td>20.4 ± 3.3</td>
<td>21.5 ± 6.0</td>
<td>0.58</td>
</tr>
<tr>
<td>Covering</td>
<td>16.0 ± 5.0</td>
<td>15.4 ± 4.6</td>
<td>0.49</td>
</tr>
<tr>
<td>Camouflaging</td>
<td>20.3 ± 8.1</td>
<td>17.6 ± 6.9</td>
<td>0.15</td>
</tr>
<tr>
<td>Return</td>
<td>1.6 ± 0.7</td>
<td>1.1 ± 1.0</td>
<td>0.16</td>
</tr>
<tr>
<td>Total nesting</td>
<td>96.0 ± 21.7</td>
<td>89.2 ± 19.0</td>
<td>0.37</td>
</tr>
</tbody>
</table>
than control nests, on average. Although it was possible for turtles to nest within 0.5 m of the wall we presented, mean distance of nests from the wall was 3.2 m (SD = 2.0 m). The nesting loggerheads we observed seemed to be distributing their nesting attempts as if the beach seaward of the barrier wall were a narrow beach.

Several hypotheses have been forwarded to explain nest-site selection in sea turtles. One hypothesis is that sea turtles select nest sites randomly, resulting in a spatial distribution of nests that is scattered relative to beach and dune features (Mroskovsky, 1983; Eckert, 1987). This hypothesis was tested by Hays et al. (1995), who measured a clumped distribution for loggerhead nests on a Florida beach and proposed that the distribution could result from turtles crawling a normally distributed mean random distance from the high tide line. The Hays et al. study supports an unbiased nest distribution relative to beach features other than the high tide line.

Other hypotheses propose that sea turtles use micro-habitat cues to determine where nests would be made. Various authors have presented correlative evidence that sea turtles select cross-beach (vertical) nest locations using cues from temperature (Stoneburner and Richardson, 1981), beach slope (Provancha and Ehrhart, 1987; Wood and Bjorndal, 2000), or dune height (Camhi, 1993). Supporting the use of temperature cues, Stoneburner and Richardson (1981) found that digging by nesting loggerhead turtles correlated with abrupt temperature increases of approximately 1.5°C. But this temperature-cue hypothesis was not supported by the observations of Camhi (1993) nor by analyses of a range of beach characteristics measured by Wood and Bjorndal (2000). Wood and Bjorndal found that among the beach characters of slope, temperature, moisture, and salinity, only slope strongly predicted where loggerhead nests would be made. This slope-cue hypothesis is supported by observations made by Provancha and Ehrhart (1987) who found loggerhead nesting near Cape Canaveral, Florida, to be positively correlated with beach steepness.

Results from the present experiment conform best with the observations of Camhi (1993), who hypothesized that dune features influence spatial nest placement in loggerheads. In this extension of our results, we propose that nesting loggerheads may respond to artificial walls no differently than to dune topography or to prominent escarpments on the beach. We further propose that this response is to visible topographical cues. Support for this is that the turtles in our wall treatment positioned their nests more seaward than those in the control, even though 91% of the wall-treatment turtles did not physically encounter the wall. Additional support of visual cues used by nesting sea turtles comes from experiments by Witherington (1992) who found artificial lighting to deter sea turtles from making nesting attempts, and by Salmon et al. (1995), who observed loggerhead nests on a beach back-lighted by urban glow to be clustered along the beach in front of large trees and multi-story buildings. Similar observations of loggerhead nests clumped in front of vegetation on a natural beach (Hays and Speakman, 1993) suggest that under an array of ambient conditions, the silhouette of elevated dune features may be important in guiding sea turtle nest-site choice.

The present study and Witherington (1992) appear to be the only experimental analyses, controlled for confounding (correlated) factors, to assess how external stimuli affect the distribution of sea turtle nests. Granted, the portable wall that we presented to turtles was not a stimulus found on natural beaches, but it may approximate the stimulus provided by an escarpment or by other barriers that turtles would naturally encounter on a beach. Indeed, two of our turtles seemed to treat the wall as if it were a surmountable (i.e., collapsible) feature. The hypothesis for nest-placement stimuli most supported by our study is the prediction that visible dune features influence nest placement. The stimulus that the wall provided to turtles that never reached it may mimic the stimuli provided by visible dune features. Our study does not give an adequate test of the importance of slope, temperature, or other beach characters, and it is possible that several of these factors also play a role in sea turtle nest placement.

4.2. Barrier effects on nesting behavior

The presence of the portable wall did not significantly affect the duration of individual action patterns or the total duration of nesting (Table 2). Although the portable wall clearly affected the location where the nesting behavior was expressed, there was no observable effect on the effort turtles made toward preparing the nest site, digging an egg chamber, filling it with eggs, covering the eggs, or camouflaging the nest site. Only two of 22 turtles attempted to crawl around the wall and access the upper beach. This is in contrast to the behavior of turtles in the control treatment, where 10 of 22 turtles attempted to nest on the beach beyond the line where the wall would have been positioned. Two control turtles crawled up the sand escarpment and into the dune to nest landward of the dune toe. Turtles scaled this obstacle by cutting away at the sand escarpment and partially collapsing it so that an inclined plane of sand formed allowing access to the dune. The two wall-treatment turtles that contacted the wall during their nesting attempts seemed to behave similarly to the turtles attempting to scale the sand escarpments.

4.3. Barrier effects on egg survivorship

It is likely that egg survivorship is the principal selective force that has shaped sea turtle nesting behavior. Egg survivorship is also critical to sea turtle conservation efforts. Anthropogenic effects that create conditions favoring egg mortality are important impediments to the recovery of the loggerhead and other sea turtles (National Marine Fisheries Service and US Fish and Wildlife Service, 1991). We do not feel that our study was an adequate test of egg survivorship affected by nest placement. Our sample size was not large enough to detect biologically significant differences in hatching success amidst the high variation in the data. An additional factor that made our test of hatching success less rigorous was the absence of significant beach erosion during the study period. Erosion from storms and persistent high waves is the principal cause of mortality to eggs in nests low on the beach. In a stormy year, we have observed erosion to destroy nearly 100% of the nests in the region of beach where the wall-treatment nests were located (Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Hatching Productivity Database, unpublished data).

In a study that took place on the same beach in southern Brevard County, Witherington (1986) found that loggerhead nests within the lowest of three beach zones had the lowest hatching and emerging success. This lowest beach zone was similar to the area of beach seaward of the portable wall in this study. In the authors’ experience with hatching success assessments as part of a multi-year hatching productivity survey in Florida, it is clear that during tropical storm events, the only surviving eggs are found in nests on the landward half of the beach, above the location where the portable wall was positioned in this study.

5. Conclusions

Barriers such as exposed seawalls and other types of coastal armoring can prevent use of the upper beach by nesting sea turtles. One important outcome of this restriction of beach access is a change in the spatial distribution of nests on the beach. Rather than abandoning their nesting attempts, the turtles in this study made nests seaward of the barrier in a zone that would normally receive only a small proportion of nesting. Nests in this seaward zone have the greatest risk of egg mortality from erosion and inundation, especially in seasons with effects from tropical storms.

Many effects from coastal armoring on sea turtle nesting remain unclear. In addition to presenting a physical barrier to nesting, seawalls also may provide stimuli that discourage turtles from nesting adjacent
to the structure. We recommend additional experimental study of this problem so that superimposed effects from armoring, beach erosion, and coastal development can be understood.

Acknowledgements

We thank K. Signor, S. Smiley, D. Witherington, and E. de Maye for their assistance with the nightly fieldwork. S. MacPherson assisted in the beginning stages of the project, and L. Ehrhart graciously allowed us access to his southern Brevard study area. This study was funded by a grant from the U.S. Fish and Wildlife Service and by the Marine Resources Conservation Trust Fund. [SS]

References


